Market microstructure, banks' behaviour, and interbank spreads

Abstract

We present an empirical analysis of the European electronic interbank market of overnight lending (e-MID) during the years 1999–2009. The main goal of the paper is to explain the observed changes of the cross-sectional dispersion of lending/borrowing conditions before, during and after the 2007–2008 subprime crisis. Unlike previous contributions, that focused on banks' dependent and macro information as explanatory variables, we address the role of banks' behaviour and market microstructure as determinants of the credit spreads.

Keywords: interbank lending, market microstructure, subprime crisis, liquidity management

1. Introduction

Interbank markets play a key role in banks liquidity management and the transmission of monetary policy. It is in such markets that central banks actively intervene to guide their policy interest rates. Well functioning interbank markets effectively channel liquidity from institutions with a surplus of funds to those in need, allowing for more efficient financial intermediation. Variations in interbank rates are rapidly transmitted to the entire term structure, affecting borrowing conditions for households and firms. Interbank rates provide benchmarks (e.g. the LIBOR, Euribor and Eonia)[1] for the pricing of fixed-income securities and underlie derivatives contracts such as short term interest rate futures and interest rate swaps, used by banks to hedge their short-term interest rate risks. Thus, policymakers have an interest in having a financial system with a well-functioning and robust interbank market, that is, one in which the central bank can achieve its desired rate of interest and one that allows institutions to efficiently trade liquidity.

In normal times, interbank markets are among the most liquid in the financial sector and the financial literature has historically devoted a relatively low consideration to the interbank market due to the short-term nature of the exchanged deposits. Banks have accepted non-collateralized loans as counterparties were considered safe and sound enough

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[1] Unlike the Euribor and Libor that are offered rate, the Eonia (Euro OverNight Index Average) is computed as a weighted average of all overnight unsecured lending transactions executed by panel banks in the interbank market. The banks contributing to Eonia are the same as the Panel Banks quoting for Euribor.

and liquidity risk has been perceived as marginal due to the central bank role as lender of last resort. However, during the 2007–2008 financial crisis liquidity in the interbank market has considerably dried up, even at short maturities, and an increasing dispersion in the credit conditions of different banks has emerged. These events have triggered a new interest in interbank markets. The dramatic change of volumes and active banks following the subbprime crisis can be hardly explained as a real reduction of liquidity need by banks. A number of papers in the literature have addressed the causes of this "market freeze" and in particular compared the two hypotheses of liquidity hoarding versus credit monitoring (Heider et al., 2009; Acharya and Merrouche, 2010; Gale and Yorulmazer, 2011). On the demand side, a possible explanation for the crunch suggested by Cassola et al. (2010) was adverse selection, with banks preferring not to reveal their needs for liquidity, which could lead to credit rationing, and switching from a highly transparent electronic market to more opaque over-the-counter trades.

On the empirical side, a number of investigations of the interbank market microstructure before the crisis has been carried out. The US Federal Funds market was studied by Hamilton (1996) and Furfine (2000, 2001, 2002). Beaupain and Durré (2008) presented a comprehensive analysis of the dynamics of the Euro overnight money market using data until April 2007. They uncovered regular seasonal patterns of market activity and liquidity, as well as patterns determined by the Eurosystems operational framework. Iori et al. (2008) studied the evolution of the network topology of the e-MID within maintenance periods in the years 1999-2002, by applying methods of statistical mechanics. They showed that a large number of small/medium size banks tend to be liquidity providers, and lend to a small number of large banks; strategic behaviour, in terms of preferential and speculative lending, tends to be rather limited in e-MID. Baglioni and Monticini (2008b,a) showed the presence of an intraday term structure of interest rates, as the overnight rate displays a clear downward pattern throughout the trading session, with banks borrowing at a premium early in the morning and at a discount at the end of the day.

An increasing number of studies has analysed how the financial crisis has affected the credit conditions of banks in the interbank market. Angelini et al. (2009) analysed the spreads between uncollateralized e-MID rates and collateralized Eurepo rates on maturities from one week to 12 months. They observe that the mean spread increases and the distribution becomes more disperse during the crisis. The question they address is what share of the soaring spread is due to an increased bank-specific default risk and what to a generalized surge in risk aversion measured from the equity market. They find that before the crisis bank size is the only important borrower caracteristic to determine spreads, and large banks get better rates. During the crisis the effect of borrower creditworthiness, measured by rating and capitalization, becomes significant and sizeable, with larger banks still experiencing better borrowing conditions both before and after the Lehman collapse. Nonetheless the main determinant of the increasing spreads (two thirds of the effect) appears to be the overall increase in risk aversion. A similar effect of size on spread is found by Gabrieli (2011), who focuses on the overnight determinant of credit spreads, defined as the difference between the volume-weighted average daily interbank rate and the ECB policy rate. Her results corroborate the existence of a too-big-to-fail guarantee implicitly granted by the market to the banks with the highest volumes of business. In fact, the price benefit enjoyed by relatively bigger banks becomes much stronger after 29 September 2008, i.e. when European governments were forced to make explicit the promise that no other systemically important financial institution would be allowed to fail.

Our analysis shows that during the crisis, while some banks did better or worse than others, they all experienced a larger variability of their rates over time. Such variability is not easy to explain in terms of bank-specific characteristics or idiosyncratic risks. Therefore we focus on the impact on spreads of banks behaviour, given the microstructural features we describe in the first part of the paper. The aim of this paper is to assess the impact of changing microstructure characteristics of the interbank market on banks borrowing and lending conditions. The contribution of our analysis is to demonstrate how, specially after the beginning of the 2007 crisis, banks behaviour within the interbank market did affect interest rate spreads more than their size.

The paper is organised as follows. Section 2 describes the mechanism of the electronic interbank market and Section 3 describes the database. Section 4 describe the general behaviour of the market before, during and after the subprime crisis. Section 5 analyses cross-sectional credit spreads. In Section 6 we analyse changes in some microstructure variables and in Section 7 we test the hypothesis that interest rates spreads may be driven by bank trading behaviour. Section 8 concludes.

2. Market mechanism

Interbank markets can be organized in different ways: physically on trading floors, by telephone calls, or on electronic platforms. In Europe, interbank trades are executed in all these ways. The only electronic market for interbank deposits in the Euro area and the USA is the e-MID (Mercato Interbancario dei Depositi). It was founded in Italy in 1990 for Italian Lira transactions and denominated in Euros in 1999. Four currencies are currently being traded: Euro, US Dollar, GBP and Polish Zloty. Credit institutions (i.e. banks and electronic currency institutions) and investment companies can participate in the market if their net capital is respectively at least 10 million US Dollars (or its equivalent in another currency) and 300 million Euros (or its equivalent in another currency). When the financial crisis started, there were 246 market members from 29 EU countries and the US, of which 30 central banks and 2 Ministries of Finance acting as market observers, and 108 domestic banks and 106 international banks acting as market players. The nationalities of banks active in the e-MID are 16: Austria, Belgium, Switzerland, Germany, Denmark, Spain, France, United Kingdom, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, and Portugal.

The number of transactions and the trading volume increased systematically until the beginning of the financial crisis, with an average of 450 transactions each day and an exposure for each transaction of about 5.5 million Euros. According to Baglioni and Monticini (2008b), this evolution is due to the trend toward real-time settlement for payments, securities, and foreign exchange transactions that took place in recent years. This trend has increased the value of intraday liquidity. As shown by Iazzetta and Manna (2009), interbank deposits as a percentage of total assets of the banking system doubled from 8% in 1993 to approximately 16% in 2007. According to the European Central Bank (2011a), the e-MID accounted, before the crisis, for 17% of the total turnover in the unsecured money market in the Euro area. Its last report on money markets (European Central Bank, 2011a) recorded around 10% of the total overnight turnovers.

Contracts of different maturities, from one day to one year, can be traded, but the overnight segment represents more than 90% of the transactions in the e-MID. Our analysis has focused on the overnight segment (the analysis of longer maturities is in progress). Trading in e-MID starts at 8 a.m. and ends at 6 p.m. The large majority of volumes are traded in the Euro section of the market, and, more specifically, on the overnight contracts, defined as the trade for a transfer of funds effected on the day of the trade and returned at 9 a.m. of the subsequent business day.

The main difference with respect to the security market is that market participants can choose their counterparties. An operator willing to trade can pick a quote and manifest his wish to close the trade. Trades are public in terms of maturity, rate, volume, and time. While the identity of the quoting bank is normally public too (the quoter may choose to post a trade anonymously, but this option is rarely used), the identity of the aggressor can only be disclosed by a quoter during the negotiation phase. A quoter willing to lend capital has the option to reject an aggression, and similarly an aggressor has the additional option of not closing a trade after knowing the counterparty, if this was not public. An aggressor can also subordinate his wish of closing a trade to some specific requests, such as a larger or smaller volume or a different rate.

The e-MID thus provides a transparent platform where all parties can monitor in real time the evolution of traded rates, while benchmarks like the LIBOR and EURIBOR, as seen by the recent Libor fixing scandal, can be easily manipulated.

3. Data set

The data base is composed by the records of all transactions registered in the period 01/1999–12/2009. Each line contains a code labeling the quoting bank, i.e. the bank that proposes a transaction, and the aggressor bank, i.e. the bank that accepts a proposed transaction. The rate that the lending bank will receive is expressed per year; the volume of the transaction, i.e. the amount of lent money, is expressed in millions of Euros. A label indicates the side of the aggressing bank, i.e. whether the latter is lending/selling ("Sell") or borrowing/buying ("Buy") capitals to or from the quoting bank. Other labels indicate the dates and the exact time of the transaction. Moreover, the records contain the contract the two banks are trading. The main difference between contracts is the length of the lending period. We consider only the overnight ("ON") and the overnight long ("ONL") contracts. The latter is the version of the ON when more than one night/day is present between two consecutive business days, e.g. on weekends. The banks are reported together with a code representing their country and, for Italian banks, a label that indicates their size measured as total assets. Following the acronyms of the data provider: MA (major), GR (large), ME (medium), PI (small), MI (minor). FB indicates a foreign bank. Italian legal entities belonging to foreign banking groups appear in the database as domestic. Appendix I provides the list of banks belonging to the different dimensionality groups as provided by the Bank of Italy. A couple of example records are reported in Table 1.

The database does not provide information on the state of the book, its dynamics and how the banks use this information when acting on the market. A similar dataset was the object of various past studies (Masi et al., 2006; Gaspar et al., 2007; Iori et al., 2007; Iori and Precup, 2007; Iori et al., 2008; Baglioni and Monticini, 2008b,a). In addition, Brousseau and Manzanares (2005) did a study using the whole book information.

Market	Duration	Date	Time	Rate	Amount	StartDate
"EUR"	"ONL"	"2007-01-02"	"8:52:41"	3.60	160.00000	"2007-01-02"
"EUR"	"ON"	"2007-01-02"	"8:52:54"	3.60	50.00000	"2007-01-02"

EndDate	Quoter	GroupQuoter	Aggressor	GroupAggressor	Verb
"2007-01-03"	"IT0276"	"ME"	"IT0271"	"GR"	"Sell"
"2007-01-03"	"IT0162"	"PI"	"GR0006"	"ND"	"Sell"

Table 1: Two example records from the data set. Quoter and aggressor are the banks participating to the trade. The "Group" classifies Italian banks with respect to their size. The label "Buy" indicates that the quoting bank is on the buy side, the label "Sell" that it is on the sell side.

4. General characteristics of the e-MID market

Some results in this and the following sections are provided for the full stretch 1999–2009, while some are specific to the crisis, for which we identify three equal periods of 440 days each defined as follows (European Central Bank, 2011b):

	start	end
pre-crisis (p1)	2006-07-05	2007-08-08
subprime (p2)	2007-08-09	2008-09-14
Lehman (p3)	2008-09-15	2009-10-21

Table 2: The three periods in yyyy-mm-dd format.

As a first step we compute the volume-weighted mean rate in each analysed trading day,

$$r_d = \frac{1}{V_d} \sum_{j=1}^{N_d} \sum_{i=1}^{N_{j,d}} V_{i,j,d}\, r_{i,j,d}, \tag{1}$$

where $V_{i,j,d}$ and $r_{i,j,d}$ are the volume and rate of transaction i of bank j in day d, $N_{j,d}$ is the number of transactions of bank j in day d, and $V_d = \sum_{j=1}^{N_d} \sum_{i=1}^{N_{j,d}} V_{i,j,d}$ is the total trading volume of all N_d banks active in day d. The results are reported in Fig. 1 (left) together with the ECB key rates for the considered period. ECB rates are defined as follows (European Central Bank, 2011b):

- **Marginal lending facility rate (EuroMLR):** the rate fixed by the ECB for operations where counterparties can use the marginal lending facility to obtain overnight liquidity from the National Central Banks (NCBs) against eligible assets. The interest rate on the marginal lending facility normally provides a ceiling for the overnight market interest rate.

- **Main refinancing facility operations (EuroRPS)** are regular liquidity-providing reverse transactions with a frequency and maturity of one week. They are executed by the NCBs on the basis of standard tenders and according to a pre-specified calendar. The main refinancing operations play a pivotal role in fulfilling the aims of the Eurosystem's open market operations and normally provide the bulk of refinancing to the financial sector.

- **Deposit facility rate (EuroDEP):** counterparties can use the deposit facility to make overnight deposits with the NCBs. The interest rate on the deposit facility normally provides a floor for the overnight market interest rate.

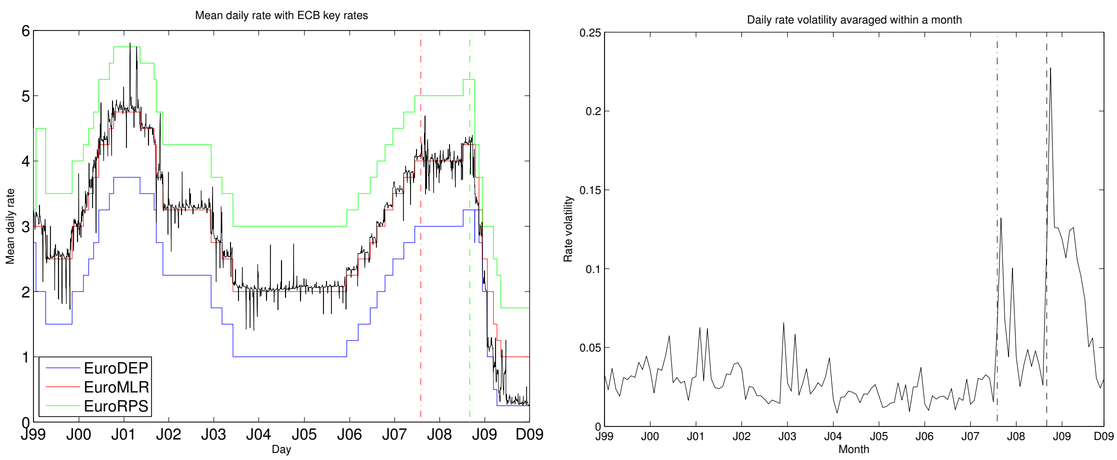

Figure 1: Left: mean daily rate plotted together with the ECB key rates. Right: Daily rate volatility averaged within a maintenance period. The vertical lines indicate the beginning of the subprime crisis (August 2007) and the collapse of Lehman Brothers (September 2008).

The extreme uncertainty of interest rate levels is highlighted by the daily volatility shown in Fig. 1, right panel. Volatility (averaged within a maintenance period[2]) has reached two

[2]Credit institutions in the Euro area are required to hold minimum reserve balances with NCBs that have to be fulfilled only on average over a one-month maintenance period. Until the beginning of 2004 the maintenance period used to run from the 24th of a month to the 23rd of the following month. This has changed and now the exact dates are announced by ECB every month in advance.

peaks (respectively 3 and 6 times the previous volatility average) soon after the beginning of the crisis and after the Lehman Brothers bankruptcy.

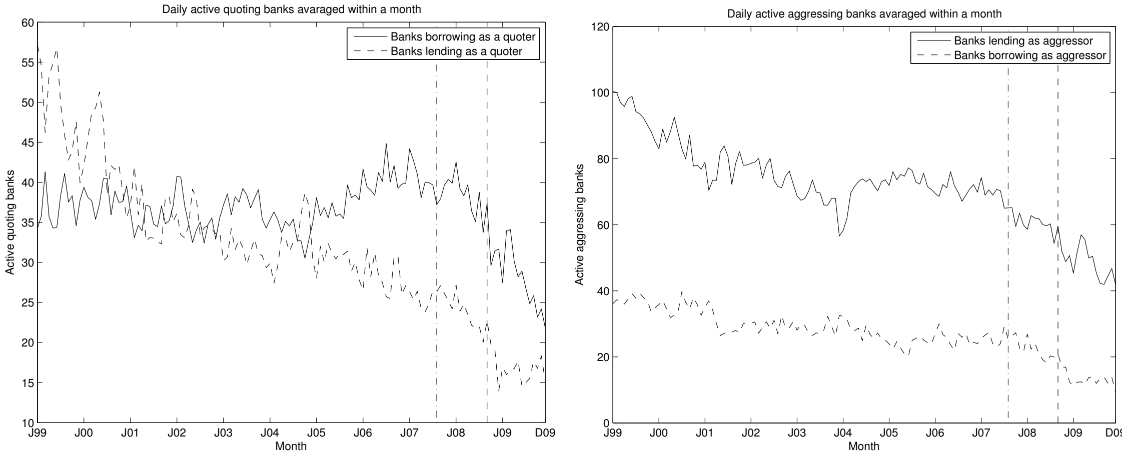

Figure 2: Left: average of the daily number of quoter banks in a maintenance period. Right: average of the daily number of aggressor banks in a maintenance period. In both cases transactions have been separated into lending and borrowing.

One of the most significant impact on the functioning of the interbank market can be appreciated looking at the number of active banks. Tables 9 and 10 and Fig. 2 show three long-term trends. First, from 1999 to 2004, the number of active banks decreases for two reasons: the market was basically domestic, and that period was characterised by a lower number of medium and large banks, due to mergers and acquisitions; From 2004 to mid 2007, the markets become more internationally oriented, and the number of foreign banks equals the number of domestic ones. This period is characterized by a constant number of daily active banks, around a monthly average of 130 agents. After the beginning of the crisis, the number of active banks dropped below 80. On the quoter side (left side of Fig. 2) we observe that the number of lending banks declined steadily between 1999 and 209, while the number of borrowing banks surged between 2005 and 2007 but declined faster after the sumer of 2007.

Figure 2 (right) shows that the majority of banks act as aggressor when lending. This asymmetry is confirmed at the intraday scale. The intraday proportion of borrowing quotes is plotted in Fig. 3 for the three periods p1, p2, p3. More than 70% of the quotes are to borrow (in terms of number (left) and volume (right) of transactions), a proportion that increases both with the progression of the crisis and the time of the day.

To better investigate how the crisis affected banks of different size and nationality we plot, in Fig. 4, the average daily lending and borrowing volume per group (as defined in Section 3) and in Fig. 5 the net trading volume per group. Figure 4 shows that the five Italian groups, while composed of very different numbers of banks (see Tables 3 and 4), have a similar market share. Participation of foreign banks has fast increased since the opening of the market and just before the crisis the foreign banks shared, almost equally, the market

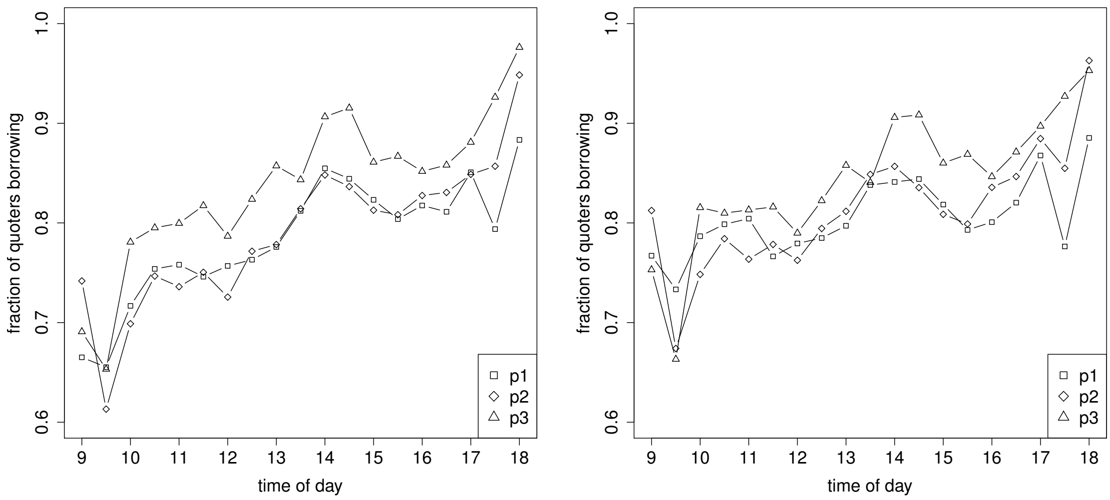

Figure 3: Left: intraday average fraction $N^{\mathrm{b}}/(N^{\mathrm{b}}+N^{\mathrm{l}})$ of number of borrower quotes over all quotes. Right: intraday average fraction $V^{\mathrm{b}}/(V^{\mathrm{b}}+V^{\mathrm{l}})$ of volume of borrower quotes over all quotes.

with the Italian banks. Since 1999 the positions of some of the groups changed from being net borrowers to net lenders and vice versa (Fig. 5). In particular during the crisis the minor (MI) banks acted as the main net lenders to the system, while the large (GR) and medium (ME) banks were the main net borrowers. Small (PI) banks had a more balanced position, but predominantly acted as net lender before and during the crisis. Major (MA) banks acted as net borrowers during the first part of the crisis, but their net position became erratic after the Lehman default. Foreign banks (FB) acted as net borrowers until 2005, but took a more balanced position during the crisis, acting predominantly as net lenders.

5. Cross-sectional spreads

To assess whether some banks are able to borrow or lend money at a better rate than others, we define the average daily credit spread $c_{j,d}$ for each bank j in day d, as

$$c_{j,d} = \frac{1}{V_{j,d}} \sum_{i=1}^{N_{j,d}} V_{i,j,d}(r_{i,j,d} - r_d), \tag{2}$$

where $V_{j,d} = \sum_{j=1}^{N_d} V_{i,j,d}$ is the total volume traded by bank j in day d, while the other variables have been introduced in Eq. (1). In a day a bank may participate in both borrowing and lending transactions, in which case two separate credit spread coefficients $c^{\mathrm{b}}_{j,d}$ and $c^{\mathrm{l}}_{j,d}$ can be defined. The credit spread so defined provides a measure of the ability of a bank to borrow or lend at competitive rates relatively to the mean rate observed in that day in the same market. Thus the spread does not depend on specific features of the interbank market

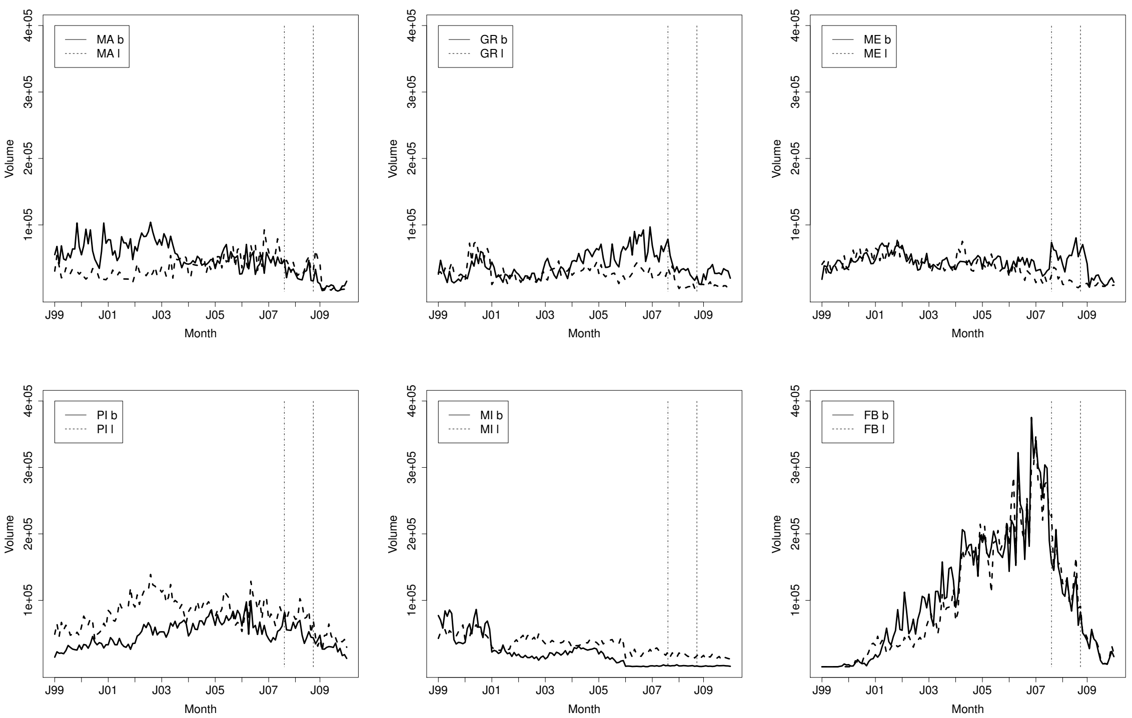

Figure 4: Average daily volume per maintenance period per group as lender (dashed line) and borrower (continuous line).

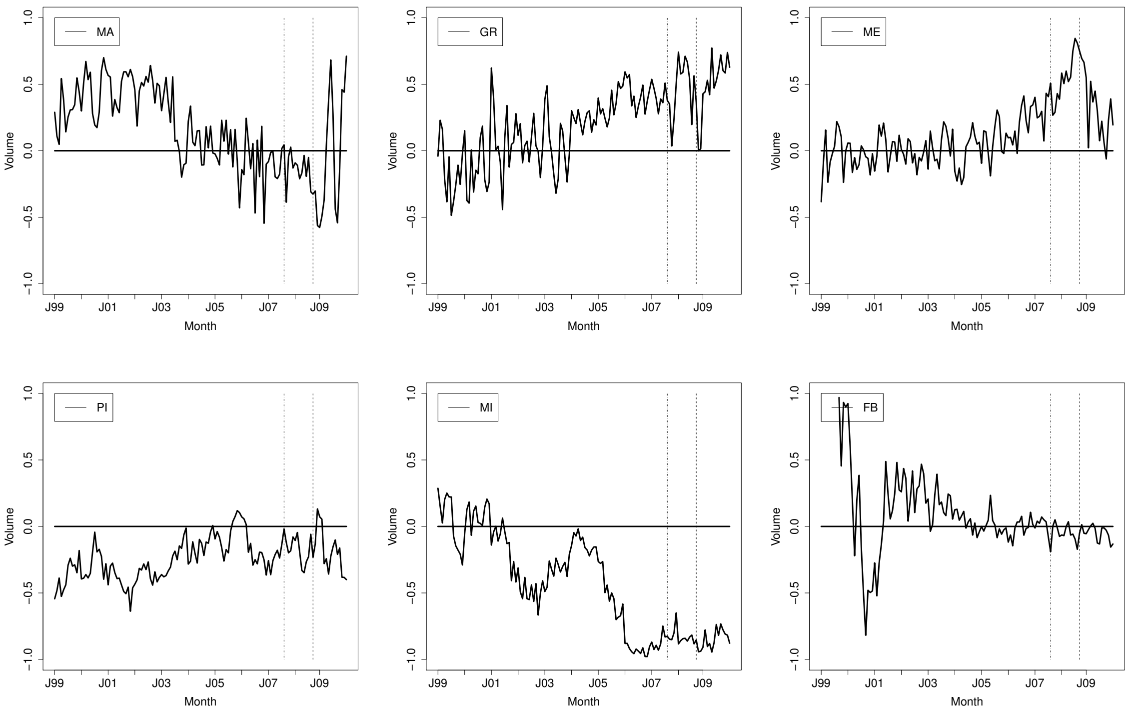

Figure 5: Net percentage traded volume per group as lender and borrower.

with respect to other markets, such as when the spread in the uncollateralized market is defined by using a collateralized market as reference. Fig. 6 shows the quantile plots of the cross-sectional daily borrowing and lending spreads. The figure clearly indicates that while, before the crisis, banks were experiencing similar credit conditions with respect to each other, during the crisis much more variation was observed among borrower and lender spreads, with a peak in correspondence of the Lehman default. In fact the cross-sectional mean spread value is negative indicating that several banks where experiencing better than average borrowing conditions (and worse than average lending conditions), but for a few banks in the tails trading happened of very different terms. As mentioned before, there has been a considerable effort in the literature to explain this variation, and size has been identified as the main bank-specific factor to drive banks' spreads (Angelini et al., 2009; Gabrieli, 2011).

Nonetheless during the financial turmoil all banks, and in particular the larger ones, have experienced a high variability in their borrowing and lending rates.

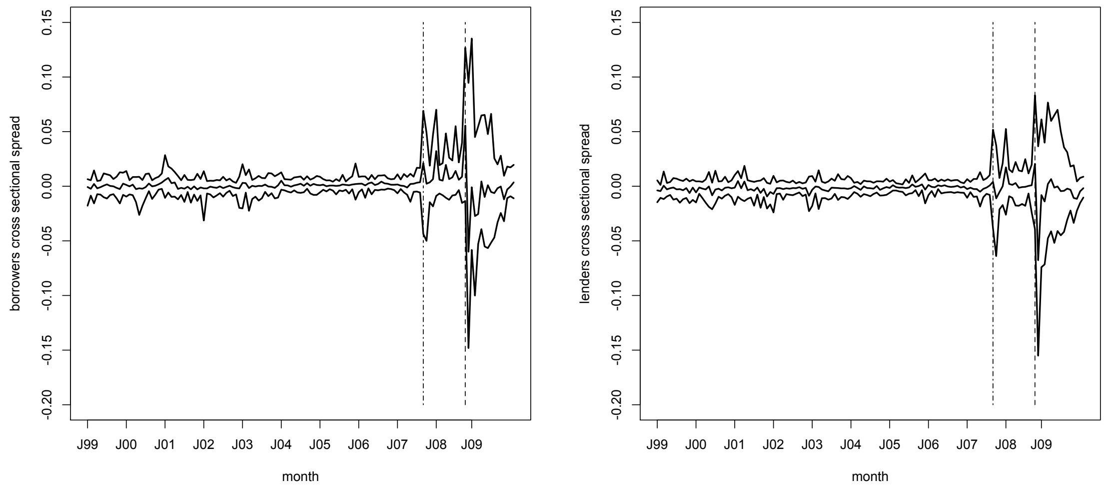

Figure 6: Cross-sectional spreads for borrowers (left) and lenders (right).

Indeed the first contribution of our analysis is to show that not only the volatility of the average e-MID rate increased during the crisis, as already seen in Fig. 1, but that the borrowing and lending spreads of individual banks experienced a large variability too. To quantify this effect we show in Fig. 7 the quantile plot of the variance of the cross-sectional spreads of individual banks, separately for borrowing and lending transactions. The volume-weighted variance of each bank is calculated as

$$\mathrm{Var}(c_{j,m}) = \frac{1}{V_{j,m}} \sum_{d=1}^{N_m} \sum_{i=1}^{N_{j,d}} V_{i,j,d}(r_{i,j,d} - r_d)^2 - \left[\frac{1}{V_{j,m}} \sum_{d=1}^{N_m} \sum_{i=1}^{N_{j,d}} V_{i,j,d}(r_{i,j,d} - r_d) \right]^2, \tag{3}$$

where $V_{j,m} = \sum_{d=1}^{N_m} \sum_{i=1}^{N_{j,d}} V_{i,j,d}$ is the number of transactions of bank j in a maintenance period m of N_m days. The figure shows how the cross sectional mean and variance of spreads variances considerably increased during the crisis, in particular after the Lehman default. Notably, while the spreads do not show significative changes ahead of the subprime crisis, the cross sectional variance presents a significant pick in the early months of 2007, providing in this way the first early warning signal of the forthcoming crisis.

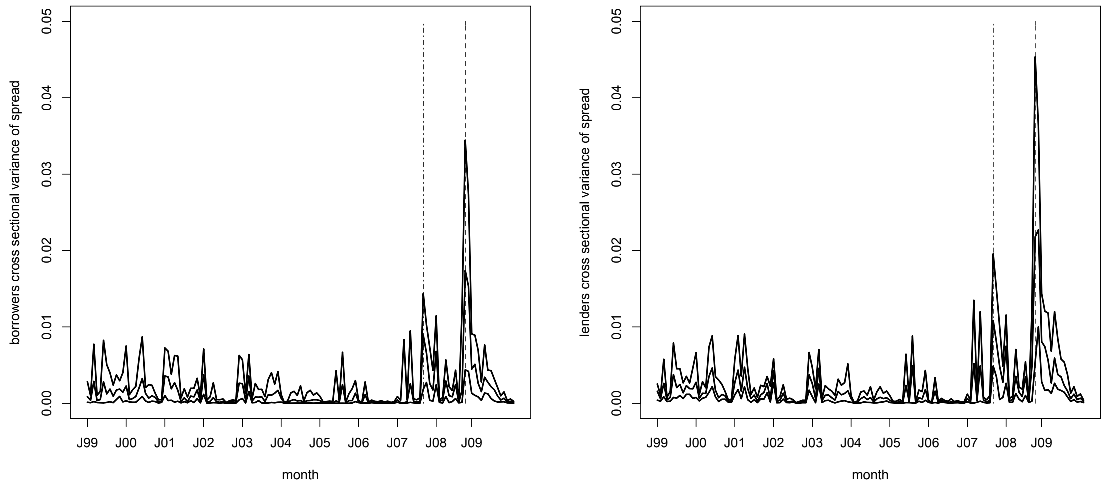

Figure 7: The cross-sectional maintenance period spread variance for borrowers (left) and lenders (right).

Moreover, banks' good and bad performances were not consistent over time. As a measure of consistency of bank performance we measure the autocorrelation of lending and borrowing credit spreads in trading time units (banks differ substantially in term of size and frequency of trades, with some banks settling only a few trades in a year and others trading several times a day; see column 3 in Tables 5–10 for the average intertrade time per group). We estimate the cut-off lag as the first time lag at which the autocorrelation becomes statistically not significant (at significance level 5%). The meaning of this measure is to identify the continuity of banks' behaviour either as a borrower or as a lender. We then compare the cut-off point to the bank trading frequency, that is the average number of days a bank is active (as a borrower or as a lender) in a maintenance period.

In Fig. 8 we plot, for each bank, the ratio of the bank cut-off point to its trading frequency versus its average credit spread. The horizontal line at 0 and the vertical line at 1 separate the phase space into four regions. The left quadrants Q1 and Q4 contain banks whose performance autocorrelation is shorter than a maintenance period, while the right quadrants Q2 and Q3 identify banks with a performance autocorrelation longer than a maintenance period. The figure shows that, as the crisis progressed from p1 to p3, banks' performances became more diversified and banks were locked for longer in their patterns of over- or under-performance. Nonetheless, only very few borrowers and lenders experienced autocorrelations beyond a single maintenance period. If spreads were determined by bank-specific characteristics, such as credit rating or size, or by a consistent strategic behaviour, we would expect to find a long-term autocorrelation in their performance, that is not observable here. Thus our analysis questions whether banks' spreads may have been affected not only by idiosyncratic factors, in particular credit ones, but also by factors such as the market conditions at the time banks execute their trades.

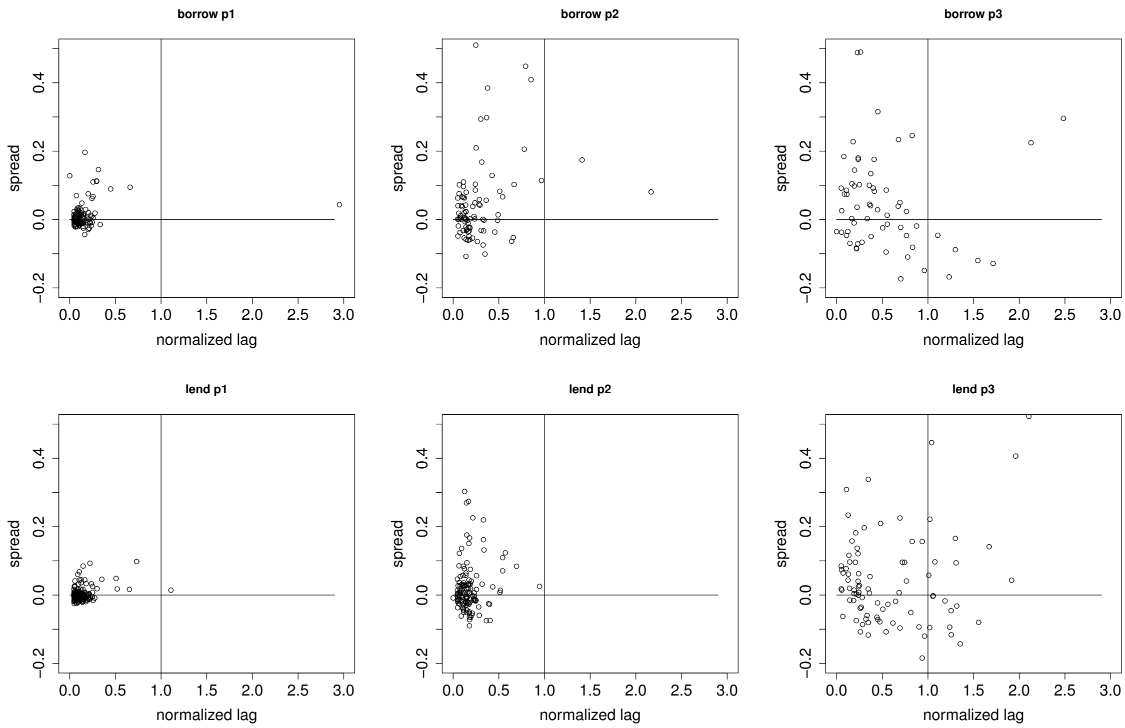

Figure 8: Cut-off lag (normalised by mean participation in maintenance period) versus bank borrowing (top) and lending (bottom) spreads (y-axis) for p1, p2, p3.

6. Market microstructure features

The second contribution of our analysis is to assess to what extent the variability in the cross-sectional spreads can be explained in terms of banks behaviour, particularly depending on the changing market microstructure conditions in the e-MID. As shown in the following subsections, two features of the market changed considerably after the beginning of the crisis: the market bid-ask spread and the slope of the intraday rate term structure.

6.1. Market bid-ask spread

The first effect we observe is a time-varying bid-ask spread. While we cannot measure the real bid-ask spread in the market because our data do not contain posted quotes, we construct a proxy in the following way. In each day we calculate the volume-weighted average rates at which buy-initiated transactions and sell-initiated transactions are settled. We take the difference between these two rates as a proxy of the bid-ask spread. The daily mean values r_d^{b} and r_d^{s} are defined similarly to Eq. (1) as

$$r_d^{\mathrm{b}} = \frac{1}{V_d^{\mathrm{b}}} \sum_{j=1}^{N_d} \sum_{i=1}^{N_{j,d}^{\mathrm{b}}} V_{i,j,d}^{\mathrm{b}} r_{i,j,d}^{\mathrm{b}} \tag{4}$$

$$r_d^{\mathrm{s}} = \frac{1}{V_d^{\mathrm{s}}} \sum_{j=1}^{N_d} \sum_{i=1}^{N_{j,d}^{\mathrm{s}}} V_{i,j,d}^{\mathrm{s}} r_{i,j,d}^{\mathrm{s}}, \tag{5}$$

where the superscripts b and s distinguish among the buy and sell transactions. The *bid-ask spread* (or *sell-buy spread*) can now be easily computed as $s_d = r_d^{\mathrm{b}} - r_d^{\mathrm{s}}$. Fig. 9 shows the evolution of its monthly average (left) and of its monthly variance (right).

The first non-trivial conclusion we can extrapolate from the plot is the presence of such a spread; in fact the market is not a typical limit-order book market. Moreover, the spread has dramatically increased during the crisis and two very well-defined peaks are clearly present in concomitance with the beginning of the crisis and the Lehman collapse. During the crisis, bid-ask spreads experience values higher than 200 basis points, when the usual pre-crisis level was around 3 basis points. Paradoxically, the liquidity stress seems to be absorbed just before the Lehman collapse, when the bid-ask spread drops below 5 basis points, the resistance level empirically observed before the sub-prime shock. In fact in both the landmark events, the spread trend appears to be absorbed in a few weeks, with a strong correlation with the rate volatility pattern. This is certainly due to the massive liquidity intervention of the European Central Bank, that from June 2007 to June 2010 increased its assets by about 600 billions Euros (+65%), using standing facilities, marginal lending facilities and open market operations, and easing the procedures and the eligible assets required to borrow money. The bid-ask spread effect raises the question whether banks can trade at a more profitable rate if they submit their orders as quoters rather than as aggressors.

6.2. Term structure of intraday spreads

As initially reported by Baglioni and Monticini (2008b), the intraday term structure effect makes trading in the morning more expensive than in the afternoon. This is due to the implicit intraday maturity of overnight deposits, which are not expected to be reimbursed after 24 hours, but at 9 am of the day following the trade (foreign banks were allowed to settle the operations at 12 am, but only one does so). Therefore, overnight deposits traded earlier in the morning have a longer maturity and higher expected yields. In a more recent paper, Baglioni and Monticini (2008a) study the evolution of the intraday term structure during the crisis. The authors report a considerable increase of the slope of the yield curve after the default of Lehman that seems to create a risk-free profit opportunity (lend in the morning and borrow in the afternoon). The authors suggest that this opportunity is not arbitraged

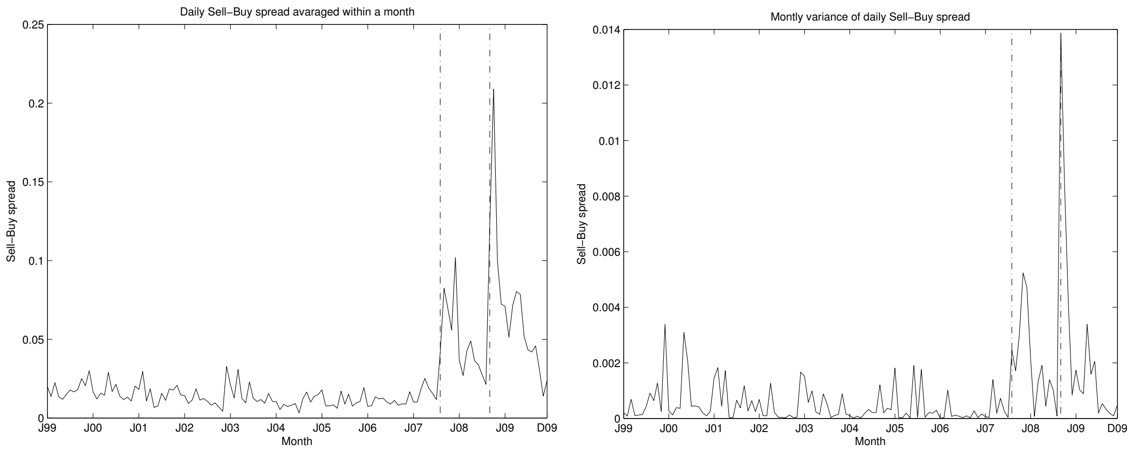

Figure 9: Montlhy average of the daily sell-buy spread and its variance. Two very well defined peaks are clearly present after the crisis milestones.

away after the crisis for two main reasons, uncertainty about availability of liquidity late in the afternoon and an increase in the implicit cost of collaterals. We calculate the intraday interest rate spread $s_d(t)$ as the difference between the instantaneous rates within a window of one hour centered around time t of day d (i.e., considering the trades performed in the 30 minutes before and after t) and the average rate of that day.[3] Fitting $s_d(t)$ for each day d with the simple linear relation $s_d(t) = a_d t + b_d$, where t is in minutes, we estimate the slope of the intraday term structure and its evolution as a function of the day d. Fig. 10 shows the average intraday interest rate spread in p1, p2 and p3, while Fig. 11 shows the evolution of the slope of the monthly average of a_d over time.

The observation of such a slope in the term structure of overnight rates suggests the possibility of an opportunistic behaviour for banks with liquidity surplus: lend in the morning, borrow in the afternoon. Nonetheless such a strategy would entail some risk. In fact a negative slope of the rates was not observed every single day and while the average spread is lower in the afternoon, it is also more volatile as shown by the higher variance bars in Fig. 10. It is also interesting to observe the evolution in the time of the day $t_{\max}$ and $t_{\min}$ at which the maximum and minimum rates are observed (Fig. 6.2). Before the Lehman collapse the minimum rate was mostly recorded around 4–5 pm, but after the Lehman collapse its distribution becomes almost uniform. On the other side, the distribution of the time at which the maximum rate is observed becomes more and more concentrated in the first hour of the day as the crisis progresses. This shows that any strategy needs not only a liquidity excess or the availability for eligible securities, but also the risk appetite to take a speculative position over an interest rate forecast and the assumption to borrow money in the afternoon.

Our findings suggest that while the slope of the intraday yield curve did not guarantee

[3]Baglioni and Monticini (2008a) use the main refinancing rate as reference. We choose to estimate the spread with respect to the average market rate so that the spread is not directily affected by official rates and monetary policy decisions.

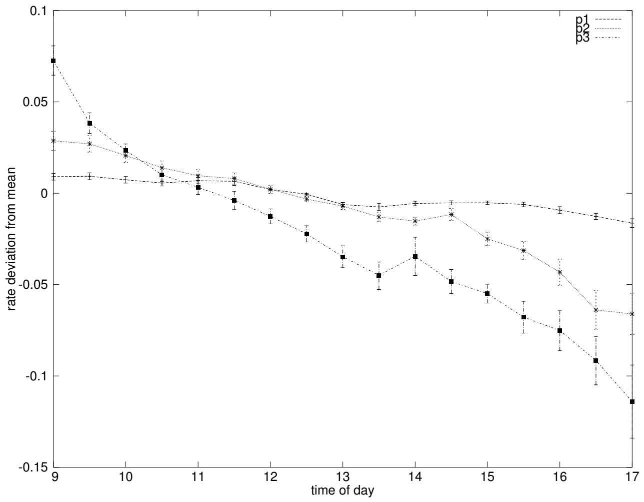

Figure 10: Intraday deviation from mean daily rate averaged over p1 (black), p2 (red) and p3 (green).

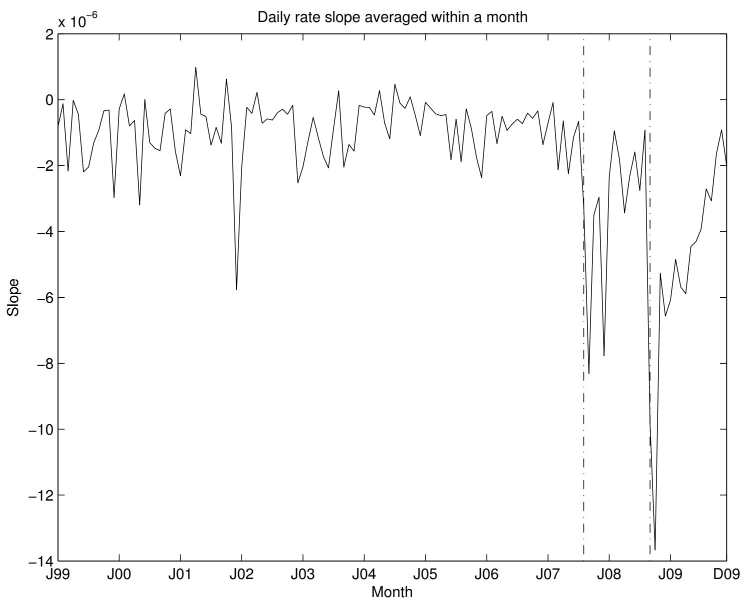

Figure 11: Monthly average of the slope a_d of the intraday spread $s_d(t)$.

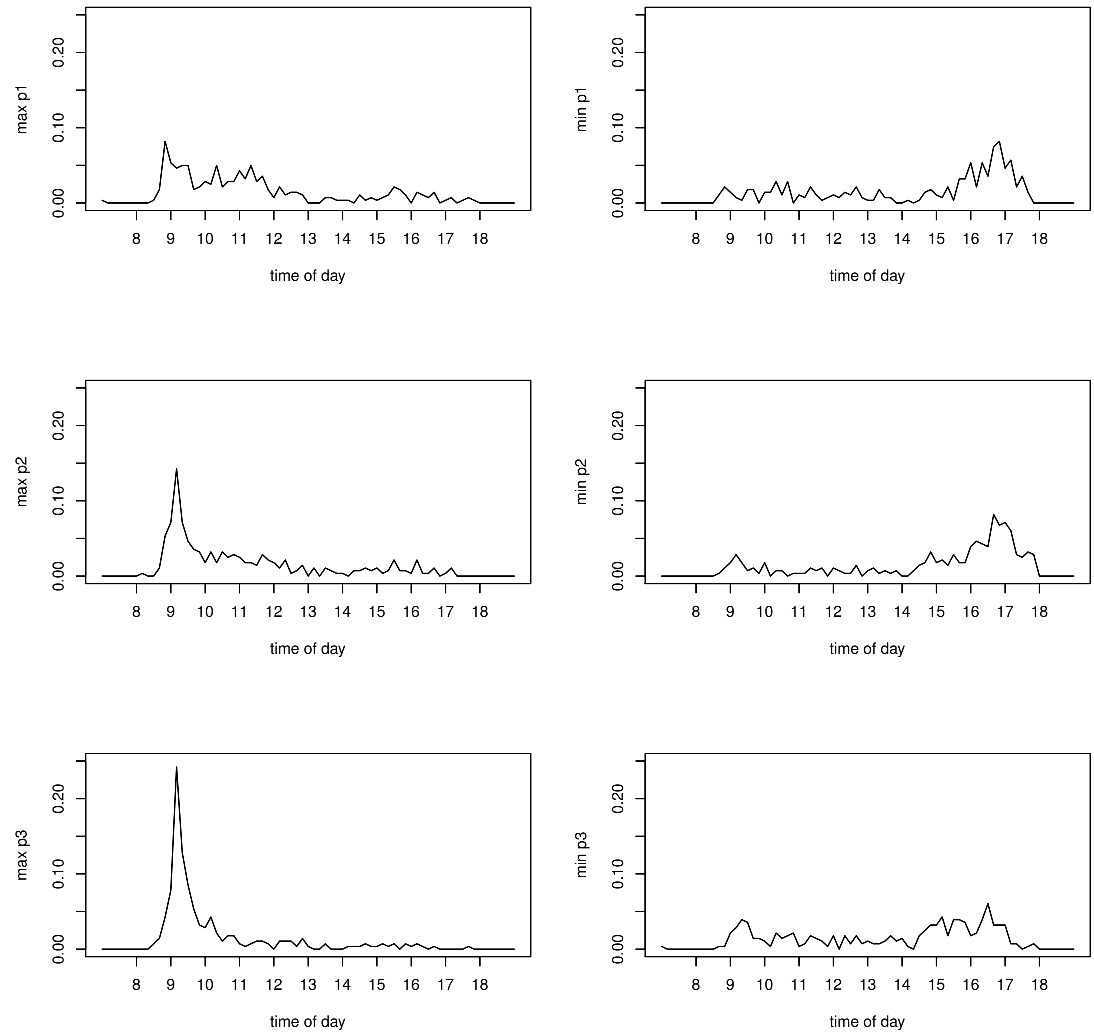

Figure 12: Time of maximum (left) and minimum (right) intraday rate deviation from mean daily rate for the three periods p1–p3 (top to bottom).

arbitrage opportunities it did nonetheless create opportunities for risk oriented banks to profit from the pattern of intraday rates. This raises the interesting question "Are interbank spreads affected by the agents decisions to trade either in the morning or in the afternoon?".

7. Banks' behaviour and interest rate spreads: individual banks' time series regressions

The empirical analysis presented in this section is restricted to the impact of the market microstructure on interbank spreads. While previous researches have focused on credit risk and monetary policy factors to explain the dynamics of interest rate spreads paid by borrowers, relatively little attention has been paid to banks intra-day and intra-month behaviour, their decision to play either as quoter or as aggressor and the concentration of their trades out of the total volume traded in the market. To assess the impact of banks' behaviour on banks' spreads we regress the average daily credit spread (separately for borrowing and lending spreads) of each bank versus four variables. The identification of the four explanatory variables is justified on both theoretical and empirical grounds:

1. VOLUME (x_1), defined as (daily volume traded in the morning - daily volume traded in afternoon) / total daily volume, is a measure of banks' decision either to borrow or to lend money when, on average, the rate is respectively higher or lower. The variable helps to check the price-volume hypothesis supported by many empirical studies in securities markets (**????**), but underestimated in money markets.

2. QUOTER/AGGRESSOR (x_2), defined as (daily volume traded as quoter - daily volume traded as aggressor) / total daily volume, is a measure of banks' decision either to borrow or to lend money as an aggressor or a quoter. This action is related to the information content of order flows. Before the crisis, the purchase of liquidity from an aggressor could have been a signal, with noise, that the aggressor believed the rate was undervalued (**?**). After the crisis, the information content may have changed and simply reveal how bank treasuries have to balance inflows and outflows.

3. CONCENTRATION (x_3), defined as daily volume traded by a bank (as lender or borrower) / total daily volume traded in the market, aims at testing the impact of order size on spread. We can also test in this way if some results that apply to equity market may also be valid for credit markets. The empirical evidence are mixed: in particular **?** suggest that companies with high trading volume concentration perform better in equity market, while **?** find that volume concentration is negatively correlated to abnormal spread. After the beginning of financial crisis, the role of order size could have changed because of the liquidity pressure and the low market depth.

4. PERIOD (x_4), a dummy variable indicating whether the analysed day falls in the last two days of the maintenance period, is included because previous evidence shows that rates tend to increase at the end of the maintenance period as a result of the difficulty to satisfy the reserve requirement constraint (Iori et al., 2008). The effect should be even higher during the crisis.

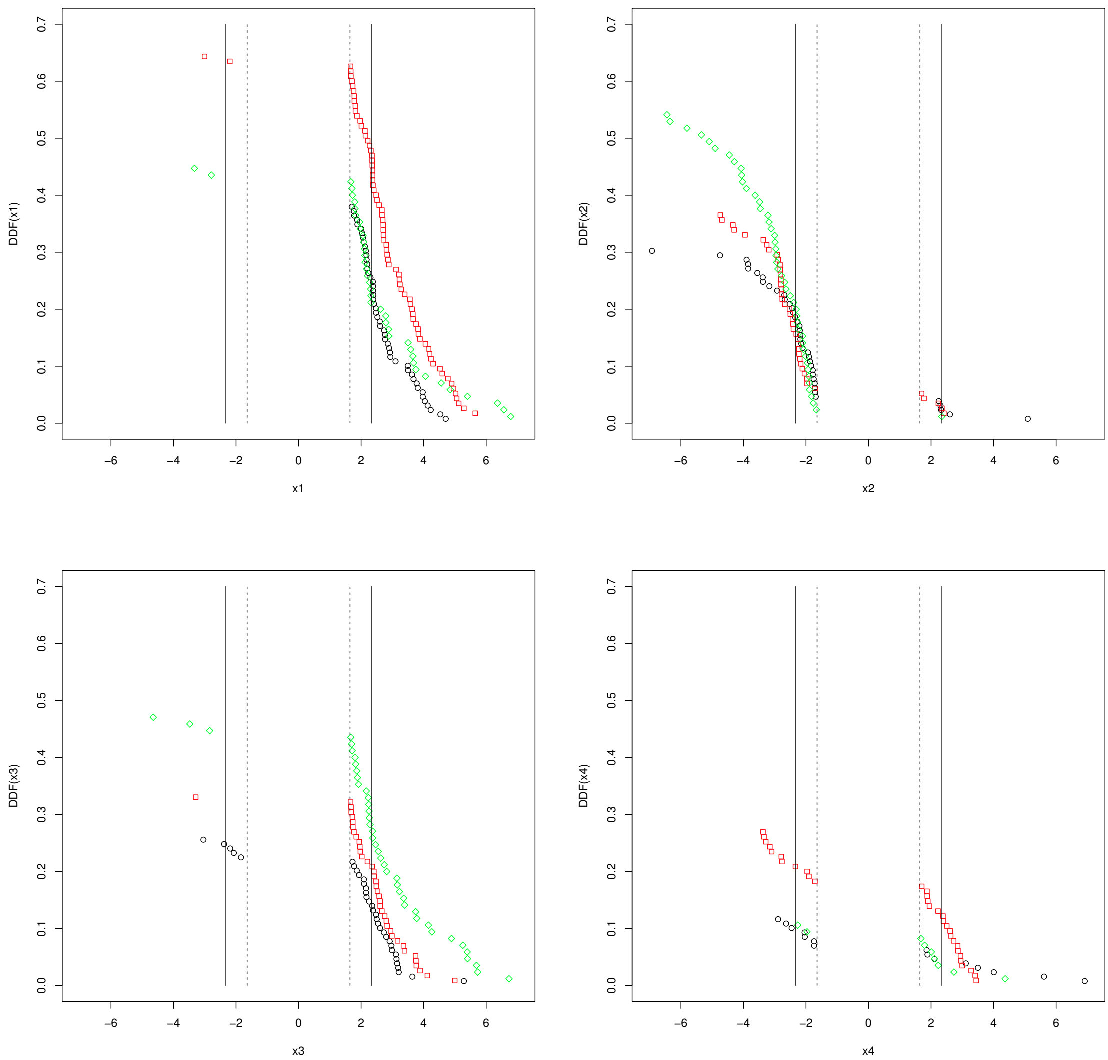

Figure 13: Decumulative distribution function of the t statistics for x_1, x_2, x_3, x_4, for borrowers in p1 (black), p2 (red), and p3 (green).

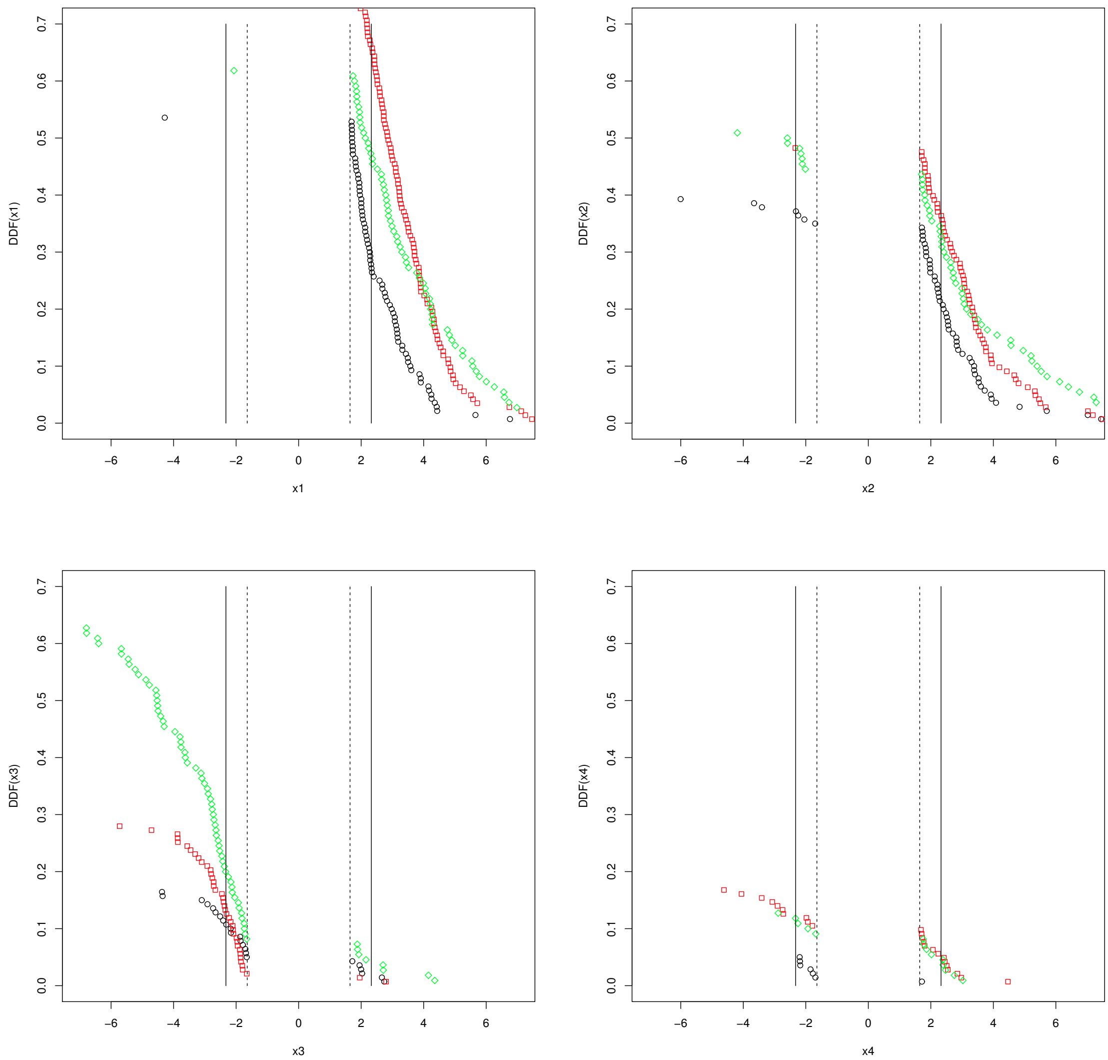

Figure 14: Decumulative distribution function of the t statistics for x_1, x_2, x_3, x_4, for lenders in p1 (black), p2 (red), and p3 (green). The vertical lines indicate the 5% (dotted) and 1% (solid) thresholds.

We performed, separately for borrowing and lending banks, the following time series regressions

$$c^{\mathrm{b}}_{j,d}(t) = \alpha^{\mathrm{b}}_{j,d} + \sum_{k=1}^{4} \beta^{\mathrm{b}}_{j,d,k} x^{\mathrm{b}}_{j,d,k}(t) \tag{6}$$

$$c^{\mathrm{l}}_{j,d}(t) = \alpha^{\mathrm{l}}_{j,d} + \sum_{k=1}^{4} \beta^{\mathrm{l}}_{j,d,k} x^{\mathrm{l}}_{j,d,k}(t). \tag{7}$$

Only banks which have traded at least 50 times in each of the three periods were included in the sample. Results are reported for the borrowing banks (Fig. 13) and the lending banks (Fig. 14) in terms of the decumulative distribution function of the t statistics for x_1, x_2, x_3, x_4 in the three periods p1, p2, and p3, together with the 5% and 1% thresholds.

The analysis show that time of trading (Figs. 13 and 14, top left) is significative and positively correlated with spreads both on the lending and the borrowing side (trading preferentially in the morning improves lender performance and reduces borrower performance) in all three periods, and appears to increase after the beginning of the crisis, but reduces after the Lehman default. Possibly the changing microstructure condition induced banks to try and take advantage from the timing, but the liquidity crunch observed after Lehman reduced their ability to do so, particulary for borrowers. Indeed, the percentage of borrowers with a significant coefficient for x_1 fell to the pre-crisis level of about 40%.

Trading preferentially as a quoter improves the performance of both lenders and borrowers (Figs. 13 and 14, top right) and the significativity of this variable increases for all groups except for the largest banks as the crisis progresses.

The concentration of the total daily traded volume (Figs. 13 and 14, bottom left) is significant for a smaller group of banks, but becomes more and more important with time to explain the spread, in particular for lenders. Our estimates show that the sign is mostly positive for borrowers and negative for lenders, indicating that with the crisis the cost for deposits becomes positively correlated with the size of trades.

The last variable we tested to explain the spread was indicating whether trading occurs in the last day of the maintenance period (Fig. 13 and Fig. 14, bottom right). This variable plays a role, but is less significative. Its capacity to explain the spread increased after the crisis, but in the third period the number of banks whose spread depends on the stress due to the reserve requirement management decreases to the pre-crisis level of about 10% for borrowers and 5% for lenders.

Our analysis demonstrates that spreads incorporate a liquidity risk premium (the widening bid-ask spreads and the increasing intraday slope of interest rates are indicators of liquidity shortages) in addition to a credit risk premium (that previous studies have associated to bank sizes). This corroborates the analyses of Michaud and Upper (2008) and Eisenschmidt and Tapking (2009), which both point out that after August 2007 rates reached levels that cannot be explained alone by a higher credit risk.

8. Banks' behaviour and interest rate spreads: cross sectional regressions

The aim of tho session is to establish if, when controlling for the liquidity variables, banks size is still a significant determinant of banks spreads, as previously identified in the literature. Our hypothesis is that banks trade at better condition not because they are perceived as safer by market participants but as a consequence of their strategic trading behaviour. First we report, in tables 7–12 in Appendix II, the average value, per each group of banks, of the independent variables x_1, x_2, x_3, in p1, p2, and p3. The variable x_4 does not appear to affect spreads considerably so we drop it in this section. The first column in the table indicates the bank capitalization group in decreasing order (except the foreign group FB for which we have no such information), while the second column reports the number of banks per group. The third column reports the group's average intertrade duration Δt, i.e. the time between two consecutive transactions i and $i+1$. Columns 4–6 report the group average of the first 3 independent variables in the relevant period.

Overall we observe a tendency for all banks to shift borrowing later in the afternoon, and lending earlier in the morning as the crisis progresses: x_1 decreases over time for borrowers and increases for lenders. Notably, the average value of x_1 is lower and becomes negative in p2 for the major Italian and the foreign borrowing banks, indicating that these are the banks more likely to borrow in the afternoon minimising borrowing costs. But x_1 reduces after the Lehman default. Possibly the liquidity crunch observed after Lehman reduced the ability of banks to take advantage from later transactions, particularly for borrowers.

Similarly x_2 is larger for the larger Italian and foreign banks, which are thus the ones profiting most from the widening bid-ask spreads. These findings indicates that, in addition to the too-big-to-fail argument, the favourable borrowing conditions of larger banks have partly been the result of a more strategic liquidity management. On the lending side we observe that foreign banks have not been able to optimise their strategies (small or negative x_1 and x_2 indicate too much lending in the afternoon and as aggressors, which is less profitable). This observation confirms a poor market integration on this side of the market, with foreign banks lending mostly to other foreign and large Italian banks that, as seen before, tend to borrow later in the afternoon.

To quantify the effect of bank size when controlling for the bank strategic behaviour, measured by the variables x_1 and x_2, we run cross-sectional regressions[4] for each month between 1999 and 2009. Details of the model are in Appendix III. In this section, we rename variable x_1 with M for morning ($M > 0$ if trading occurs predominantly in the morning) and variable x_2 with Q for quoter ($Q > 0$ if trading occurs predominantly as quoter). The bank capitalization variable is represented by five levels and dummy coded as shown in Tab.(9). We chose the smallest capitalization group MI as reference.

Results of the regression[5] are reported, separately for the lending and borrowing side, in

[4]Tables 7–12 show that variable x_3 is positively correlated with size in all three periods so we do not include it in the cross-sectional regression

[5]We have also considered an expanded model to include interactions between the group variables and

market side	M	Q	MA	GR	ME	PI	MI	FB
lenders	0.766	0.744	0.090	0.124	0.140	0.140	0.008	0.071
borrowers	0.735	0.719	0.090	0.140	0.057	0.049	0.312	0.140

Table 3: The fraction of maintenance periods for which the regressor coefficients have been found to be significant at the 0.05 level.

table 3. The M coefficient is significant at the 0.01 level for 69% of the maintenance periods and at the 0.05 for 77% of the maintenance period. For the Q coefficient the values are 65% and 74% of total maintenance periods respectively. For borrowers, as before variables M, Q are generally highly significant whereas we find that the group variable adds little to the model. The M coefficient is significant at the 0.05 level for 74.4% of the maintenance periods, whereas the Q coefficient for 71.4% of total maintenance periods. On the contrary, the group categorical variable, that allow for different intercepts per bank calitalization, add very little explanatory value to the model (as show also by the large p-values of the group coefficients in Fig. 17). The most significant result for the group line indicates that 31% of the times MI banks pay higher rates as borrowers, even after controlling for the liquidity effects.

The values of the coefficients of the M and Q variables are shown as time series in Fig. 15 for the lending side and in Fig. 16 for the borrowing side. The average value of all the coefficients are summarised in table 4. The sign of the variables confirms that trading in the morning and trading as quoter is advantageous to both lenders and borrowers, and more so as the crisis progresses. The effects of size, while rarely significant, is in line with previous studies and show that larger banks tend to pay less as borrowers and charge more as lenders.

Overall our analysis demonstrates that, after controlling for the strategic behaviour of banks, the effect of size on spreads becomes negligible. While our analysis confirms that larger banks did perform better during the crisis, we identify the reasons for their success. The larger and foreign banks are the ones who better responded to the changing market microstructure condition and optimised their trades so to reduce the liquidity costs. Their better performance was actively achieved by a sophisticated liquidity management and not the result of the market participants perceiving them as too big to fail.

the strategic variables. The results show that the coefficient of the regressions are the same for all groups and the interaction terms not relevant

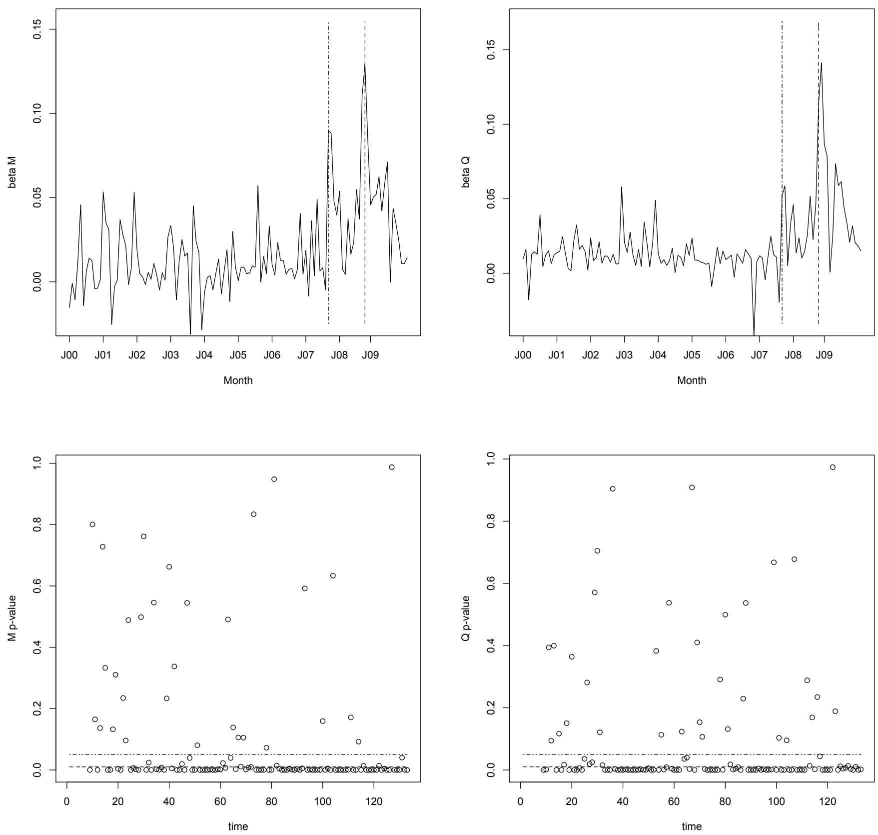

Figure 15: Left: The magnitude (top) and p-value (bottom) of the β_6 coefficient for the M variable. Right: The magnitude (top) and p-value (bottom) of the β_6 coefficient for the Q variable.

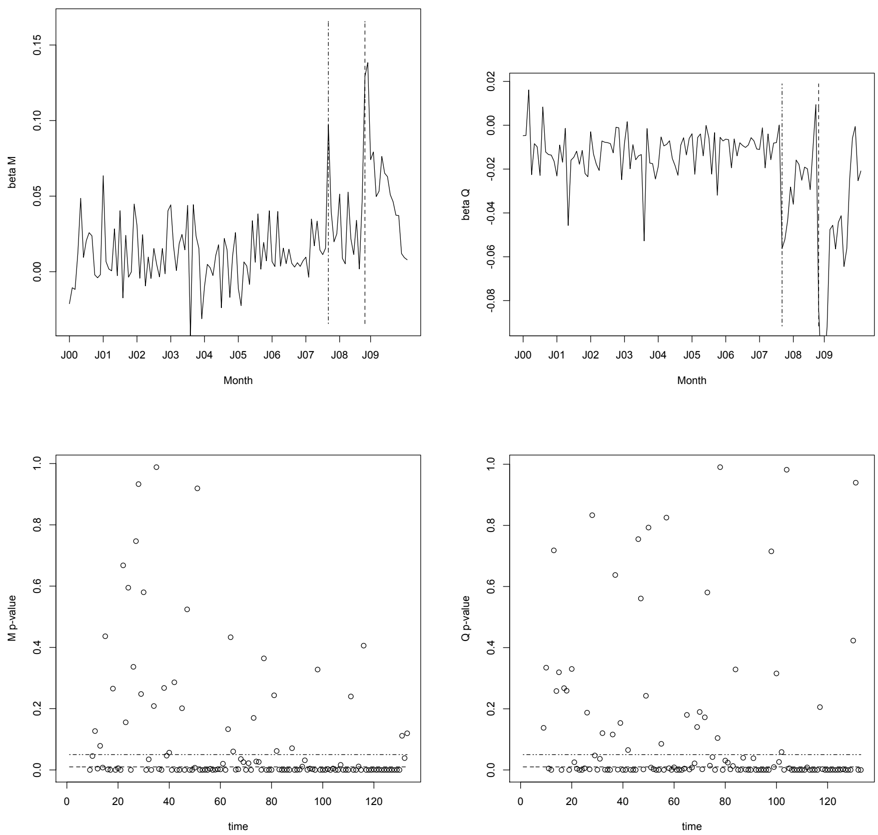

Figure 16: Left: The magnitude (top) and p-value (bottom) of the β_6 coefficient for the M variable. Right: The magnitude (top) and p-value (bottom) of the β_7 coefficient for the Q variable.

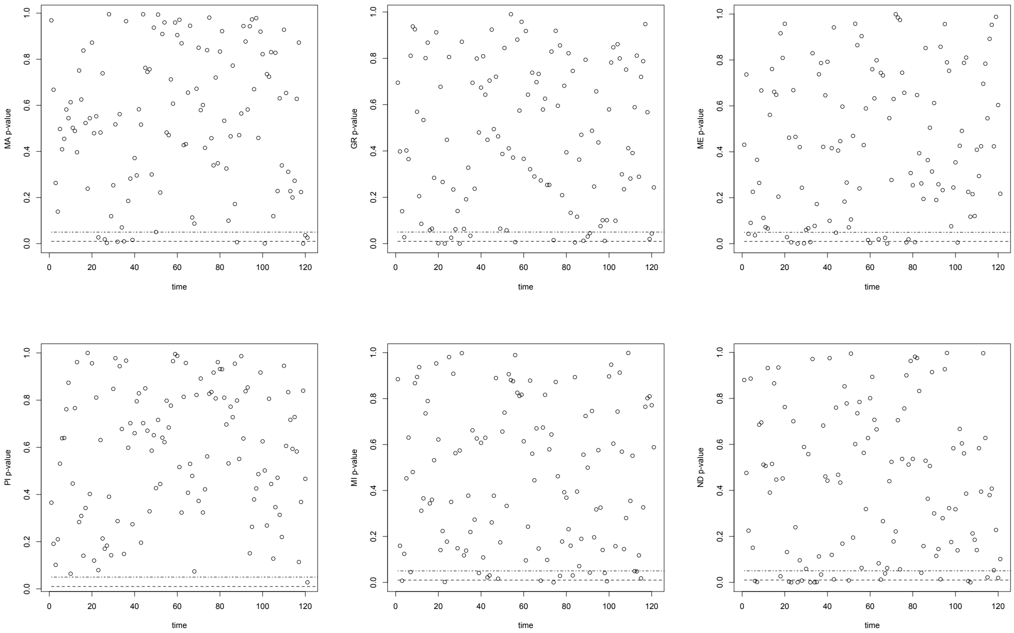

Figure 17: The statistical significance of the group effect for lenders.

market side	variable	p1	p2	p3
	M	0.012	0.051	0.038
	Q	0.005	0.035	0.045
	MA	0.01	0.0	0.031
Lenders	GR	0.01	0.023	0.001
	ME	-0.009	0.011	0.011
	PI	0.0	-0.006	0.008
	MI	-0.003	0.012	0.014
	FB	0.0	0.006	0.007
	M	0.012	0.041	0.052
	Q	-0.009	-0.031	-0.049
	MA	-0.013	-0.037	-0.054
Borrowers	GR	-0.015	-0.013	-0.051
	ME	-0.006	0.003	-0.026
	PI	-0.004	-0.002	-0.21
	MI	0.007	0.017	0.022
	FB	-0.006	-0.006	-0.003

Table 4: The mean values of the regressor coefficients for lenders and borrowers in (p_1, p_2, p_3).

9. Conclusions

In this paper we have investigated the impact of the 2007–2009 financial crisis on the behavior of banks within the interbank market and, in turn, on their lending and borrowing spreads. Running econometric analyses we have highlighted the role of the changing intraday term structure of interest rate and of the market bid-ask spread as explanatory variables for the variability in credit conditions. In particular our results show that the higher the volume traded by a bank in the morning, the higher are the spreads (that is borrowing conditions deteriorate in the morning for borrowers and improve for lenders) and the higher the volume traded as quoters, the better are the rates obtained, both for lenders and borrowers.

The policy implications of our findings are as follows. To reduce the volatility of interbank market rates, central banks should provide liquidity by calibrating their interventions according to the intraday term structure slope. Since the slope depends on expected short rates, central banks can fine-tune how they provide liquidity playing as market makers continuously during the trading day, coherently with the real-time gross settlement of the payment system.

The interest rate volatility stabilization and spread normalization could be pursued introducing overnight deposits expiring after 24 hours. This way the liquidity settlement would be distributed along the day, avoiding the concentration of all the interbank trades early in the morning. This innovation could go along with the introduction of intraday deposits, completing the Arrow-Debreu market structure.

Finally, the evidence about the dependence of interest-rate spreads on banks' behavior supports a revision of their liquidity-management practice. Banks' treasuries should try to manage and net their financial balances by optimizing costs and returns according to the features of the market microstructure, such as timing their trades, adjusting the concentrations of volumes, possibly via pooling operations, and choosing strategically the quoter/aggressor side to lend and borrow money.

Acknowledgments

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Appendix I

Bank classification by size

Banks are classified into 5 groups according to their weighted asset portfolio: major banks (higher than 60 billion Euro), large banks (from 26 to 60 billion Euro), medium banks (from 9 to 26 billion Euro), small banks (from 1.3 to 9 billion Euro) and minor banks (less than 1.3 billion Euro). Banks belonging to the different groups, except for the smallest, are listed by the Bank of Italy (2011) as reported below.[6]

- **Major ("maggiori", 5):** Cassa Depositi e Prestiti spa; Banca Monte dei Paschi di Siena spa; Banca Nazionale del Lavoro spa; Intesa SanPaolo spa; UniCredit spa.

- **Large ("grandi", 11):** Banca Antonveneta spa; Banca IMI spa; Banca Infrastrutture, Innovazione e Sviluppo spa; Banca Popolare dell'Emilia Romagna; Banca Popolare di Bergamo spa; Banca Popolare di Lodi spa; Banco Popolare di Verona, S. Geminiano e S. Prospero spa; Banca Popolare di Milano; Dexia Crediop spa; Mediobanca — Banca di Credito Finanziario spa; Unione di Banche Italiane scpa.

- **Medium ("medie", 34):** Aletti & C. Banca di Investimento Mobiliare spa; Banca Agrileasing spa — Banca per il Leasing delle BCC/CRA; Banca Carige spa — Cassa di Risparmio di Genova e Imperia; Banca Carime spa; Banca delle Marche; Banca Italease spa; Banca Popolare Commercio e Industria spa; Banca Popolare di Ancona spa; Banca Popolare di Novara spa; Banca Popolare di Sondrio scpa; Banca Popolare di Vicenza scpa; Banca Regionale Europea — B.R.E. Banca; Banco di Brescia S. Paolo Cab spa; Banco di Napoli spa; Banco di Sardegna spa; Banco Popolare sc; Barclays Bank plc; BNP Paribas; Cassa di Risparmio del Veneto spa; Cassa di Risparmio di Firenze spa; Cassa di Risparmio di Lucca Pisa Livorno spa; Cassa di Risparmio di Parma e Piacenza spa; Cassa di Risparmio in Bologna spa; Credito Bergamasco spa; Credito Emiliano spa; Deutsche Bank spa; Findomestic Banca spa; ING Direct nv; MCC — MedioCredito Centrale spa; Mediocredito Italiano spa; Monte dei Paschi di Siena Capital Services Banca per le Imprese spa; MPS Leasing & Factoring spa; Société Générale; State Street Bank spa.

- **Small ("piccole", 142):** Aareal Bank AG; Abaxbank spa; Allianz Bank Financial Advisors spa; Banca 24-7 spa; Banca Agricola Popolare di Ragusa; Banca Akros spa; Banca Alpi Marittime Credito Cooperativo Carrù scpa; Banca Apulia spa; Banca Carim — Cassa di Risparmio di Rimini spa; Banca Caripe spa; Banca del Fucino;

[6] sc = società cooperativa, scpa = società cooperativa per azioni, spa = società per azioni.

Banca della Campania spa; Banca dell'Adriatico spa; Banca della Marca Credito Cooperativo sc; Banca del Piemonte spa; Banca di Cividale spa; Banca di Credito Cooperativo del Garda — Banca di Credito Cooperativo Colli Morenici del Garda sc; Banca di Credito Cooperativo delle Prealpi sc; Banca di Credito Cooperativo di Alba, Langhe e Roero sc; Banca di Credito Cooperativo di Brescia sc; Banca di Credito Cooperativo di Cambiano; Banca di Credito Cooperativo di Carate Brianza sc; Banca di Credito Cooperativo di Pompiano e della Franciacorta sc; Banca di Credito Cooperativo di Roma sc; Banca di Credito Popolare scpa; Banca di Credito Sardo spa; Banca di Imola spa; Banca di Legnano spa; Banca di Piacenza scpa; Banca di Sassari spa; Banca di Trento e Bolzano spa — Bank für Trient und Bozen; Banca di Valle Camonica; Banca Fideuram spa; Banca Generali spa; Banca IFIS spa; Banca Intermobiliare di Investimenti e Gestioni spa; Banca Mediolanum spa; Banca Monte Parma spa; Banca Nuova spa; Banca Padovana di Credito Cooperativo; Banca Passadore & C. spa; Bancaperta spa; Banca Piccolo Credito Valtellinese sc; Banca Popolare dell'Alto Adige/Südtiroler Volksbank; Banca Popolare del Lazio scarl; Banca Popolare dell'Etruria e del Lazio sc; Banca Popolare del Mezzogiorno spa; Banca Popolare di Bari scpa; Banca Popolare di Crema spa; Banca Popolare di Cremona spa; Banca Popolare di Lanciano e Sulmona; Banca Popolare di Marostica scarl; Banca Popolare di Puglia e Basilicata scpa; Banca Popolare di Ravenna spa; Banca Popolare di Spoleto spa; Banca Popolare Friuladria spa; Banca Popolare Pugliese scpa; Banca Profilo spa; Banca Sella Holding spa; Banca Sella spa; Banca UBAE spa; Banca Valsabbina scpa; Banco Bilbao Vizcaya Argentaria sa; Banco di Desio e della Brianza; Banco di San Giorgio spa; Banque PSA Finance; Bayerische Landesbank; BHW Bausparkasse AG; Bnp Paribas Personal Finance; BNP Paribas Securities Services; Carifano — Cassa di Risparmio di Fano spa; Cariprato — Cassa di Risparmio di Prato spa; Carispaq — Cassa di Risparmio della Provincia dell'Aquila spa; Cassa Centrale Banca — Credito Cooperativo del Nord Est spa; Cassa Centrale Raiffeisen dell'Alto Adige; Cassa dei Risparmi di Forlì e della Romagna spa; Cassa di Risparmio del Friuli Venezia Giulia spa; Cassa di Risparmio della Provincia di Chieti spa; Cassa di Risparmio della Spezia spa; Cassa di Risparmio di Alessandria spa; Cassa di Risparmio di Ascoli Piceno spa; Cassa di Risparmio di Asti spa; Cassa di Risparmio di Biella e Vercelli — Biverbanca spa; Cassa di Risparmio di Cento spa; Cassa di Risparmio di Cesena spa; Cassa di Risparmio di Fabriano e Cupramontana spa; Cassa di Risparmio di Fermo spa; Cassa di Risparmio di Ferrara spa; Cassa di Risparmio di Pistoia e Pescia spa; Cassa di Risparmio di Ravenna spa; Cassa di Risparmio di Rieti spa; Cassa di Risparmio di San Miniato spa; Cassa di Risparmio di Savona spa; Cassa di Risparmio di Venezia spa; Cassa di Risparmio di Volterra spa; Cassa Padana Banca di Credito Cooperativo sc; Cassa Risparmio di Bolzano spa; Cassa Rurale — Banca di Credito Cooperativo di Treviglio sc; Cassa Rurale e Artigiana di Cantù Banca di Credito Cooperativo; Cassa Sovvenzioni e Risparmio fra Personale della Banca d'Italia; Centrobanca — Banca Centrale di Credito Popolare spa; CheBanca spa; Citibank International plc; Citibank na; Crédit Agricole Corporate and Investment Bank; Credito Artigiano; Credito Cooperativo Ravennate e Imolese sc; Credito Siciliano spa; Depfa Bank plc; Efibanca spa; Eurohypo Aktiengesellschaft;

Fce Bank plc; Finecobank Banca Fineco spa; Ge Capital spa; HSBC Bank plc; Hypo Alpe Adria Bank Italia spa; ICCREA Banca spa — Istituto Centrale delle Banche di Credito Cooperativo; ING Bank nv; Intesa Sanpaolo Private Banking spa; Istituto Centrale delle Banche Popolari Italiane; Istituto per il Credito Sportivo; IW Bank spa; J.P. Morgan Chase Bank National Association; Maple Bank GmbH; Mediocredito del Friuli-Venezia Giulia spa; Mediocredito Trentino-Alto Adige spa; Meliorbanca spa; Morgan Stanley Bank International ltd; Natixis sa; Rabobank Nederland; RCI Banque sa; Santander Consumer Bank spa; Société Générale Securities Services spa; Tercas — Cassa di Risparmio della Provincia di Teramo spa; The Royal Bank of Scotland; The Royal Bank of Scotland nv; UBS (Italia) spa; UGF Banca spa; Unicredit Bank ag; Veneto Banca scpa; Volkswagen Bank GmbH; WestLB AG.

Appendix II

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
MA	6	7	7	6	6	6	6	6	6	4	4
GR	12	12	8	7	9	7	7	9	9	6	5
ME	26	26	26	23	17	14	13	13	12	12	10
PI	68	64	74	61	57	52	53	58	54	53	51
MI	76	59	33	31	28	26	26	14	16	20	19
FB	2	13	20	31	48	54	60	59	62	58	39

Table 5: Banks active as borrowers per group per year.

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
MA	6	7	7	6	6	6	6	6	6	4	4
GR	12	12	8	7	9	7	7	9	9	6	4
ME	26	26	26	23	18	14	13	13	11	11	10
PI	75	65	76	66	60	58	55	62	58	54	55
MI	91	70	44	39	34	35	33	17	20	22	22
FB	3	11	21	32	48	57	61	66	70	70	45

Table 6: Banks active as lenders per group per year.

group	size	Δt	x_1	x_2	x_3
MA	4	336	0.009	0.562	0.026
GR	6	271	0.225	0.438	0.021
ME	14	777	0.259	0.379	0.01
PI	31	7594	0.355	-0.063	0.003
MI	26	13623	0.525	-0.29	0.001
FB	47	6398	0.009	0.339	0.024

Table 7: Average values of independent variables for borrowers in p1 (before the subprime crisis)

group	size	Δt	x_1	x_2	x_3
MA	4	483	-0.028	0.709	0.036
GR	5	606	0.103	0.397	0.024
ME	12	1627	0.219	0.263	0.019
PI	27	3639	0.384	0.032	0.005
MI	29	9961	0.387	-0.299	0.001
FB	37	7854	-0.032	0.337	0.026

Table 8: Average values of independent variables for borrowers in p2 (after the subprime crisis and before the Lehman failure.

group	size	Δt	x_1	x_2	x_3
MA	3	190	0.0	0.544	0.042
GR	3	951	0.438	0.646	0.061
ME	10	730	0.381	0.332	0.038
PI	23	7703	0.392	0.278	0.01
MI	28	7240	0.462	-0.224	0.003
FB	17	3881	0.154	0.385	0.034

Table 9: Average values of independent variables for borrowers in p3 (after the Lehman failure).

group	size	Δt	x_1	x_2	x_3
MA	4	179	0.094	-0.159	0.028
GR	6	1043	0.196	-0.185	0.009
ME	14	1163	0.047	-0.219	0.008
PI	33	1381	0.183	-0.524	0.004
MI	33	665	0.452	-0.711	0.003
FB	49	7167	0.022	-0.729	0.022

Table 10: Average values of independent variables for lenders in p1 (before the subprime crisis).

group	size	Δt	x_1	x_2	x_3
MA	4	175	0.045	-0.256	0.033
GR	4	585	0.05	-0.533	0.017
ME	12	1422	0.102	-0.341	0.009
PI	33	1115	0.231	-0.551	0.006
MI	42	996	0.31	-0.662	0.004
FB	47	5528	-0.072	-0.735	0.027

Table 11: Average values of independent variables for lenders in p2 (after the subprime crisis and before the Lehman failure).

group	size	Δt	x_1	x_2	x_3
MA	3	1068	0.446	-0.589	0.052
GR	3	1378	0.172	-0.787	0.025
ME	8	2704	0.165	-0.642	0.018
PI	33	1296	0.386	-0.639	0.011
MI	40	1949	0.418	-0.583	0.008
FB	22	6812	0.050	-0.773	0.036

Table 12: Average values of independent variables for lenders in p3 (after the Lehman failure).

Appendix III

We create a multilinear regression model using a mix of categorical and continuous regressors. The bank capitalization variable is represented by five levels and dummy coded as shown in Tab.(9). We chose the smallest capitalization group MI as reference.

	D_1	D_2	D_3	D_4	D_5
MI	0	0	0	0	0
GR	1	0	0	0	0
MA	0	1	0	0	0
ME	0	0	1	0	0
ND	0	0	0	1	0
PI	0	0	0	0	1

This scheme results in the following model:

$$Y = \beta_0 + \beta_1 D_1 + \beta_2 D_2 + \beta_3 D_3 + \beta_4 D_4 + \beta_5 D_5 + \beta_6 M + \beta_7 Q \tag{8}$$

where M, Q are the morning and quoter preference variables respectively, previously denoted as x_1 and x_2. This model allows for the effect of capitalization on spread as different intercepts are introduced via the dummy variables. Expanding the model we get the following system of equations:

$$\begin{aligned}
Y_{MI} &= \beta_0 + \beta_6 M + \beta_7 Q \\
Y_{GR} &= (\beta_0 + \beta_1) + \beta_6 M + \beta_7 Q \\
Y_{MA} &= (\beta_0 + \beta_2) + \beta_6 M + \beta_7 Q \\
Y_{ME} &= (\beta_0 + \beta_3) + \beta_6 M + \beta_7 Q \\
Y_{ND} &= (\beta_0 + \beta_4) + \beta_6 M + \beta_7 Q \\
Y_{PI} &= (\beta_0 + \beta_5) + \beta_6 M + \beta_7 Q
\end{aligned} \tag{9}$$

The expanded model to incorporate interaction effects is given by the following equations:

$$\begin{aligned}
Y_{MI} &= \beta_0 + \beta_6 M + \beta_7 Q \\
Y_{GR} &= (\beta_0 + \beta_1) + (\beta_6 + \beta_8) M + (\beta_7 + \beta_{13}) Q \\
Y_{MA} &= (\beta_0 + \beta_2) + (\beta_6 + \beta_9) M + (\beta_7 + \beta_{14}) Q \\
Y_{ME} &= (\beta_0 + \beta_3) + (\beta_6 + \beta_{10}) M + (\beta_7 + \beta_{15}) Q \\
Y_{ND} &= (\beta_0 + \beta_4) + (\beta_6 + \beta_{11}) M + (\beta_7 + \beta_{16}) Q \\
Y_{PI} &= (\beta_0 + \beta_5) + (\beta_6 + \beta_{12}) M + (\beta_7 + \beta_{17}) Q
\end{aligned} \tag{10}$$