Very preliminary draft. Please do not quote without permission of authors.

Repo Market Microstructure in Unusual Monetary Policy Conditions

Peter G. Dunne[1]

Michael Fleming[2]

Andrey Zholos[3]

16th Dec 2009

Abstract.

The financial turmoil that began in mid-2007 produced severe stress in interbank markets and prompted significant changes in central bank's funding operations. This paper examines how official interventions affected the efficiency and reliability of the secondary repo market as a mechanism for the distribution of interbank funding during this unusual period. The limit orderbook from the BrokerTec electronic repo trading platform is reconstructed to provide an accurate measure of available liquidity and funding opportunities at high frequency throughout the crisis. This provides insights about the effectiveness of 'liquidity provider of last resort' efforts by the ECB in reponse to the crisis.

Keywords: Repo, Financial crisis, liquidity, market microstructure, monetary policy operations.

Very preliminary draft. Please do not quote without permission of authors.

[1] *Central Bank of Ireland*, Dame Street, Dublin 2, Ireland. Email: peter.dunne@centralbank.ie, Tel.: 00353-1-224-6331.

[2] *Federal Reserve Bank of New York.* [3] *Queen's University Management School (Belfast, UK).*

1 Introduction

Has official intervention relieved crisis-related stress within the secondary interbank repo market and improved its reliability as a source of funding and as a redistributive mechanism? We address these issues through the lens of a microstructure analysis of the electronic secondary general collateral (GC) repo market in the euro-area throughout the recent financial market turmoil. Beginning with an analysis of the microstructural characteristics of this relatively unexplored market, aspects of how the secondary repo market was affected by the events of the financial crisis and by the resulting official interventions by the European Central Bank (ECB) are addressed. The analysis shows that crisis-related liquidity shocks had a significant effect on the functioning of the market beyond what is already described in Hördahl and King (2008). The effect of ECB interest rate announcements on the predictability of overnight repo rates and on the cross-country repo gap is also conducted.

Official funding operations by central banks have been altered greatly in response to the crisis. Changes of this magnitude have potential to produce unintended consequences. The main concern of this paper is to identify the main changes in official funding operations (of relevance to the secondary repo market) that have occurred as a result of the crisis and to identify what were the main effects of such changes on the ex-ante reliability of secondary funding markets. These goals are not fully achieved in this early draft, but what follows represents some preliminary findings that should help to define appropriate methodologies towards achieving them.

Extant literature

In Brunetti, Filippo and Harris (2009) the effect of official interventions on the unsecured, electronic, interbank lending market is analyzed. Their approach is to examine how surprises in ECB interventions affect the provision of liquidity and other characteristics of the interbank market. They conclude that ECB policy changes increased the level of uncertainty in the interbank market and crowded out private provision of liquidity. The ECB also examined specific important events in their Financial Stability Review (2009). An important distinction is made in this work between the markets' ability to redistribute liquidity across banks experiencing idiosyncratic shocks and how it copes with sudden, large, aggregate liquidity shocks. The ECB, through official operations, is often the mechanism by which such large shocks are absorbed. Since such operations are planned in advance and large shocks are by their nature unpredictable, it is practically impossible for policy makers to get their interventions exactly right. This, in itself, poses problems for market participants and may add an element of uncertainty beyond what would already be present in unusual times. The ECB emphasizes the fact that banks were hoarding funds rather than lending them (even short term or collateralized) at various stages of the crisis. The hoarding of funds is visible from the total liquidity absorbed by the ECB through their deposit facility and liquidity absorbing fine tuning operations. Since the crisis may have favoured secured lending it is not certain that a similar conclusion can be made for repo markets and this is discussed below. Since the ECB increased the range (and quality) of the collateral it accepted during the recent turmoil in its own repo operations, this may have led to higher quality collateral being redirected to the interbank repo market (see, Ewerhart and Tapking, 2008).

Counterparty risk should not be present to the same extent in the case of the repo market. But this did not prevent virtual collapse of the repo market at some instances during the crisis. Hördahl and King (2008) found that, as the financial market turmoil intensified throughout 2008, repo transactions (i) became restricted to shorter maturities (ii) involved higher quality collateral and (iii), in the case of general collateral repos, were done at reduced spreads relative to overnight index swap (OIS) rates. These changes reflected concerns about the credit worthiness of counterparties, the increasing demand for liquid assets and the hoarding of high quality collateral. Supply and demand factors can be further traced to the behavior of money market funds that increasingly retained their liquid assets and to the behavior of longer-term investment funds that were increasingly reluctant to lend out high quality assets.

There are relatively few studies that examine high-frequency, secondary repo market data, but there are a number of studies concerned with the repo operations of the ECB. In Nyborg et al. (2002) the weekly repo auctions of the ECB are examined to gain an understanding of how bidding strategies affect the outcomes. Eisenschmidt et al (2009) examine bidding behavior in ECB funding operations during the crisis and find that it was affected by the increased individual refinancing motive, the increased attractiveness of the ECB's tender operations due to its collateral framework and banks' bidding more aggressively, i.e. at higher rates to avoid being rationed at the marginal rate in times of increased liquidity uncertainty. Their study does not extend into the period of fixed-rate, full-allotment operations.

There is a large theoretical literature concerning bank (and interbank market) failure. Only some of this has direct relevance for the current work. Heider, Hoerova and Holthausen (2009) provide a model of interbank market stress that provides an explanation of recently observed phenomena of elevated adverse selection spreads, liquidity hoarding and market breakdown. Their model is also uses to assess the efficacy of policy responses and it probably could explain some developments in the secured interbank lending markets that are studied below since it implicitly involves some switching of activity between these markets by higher quality (more liquid) banks. Other important theoretical contributions include that of Freixas and Jorge (2008) who show that information-related imperfections in the interbank markets can produce rationing in the credit markets. They define interbank market rationing in terms of switching to collateralized lending (or absence of unsecured lending). They further associate this with certain banks becoming constrained and reducing their ordinary lending as a result. Whether this is a strong effect depends crucially on whether the secured lending market is really a mechanism for addressing asymmetric information and is capable of substituting for unsecured lending of a large enough proportion of borrowers.

Official funding operations in response to the financial market stress

The mechanisms by which official interventions are managed in the euro-area and the US have important differences. The ECB operates through secured lending operations with direct participation from banking institutions all over Europe. This broad participation is helpful in terms of securing liquidity distribution (and short term funding supply) across a large number of banking institutions. The only impediment to access to such funding is capital adequacy and the availability of adequate collateral to take advantage of refinancing operations. These constraints were not initially problematic during the crisis. It was thus easy for the ECB to step-up its operations and

become a major intermediary, virtually replacing interbank activity. While the interbank market may have been abruptly supplanted as a source of funding, the step-up in ECB activity may also have led to an increased need for the services of a redistribution facility such as the secondary repo market to get ECB funding to institutions with the most serious liquidity and funding needs. Since, unsecured funding markets were badly affected by the crisis due to elevated counterparty risk, the secondary repo market increased in importance but the specific effects of official intervention on this market remain unknown.

Since a good distribution of funding across a wide variety of participants is achieved through ECB operations directly, it might also be concluded that an additional distributive mechanism such as the secondary repo market is less necessary than in the US where only primary dealers have access to the official repo lending facilities. The Federal Reserve System ("the Fed") had operated through a small number of Primary Dealers some of which were under threat of insolvency after the crisis began. The distribution 'bottleneck' led the Fed to introduce an array of mechanisms by which institutions, other than primary dealers, could properly avail of official liquidity provision.

Normal facilities, such as discount window borrowing, did not ease interbank market stress because this source of liquidity was perceived as damaging to a participant's credit standing. The Term Auction Facility (TAF) was introduced on December 12th 2007 specifically to allow commercial banks to participate in a more competitive liquidity enhancing exercise (7,000 of them). The TAF involved lending on a longer term (28 days) than was usual for Fed repo operations and it accepted 'discount window' collateral.[1] While the TAF aided in getting liquidity to the place it was needed it is not clear that it addressed the deeper problem of illiquidity in the unsecured interbank lending markets. According to Taylor and Williams (2008) the introduction of the TAF did not significantly influence the spread between term LIBOR rates and overnight lending rates.

As a result of a complex set of events in early March 2008, as described by Brunnermeier (2009), the Fed introduced both the *Term Securities Lending Facility* (TSLF) and the *Primary Dealer Credit Facility*

[1] In many respects, TAF is similar to long-term repo operations that form part of the ECBs regular monthly operations.

(PDCF). The TSLF allowed primary dealers to swap various types of asset-backed and agency securities for Treasuries thereby improving the quality of collateral that could be used in interbank repos. Fleming *et al.* (2009) have examined how the TSLF changed the rate spreads between the different classes of securities involved and concluded that the effects were benign. Adrian and McAndrews (2008) also reported positive enhancement of liquidity arising from the PDCF. Other initiatives in November 2008 associated with quantitative easing involved the planned outright purchase of Government Sponsored Enterprise debt (GSE) and Mortgage-Backed Securities (MBS).

Our study considers interest rate events in three phases. The pre-crisis phase is characterized by an upward trend in interest rates and runs from Jan 2006 to July 2007. In this period there are 19 ECB interest rate decision dates. On 7 of these dates interest rates were raised. On the remaining 12 occasions interest rates were left unchanged. The second phase (Aug 2007 – Sep 2008) was characterized by stable, but relatively high official rates. There are 14 ECB interest rate decision dates in this period but only one interest rate change, which was positive. The last phase (following the Lehman collapse) is characterized by declining rates. In this post-Lehman collapse period there were 7 interest rate decision events. On 6 of these interest rates were reduced and on the remaining date they were left unchanged.

The last two phases capture two approaches used by the ECB to mitigate the effects of the financial turmoil. In phase 2 the ECB modified its funding procedures by (1) adjusting the distribution of liquidity over the reserve maintenance period by systematically allotting liquidity in excess of the theoretical 'benchmark allotment' while still aiming for balanced liquidity conditions at the end of the maintenance periods, (2) extending the average maturity of its financing, and (3), engaging with other central banks to relieve liquidity shortages of the euro-area banks in other currencies (mostly US dollars). In phase 3, in addition to aggressive reductions in the targeted refinancing rate, the ECB (1), introduced a fixed rate tender procedure with full allotment in both the main refinancing operations and the long-term refinancing operations, (2) increased the number of longer term operations,[2] (3) increased the range of assets eligible for use as collateral in Eurosystem credit operations[3] and (4) increased US dollar swap financing by use of fixed-rate tender with full allotment

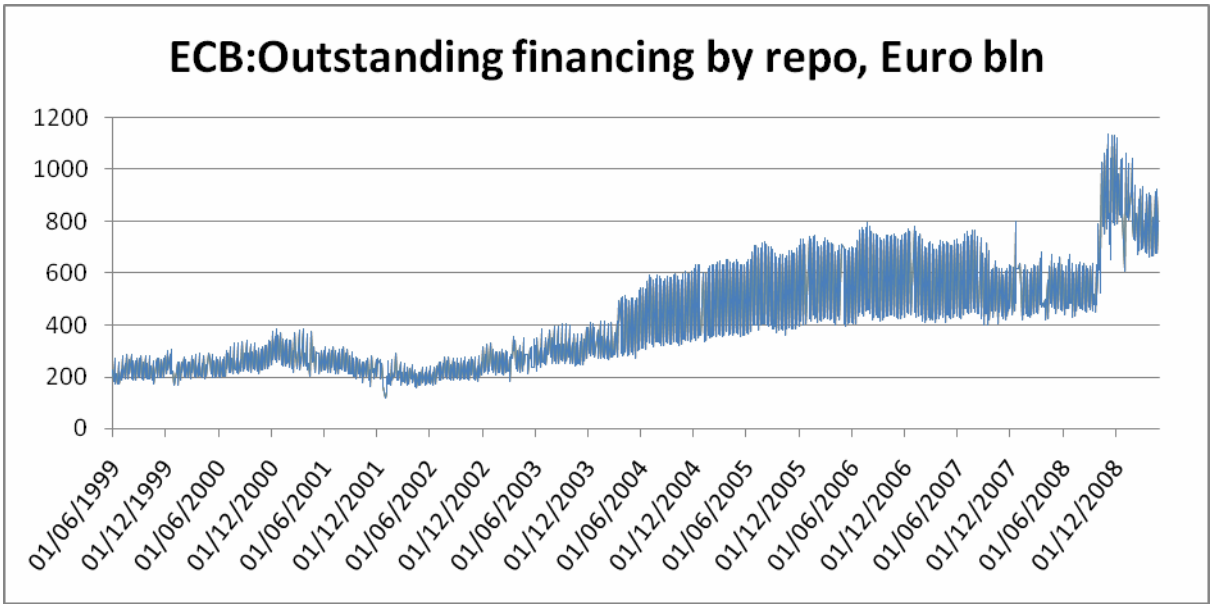
[2] The ECB introduced three additional operations per month (two with three month term and one with six month term) and an additional operation with term corresponding to the reserve maintenance period.

[3] The list of eligible was expanded on 15th October 2008 and in May 2009 this policy was prolonged until end-2010.

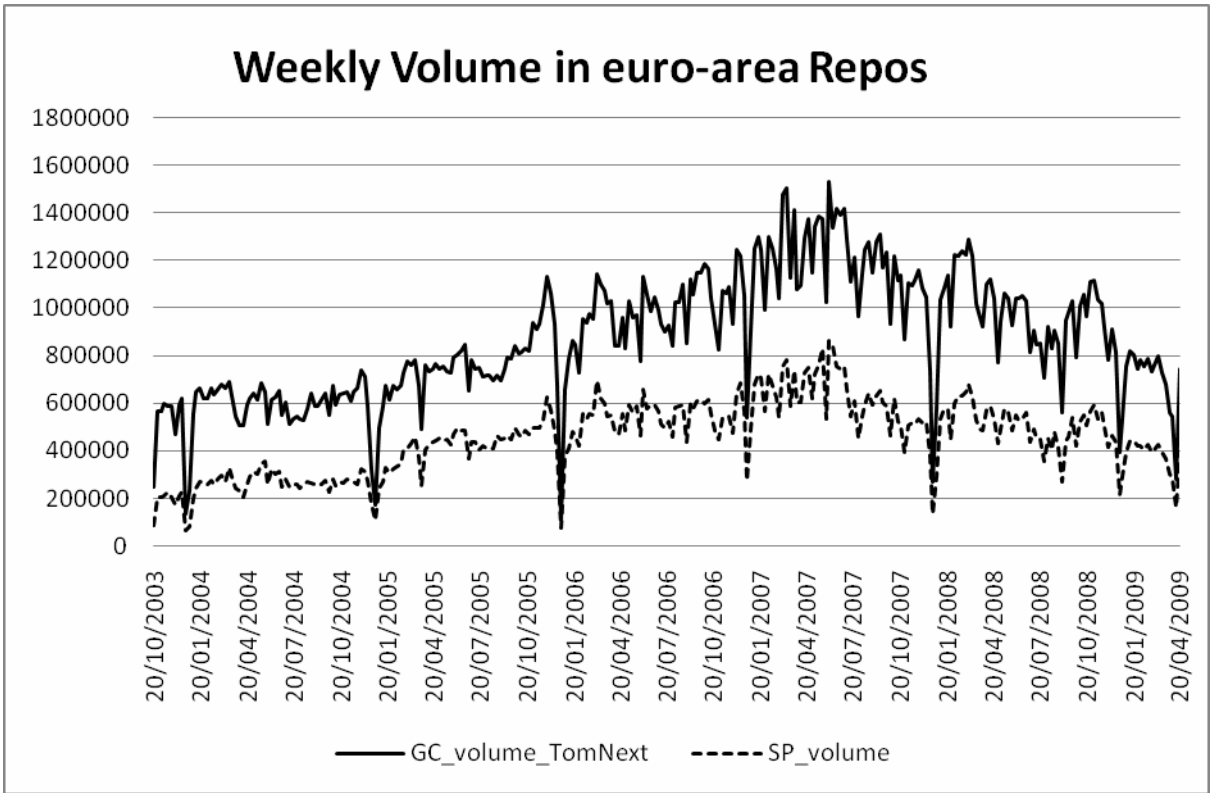
by special arrangements with the Federal Reserve System. On 7th May 2009 the ECB also announced that it would begin operations to buy EUR 60 billion of covered bonds and that the European Investment Bank (EIB) would become an eligible counterparty in Eurosystem's monetary policy operations on 8th July 2009. Some effort was made (effective 21st Jan 2009) to encourage banks to re-engage with each other in the unsecured interbank market by re-widening the corridor between rates for standing facilities to 200 basis points around the rate on main refinancing operations (the 100 bps corridor had been introduced in Oct 9th 2007).

The fixed rate full-allotment policy of the ECB that has been in place since the Lehman Bros event in Oct 2008 places a virtual floor on the repo rate. In normal circumstances the ECB tries to ensure that banks have access to short term liquidity facilities purely to avoid unanticipated, temporary shortfalls in their requirements. Under these circumstances ECB funding is rationed in a competitive setting, where the repo rate is driven to a level such that it is of only marginal benefit to banks in deriving excess risk-adjusted returns.

In the euro-area, refinancing operations of the ECB in the pre-turbulence period were on a steady incline in terms of the overall amount of refinancing undertaken. This is apparent from Figure 1 which shows the amount of outstanding financing as a continuous time series. Short term operations cause high-frequency variability in the series. Repo financing has generally increased slightly over time. This may simply be a reflection of the enlargement of the euro-area and the consequent growth in participation in official repo operations. By 2005 financing through ECB repo had doubled from its 2002 level. A significant jump occured in the last quarter of 2008 reflecting the ECBs efforts to relieve tensions in the short term financing market through increased terms of their operations.



Secondary market repo volume was also increasing in the pre-crisis period (see the Figure below and also the reported increases in volumes on the secondary repo market according to ICMA surveys). It is apparent from the figure that the recent period of generous funding by the ECB through low, fixed-rate, full-allotment (longer maturity) operations has not led to increased secondary repo market trading so far.



Market & Data Description

The secondary repo market in Europe is surveyed on a semi-annual basis by the European Repo Council of the Securities Industry and Financial Markets Association (SIFMA). The survey provides a snapshot of the volume of repo trades outstanding on a single day in June and December each year and various other indicators of the market structure and growth. This survey reveals that repo volume reached a high point of 6,504 bln EUR in June 2007. It grew at a rate of roughly 20% each year between June 2001 and June 2007 and when the financial crisis hit it declined to 4,633 bln EUR in December 2008 before recovering to 4,868 bln EUR in June 2009. This implies that it was around the same size as the US inter-dealer repo market in US Treasuries in June 2007. Anonymous electronic trading represents about 25% of repo volume but this proportion has fluctuated recently with a surge in voice brokered business occurring at the height of the crisis when a flight to liquidity required improved search mechanisms and an avoidance of counterparty risk. The most recent survey shows that more than 80% of collateral used in repos is made up of European government bonds and nearly 30% is represented by German government bonds alone. German government bonds held a steady share of around 25% in most of the previous surveys. Italian bonds are also well represented with a share of between 12 and 15% in recent surveys.

The secondary repo market that is studied here is the BrokerTec electronic, order-driven repo market provided by ICAP plc. The BrokerTec platform provides the leading venue for electronic inter-dealer trading in European repos mainly covering euro zone government debt. There are more than 70 participating banks. Nearly half of these banks are also Primary Dealers in one or more of the underlying government bond markets[4]. All participants have equal access and rights on the trading platform. There are no designated or 'specialist' liquidity suppliers. To be able to trade most of the repo products available on the platform, participants are required to be members of the central counterparty clearing system or have access through a third party clearer. Since this is a collateralized lending market it has reduced counterparty risk relative to unsecured markets. Credit

[4] There are 42 Primary Dealers listed as members of RepoClear and these are also members of the BrokerTec repo trading platform. RepoClear is part of the LCH Clearnet clearing house providing clearing, margin, netting and other facilities for trading on BrokerTec's repo platform; see, http://www.lchclearnet.com/membership/ltd/current_membership.asp.

risk is further reduced because of the balance sheet netting, settlement netting and centralized margining for most repo contracts traded on the platform. There is substantial pre- and post-trade transparency in this market for all of the participants but there is no real-time provision of market data to non-participants. Participants can view available depth in the market. Limit orders are entered by participants at their reservation prices and this provides opportunities for trading to occur. Trading is done only by accepting the specified quantities in the available limit orders. There is no negotiation over trade quantities or prices after trades are executed. The platform permits automatic replenishing of limit orders and pending orders are only visible to the firm entering the order. Pending orders do not have priority over 'shown' amounts at the same rate. Anonymity is preserved in most cases throughout trading and settlement (a central counterparty clearer took both sides of all the trades considered in this study). The market automatically opens at 06:45 London time and closes at 17:15. Outside of these times the system does not allow orders to be entered. There is no special starting mechanism.

The data from BrokerTec contains time-stamped records for all order events and trades conducted on the BrokerTec electronic platform for the period from March 2003 to March 2009 (most of our analysis concentrates on data from 2nd Jan 2006). This includes contracts for a wide range of repo collateral and terms to maturity. Table 1 provides details about the incidence of trades and of "limit order" setting activity for general collateral repo contracts. In total, there are almost 0.5 million order records and 130,000 trade records. It is clear from this table that most activity occurs for terms that are very short. Roughly 95% of GC activity is for contracts with start dates that are within a few days of the contract date and that last only a single overnight period.

While the dataset that we examine contains a number of general collateral contracts for each country, we select only a subset of these contracts for detailed analysis and the details for this group are contained in Tables 2 and 3. This selection is necessary because many of the contracts are not well populated with activity and they differ slightly in respect of the eligible collateral that can be delivered. In almost all cases, we choose the most liquid contract in each of the euro-area countries (we make an exception in the case of Germany and France where two GC series are maintained in the sample and are often combined). The GCs selected are mostly contracts that restrict the collateral to non-bills and bonds with maturity below 10 years. Data for Austria, Belgium, Germany, Spain, France, Greece, Ireland, Netherlands and Portugal are included. Italy is not covered since most of the electronic trading activity in Italian GC repos is done on the MTS platform and only sparsely on BrokerTec. Our selection process significantly restricts the size of the dataset used and Table 2 shows the breakdown of activity for the GC repo contracts that we focus on. It should be

noted that there does exist a European wide GC contract that is not traded on the BrokerTec platform. However, according to SIFMA surveys, German collateral represents the largest fraction of all collateral pledged against repo borrowing in Europe.

As is clear from Table 2, the most active contracts in our selection from the original data are referred to as "over-night", "tomorrow-next" and "settlement-next". The start dates of these contracts are zero, one, and two business days after the transaction date, respectively. We denote these as ON, TN and SN in the tables and in the rest of the paper. These three contracts account for about 95% of activity. The next most liquid contracts, with maturities of one week, are "overnight-week", "tomorrow-week", and "settlement-week". We refer to these as OW, TW and SW but often we consider them as a group. Beyond the one week maturity there are similar contracts with maturities of one month and referred to as OM, TM and SM.

Variables obtained from the raw data

The most obvious information that can be analysed using the repo microstructure data is about the repo rate itself. The deviation between the repo rate and other interest rates are commonly studied (such as comparisons with EURIBOR, EONIA or the ECB target refinancing rate). The repo-rate gap between country-specific GC contracts is seldom considered but this is of interest when considering how the recent turmoil differentially affected the risks attached to country-specific collateral (and the counterparty risk for the main banks with concentrated holdings of country-specific bonds). Of more direct interest in a microstructure context are variables such as bid-ask spreads, volume traded, liquidity in the limit orderbook, price impact of large orders and "orderflow" (defined as the difference between the accumulated "buyer-initiated" and "seller-initiated" trades at some specific frequency, where initiation is defined with respect to whether orders are submitted for immediate execution against prevailing quotes, as opposed to providing quotes that are for potential, probably delayed, execution contingent on the arrival of an appropriate trading partner). Orderflow has particular interest if it can be shown to have a relationship with repo-rate movements. Transactions information is also useful in this context.

Since this paper requires an assessment of the quality (and amount) of liquidity provision available in this market, a reconstruction of the orderbook is undertaken. This reconstruction is performed for every limit order event and at each trade event. More specifically, we reproduce the liquidity available at the three best bid and ask prices at each event. The fluctuations in liquidity being made

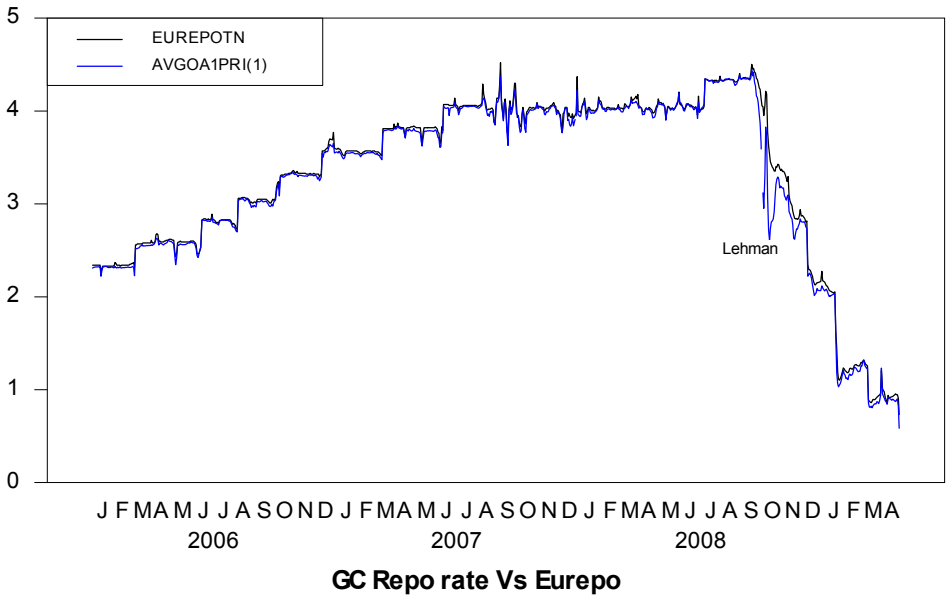
available in the limit orderbook around ECB interest rate events, across country and by term to maturity reflects much about the stress being faced by banks in managing their funding requirements throughout the crisis.

In addition to microstructure variables this study considers the predictive role of repos across the term to maturity. GC repo contracts can be thought of as collateralized Forward Rate Agreements (FRAs). A useful feature of these contracts is that they are often non-overlapping in their terms. For example, the combination of an "overnight-next" and a "tomorrow-next" contract can be regarded as a two-day lending contract with a predetermined 'roll-over' arranged using the "tomorrow-next" contract. Thus, GC repo rates can provide interesting insights into market expectations about the future expected path of interest rates. Two aspects of this insight are used in our analysis below. The first is to examine how expectations relate to outcomes. For example, we consider whether the TN repo rate is an unbiased predictor of the future ON repo rate. This is particularly useful as a way of understanding market expectations of monetary policy makers' rate decisions. The second aspect involves the variance of the ON/TN rate gap. This gives information about the uncertainty of future ON rates. If ON rates are difficult to predict we can expect the ON/TN gap to have a larger variance. Below, we consider this over time and around ECB interest rate events. This helps to answer the question as to whether ECB activity can be associated with reduced uncertainty.

Preliminary descriptive analysis

Repo Rate

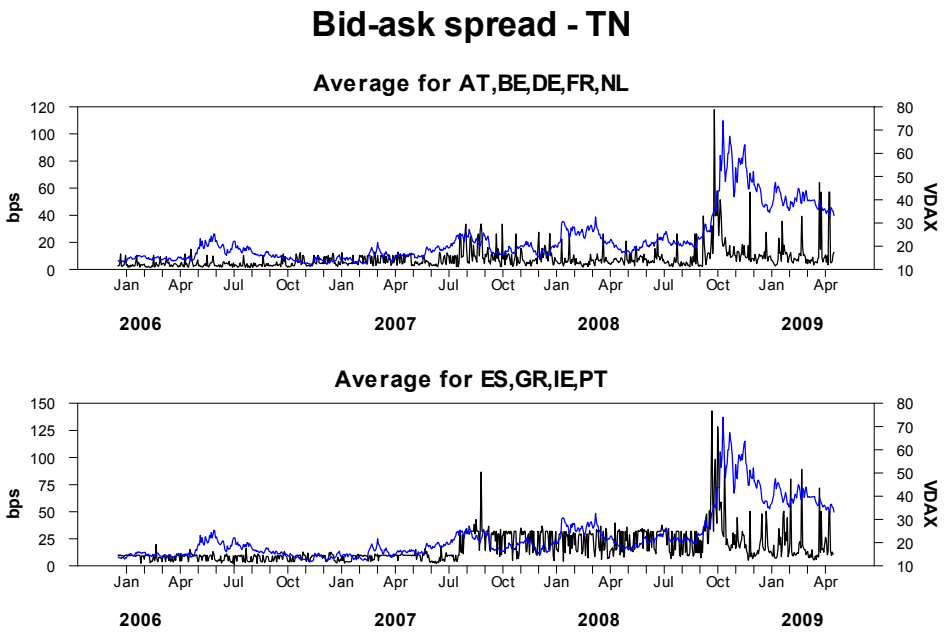
The daily average repo rate (for all offer events) is shown in the figure below for the GC tomorrow-next (TN) contract against the equivalent Eurepo® TN rate. The difference between these rates is quite marked in the period following the Lehman event of Sep '08. The Eurepo rate is calculated with survey data collected from a representative panel of banks. Thus, it reflects repo rates that encompass OTC trading. This kind of trading increased during the crisis as mentioned above. Also, as mentioned by Hördahl and King (2008), the specifics of how Eurepo rates are calculated can give rise to some divergence across specific GC instruments. The Eurepo rate is an un-weighted average of indicative GC repo rates contributed by a panel of 37 banks (excluding the highest and lowest 15%). Since there was a preference for core country collateral it is likely that the Eurepo rate doesn't sufficiently reflect the outliers during the more severely stressed periods of the turmoil.



GC Repo rate Vs Eurepo

Repo Bid-Ask spread

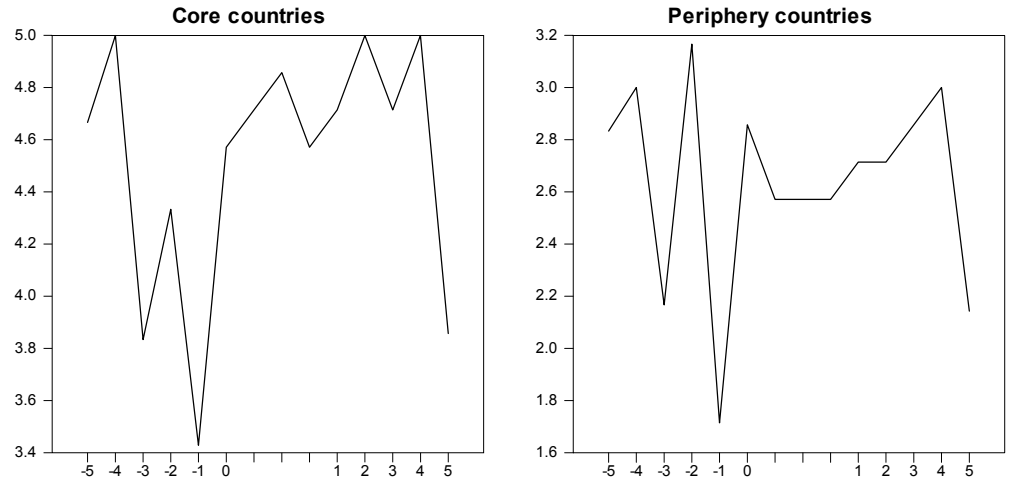
The spread between the best ask and bid quotes (for TN GC contracts) averaged over core and periphery groups of countries, is shown in the figure below. The VDAX index is also included to show the relation between general risk (and risk-aversion) on the spread. The variation in the repo bid-ask spread that is not clearly related to VDAX movements may have counterparty risk as its source. There does appear to be some lagging in the relationship between the sharp rise in the VDAX in Oct 2008 and the rise in repo market bid-ask spreads. This relationship is explored more thoroughly using Granger causality tests later in the paper.



The bid-ask spread calculation above does not take account of the fact that valid, two-sided quotes are not always available. For the case of the tomorrow-next GC contracts, the figure below shows the average number of countries for which valid quotes are available in the days around ECB interest rate announcements. The "core" countries include Austria, Belgium, Germany, France and the Netherlands. "Periphery" countries include Spain, Greece, Ireland and Portugal. In both cases there is a decline in the number of country GC markets with available valid quotes on the day just preceding interest rate announcements. We also found that there is a rise in bid-ask spreads on these days. The figures relating to interest rate events show the average of the relevant variable for all events at the end of each day from 5 days previous to the interest rate decision day to 5 days following the date upon which the new rate is effective. The decision day is usually a Thursday and the beginning of the new maintenance period, when the rate is effective, is usually the following Wednesday.

ECB Events Phase 3: No. Countries for which valid TN Quotes

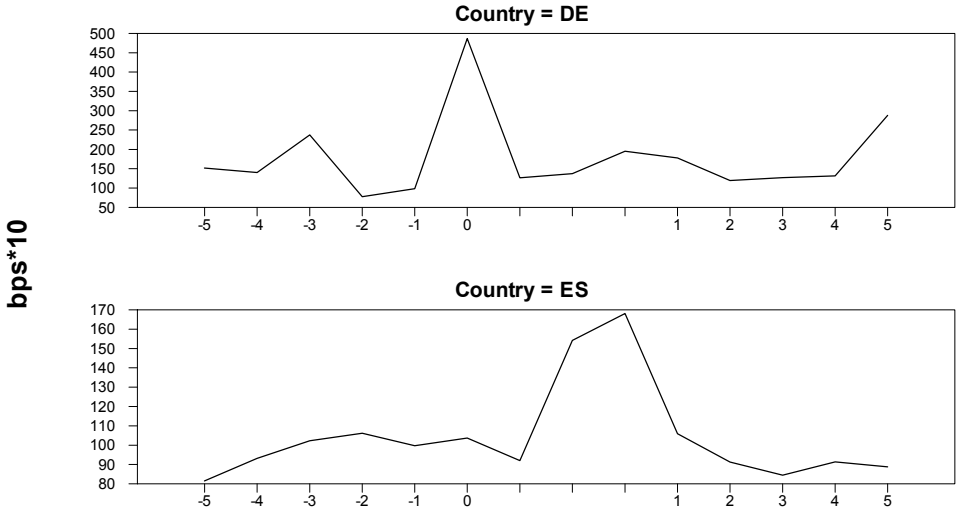
Day 0 = Announcement, Day 1 = Effective



There is evidence that bid-ask spreads widen at or soon after ECB interest rate decisions. The case of Germany and Spain are shown below for the TN contract in the post-Lehman phase of the crisis. The unusual lag in the Spanish case could simply be reflecting the lack of available quotes on the event day.

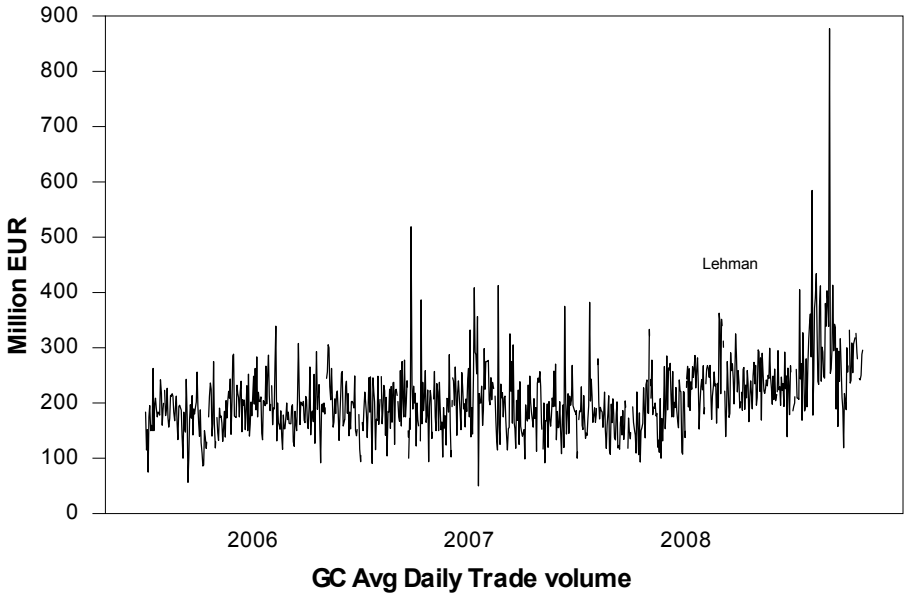
Phase 3: Bid-Ask around ECB Interest rate events

Day 0 = Announcement, Day 1 = Effective



Transaction Volume

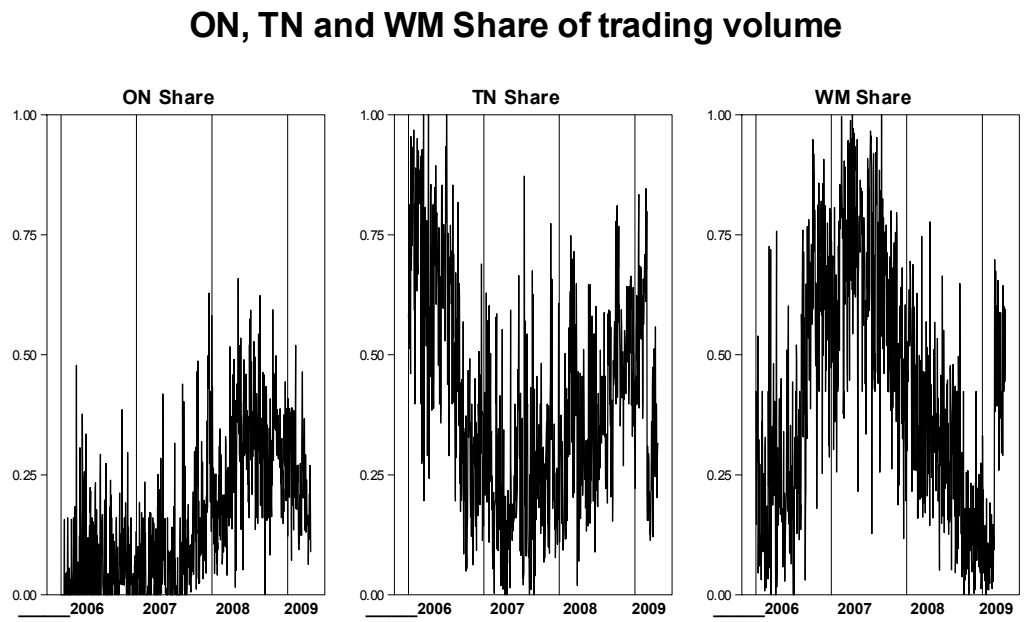
The daily average transaction volume for the GC tomorrow-next (TN) contract is shown in the figure below. This remained healthy throughout the crisis and rose in the later part of the sample. According to survey evidence this reflects the advantages of repo borrowing over unsecured alternatives when counterparty risk is elevated. The rise in volume traded towards the end of the sample might also be a reflection of the increased quality of collateral available for secondary repo trading following the probable reduction in quality of collateral being used in official ECB operations.



Concentration in trading activity

The changing location of trading activity, both across the maturity terms of contracts and across country-specific repos, can provide insights about "flight-to-quality" and "flight-to-liquidity" due perhaps to changing counterparty and credit risk. The figure below shows the share of trading at the ON, TN and week-to-month maturity terms. The first panel indicates that there was a significant move towards the very short over-night maturity term as the crisis progressed peaking just after the Lehman collapse. The last panel shows that the week-to-month long maturities had their peak at about 75% of volume just before the beginning of the sub-prime crisis in July 2007. This share then declined steadily to around 10% until it abruptly rose again in March of 2009 to about 50% of

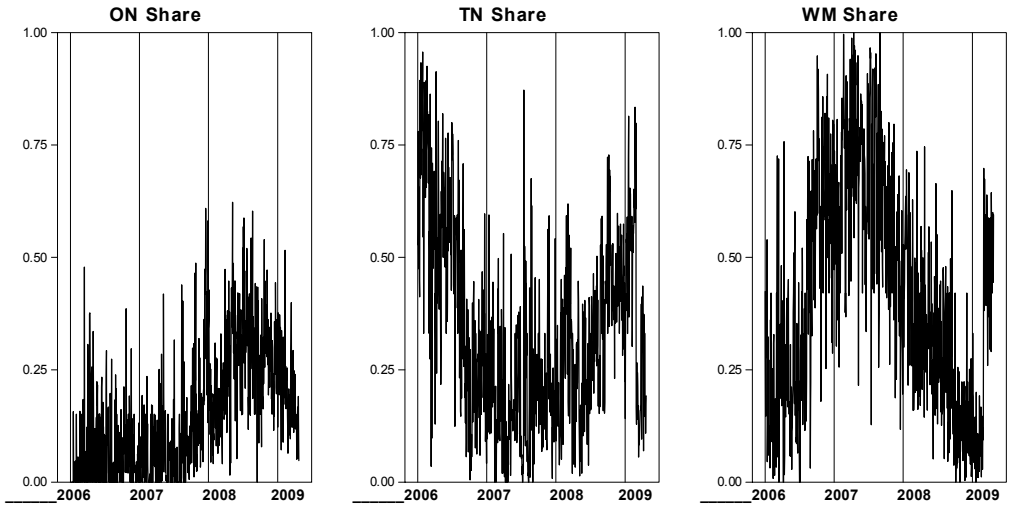
volume traded. This last move coincides with the first of the very long maturity repo operations carried out by the ECB.



The proportion of trading volume transacted in core country GC contracts has dominated throughout the crisis. The figure below shows the core country proportion of ON, TN and week-to-month activity. This appears very similar to the previous figure in regard to the change in maturity towards the shorter terms. This is only a preliminary selection as one could argue that some of these countries suffered liquidity and counterparty-style banking problems at some instances during the crisis.

Core country ON, TN and WM Share

Core = AT,BE,DE,FR,NL



The following figure covers the case of the periphery countries. This group is not well represented in the data except for the TN maturity term. The TN activity is very similar in its evolution to that of the core countries. The ON share has appeared only in the crisis periods and its rise is also similar to the core country case.

Periphery country ON, TN and WM Share

Periphery = ES,GR,IE,PT

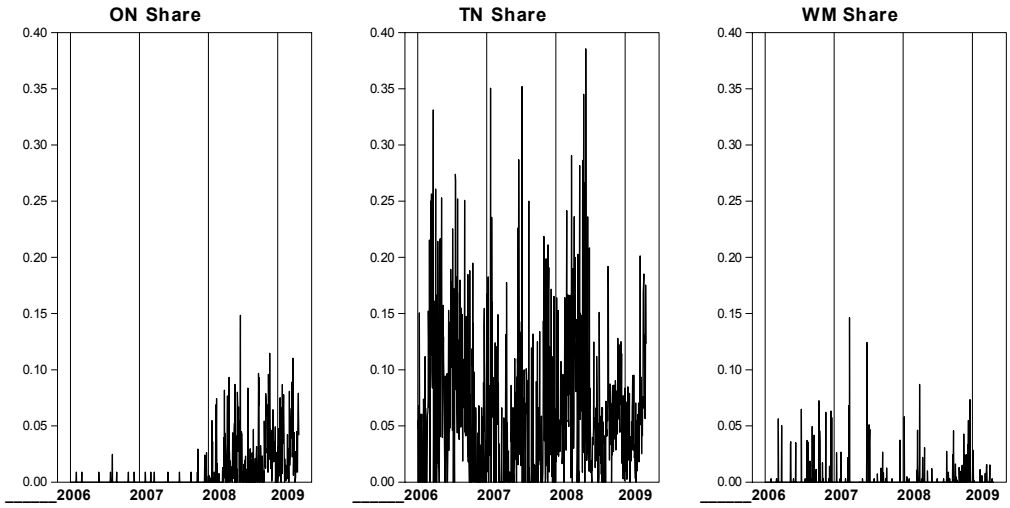
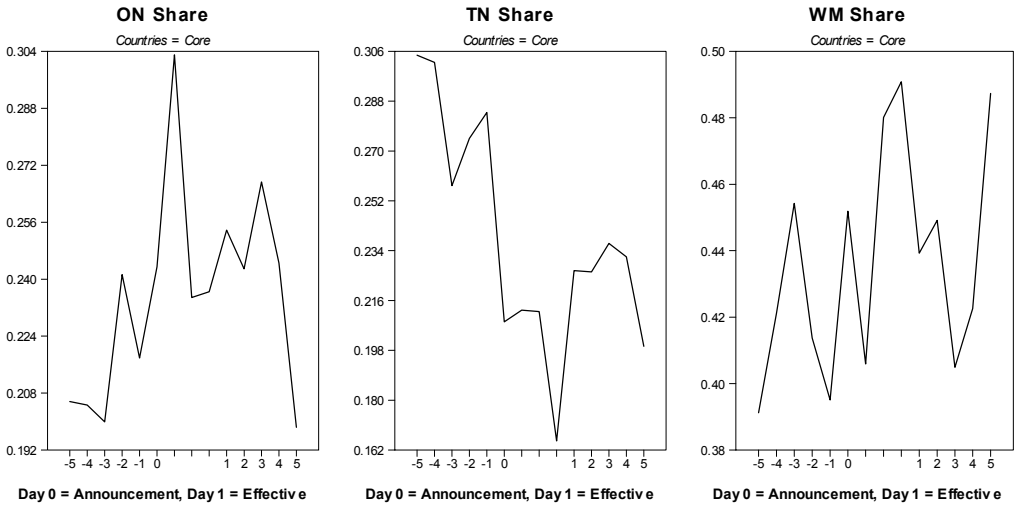


Table 2 gives some additional detail about the volume traded and its distribution by country and term within the three phases studied. This makes it clear that either Germany or France dominates activity for most maturities in all periods. Thus, the "core" represented in the figures above is mainly representative of these two countries. Where Spanish activity of the week maturity term is dominant this is a maturity that is not a significant share of overall activity. The changing concentration in activity is not very revealing around ECB interest rate events. However, the figure below shows the concentration of traded volume by term for the core country group in the ECB event window in the first phase of the crisis (the second sub-sample period). We see from this that there is a peak in concentration in the ON contract on the day of ECB announcements and a drop in the TN share of activity soon after.

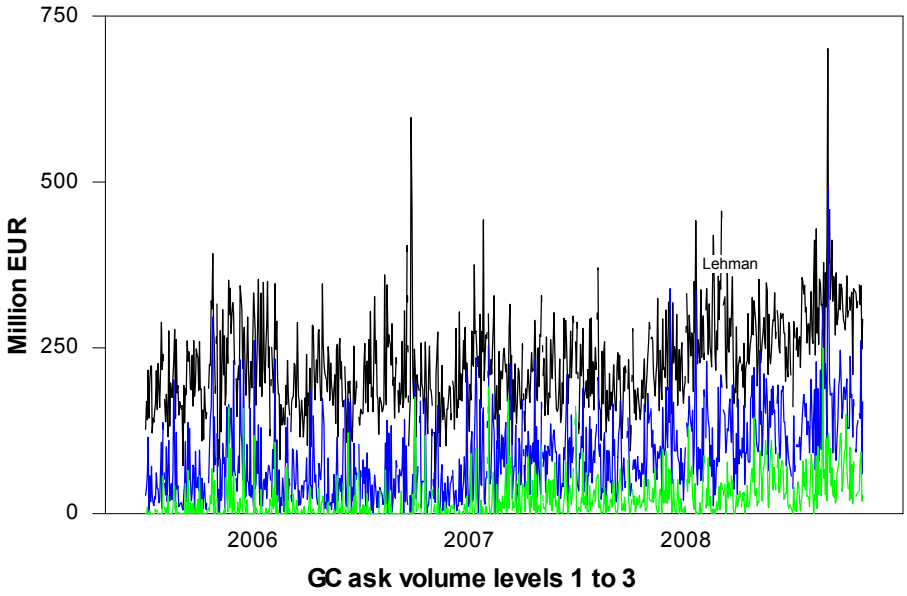
Phase 2: ECB rate announcements - Proportional Volume Traded

Core = AT,BE,DE,FR,NL

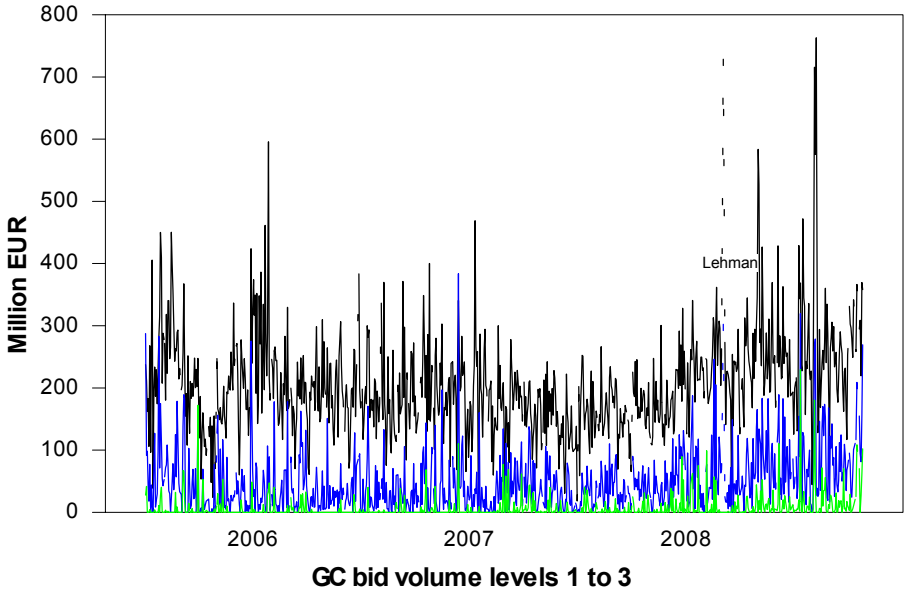


Liquidity available in the orderbook

The daily average volume at each of the first three levels of the orderbook (ask-side) for the GC tomorrow-next (TN) contract is shown in the figure below. There is progressively less liquidity deeper into the book. This also reveals that there was a slight growth in liquidity available at all levels through the crisis period.



Bid side liquidity

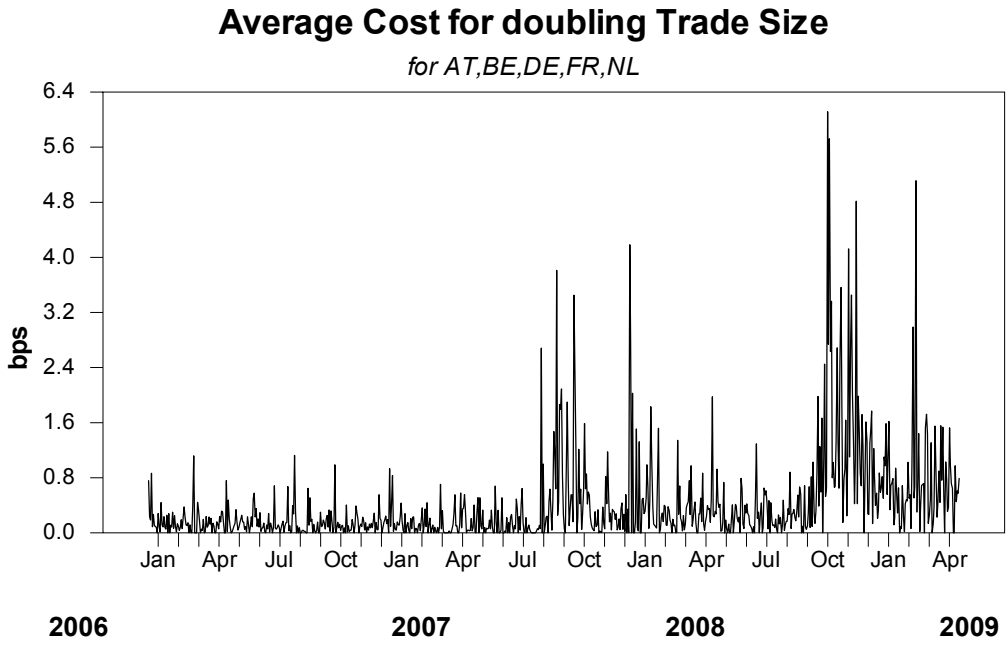


Price of Accessing to Depth

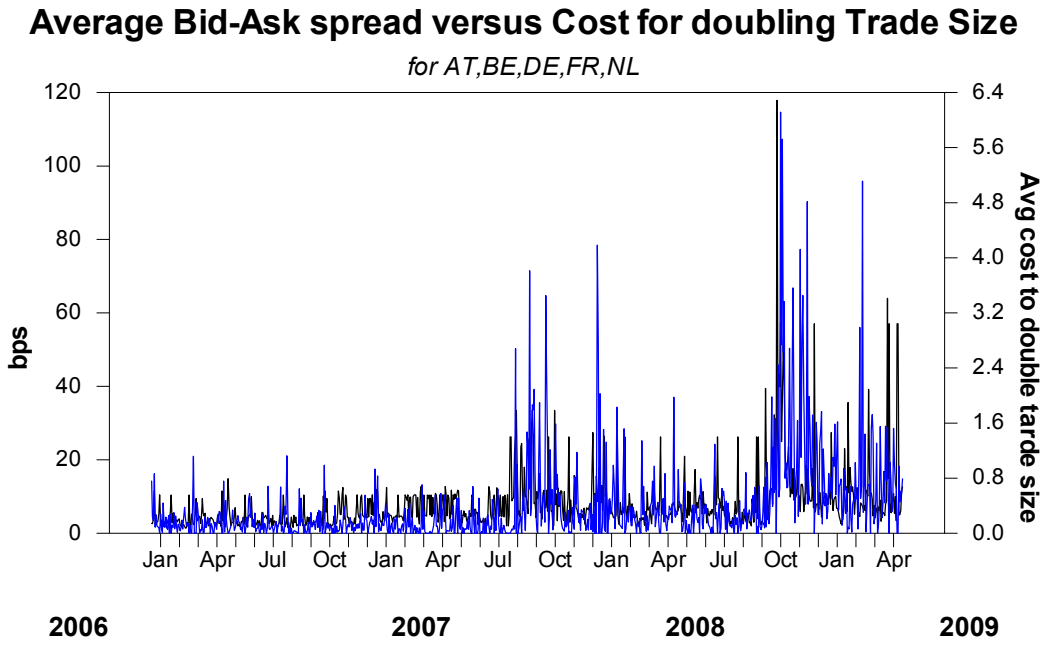
We consider the rate at which costs would rise for accessing deeper levels of the orderbook. Specifically, for every trade we examine the increase in cost associated with a doubling of the size of the trade. We perform this calculation for all trade events and then average the extra cost to arrive

at a daily frequency. Most measures of price impact consider the price movement following trades that can be considered large. The problem with these is that what can be considered large is time varying. The size of trade is endogenously chosen to reflect the potential price impact so by relating our size variable to reflect this we are getting closer to an indication of what costs are associated with speeding-up activity in relative terms while taking advantage of liquidity when it is available. From a practical point of view, our strategy avoids the need to ignore observations where liquidity is too thin to accommodate what is usually defined as a large trade.

The figure below shows the time series for the daily average cost of doubling the size of all core country TN GC trades. The increased cost arises from the fact that such trades require eating deeper into the liquidity available at the quotes beyond the best.



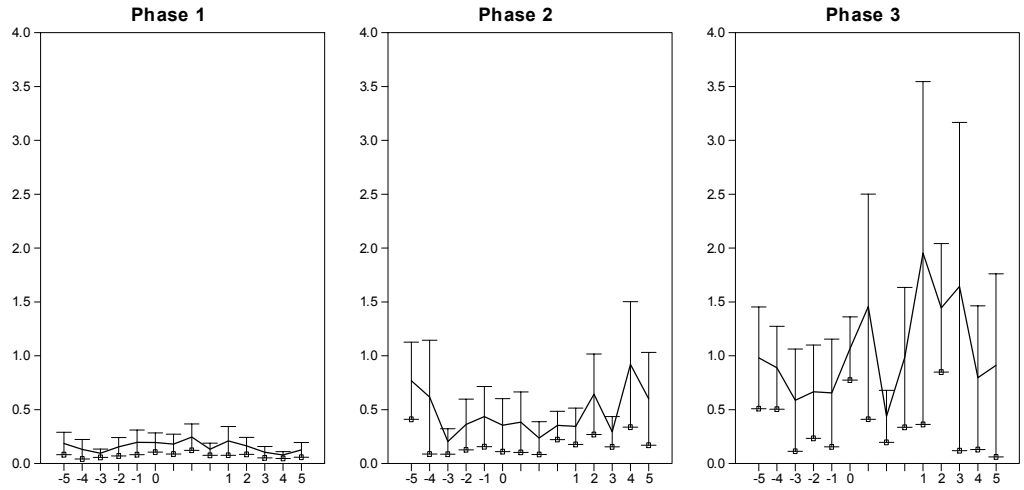
The following figure shows the core country bid-ask spread along with the average cost of doubling trade size. We see that the two series are closely related. The cost of doubling trade size is about one-twentieth of the size of the bid ask spread.



The impact of ECB interest rate events on the cost of doubling trade size is considered below. The most striking feature of this is the fact that this cost increases greatly over the three phases of the crisis. However, it is difficult to detect any direct effect from ECB events on the cost. The last phase seems to have some slight increase in the cost after the interest rate moves but there is also more variability in these costs so it is not possible to make a statistical statement to this effect with confidence. The figure shows standard error bounds based on the standard deviation of the observations on each event day period.

Cost of Doubling Trade size around ECB Interest rate events

Day 0 = Announcement, Day 1 = Effective



Time Series Regression Analysis:

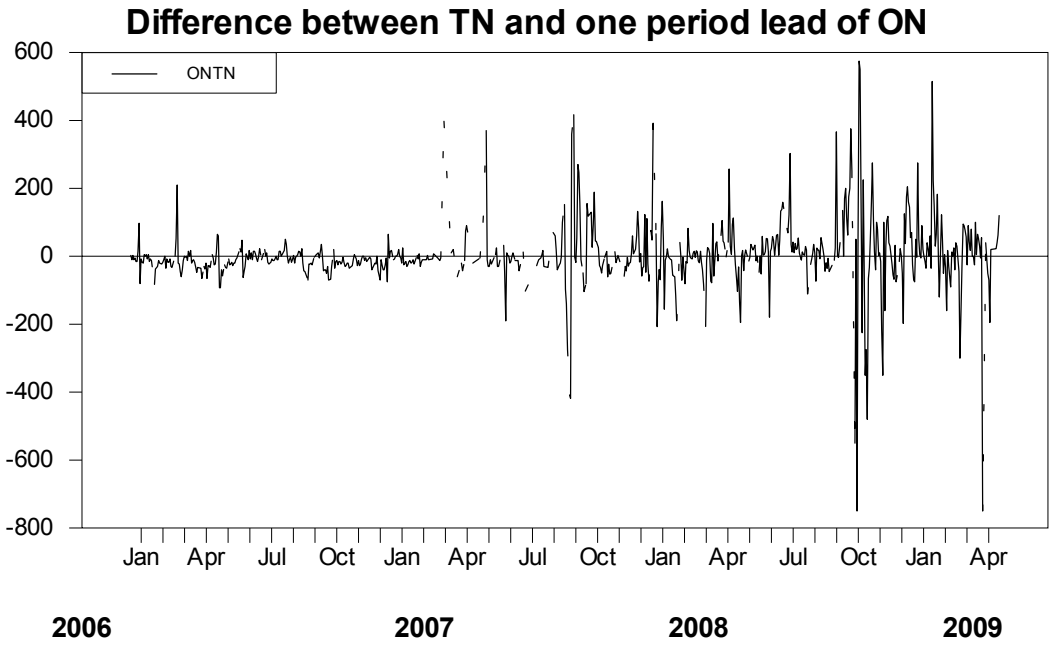
The following section conducts various time-series, vector auto-regressions on a daily frequency to determine whether market quality is persistent and can be predicted and therefore relied-upon as a source of liquidity and funding. Large surprise changes in market quality are identified and related to crisis events and policy changes.

Bias and variance of expectations of ON repo rates during the turmoil

In this section we make use of the fact that tomorrow-next (TN) repo rates can be considered as the markets' best forecast of the next day's overnight (ON) repo rate. In essence, we can conduct an analysis of the efficiency of this forecast in a similar way to studies about the forward rate puzzle in foreign exchange markets. We can also assess the level of uncertainty in the repo market about future repo rates based on the variation in the variance of the forecast error implicit in the difference between the TN and a one-period lead of the ON rate. We can examine how ECB interest rate events affected this variance. Where there are outliers in these forecast errors we can make an assessment about how these may have affected the cross country repo rate differences. Since underlying interest rate shocks can be expected to differentially alleviate or worsen the credit risk of

individual country sovereign bonds, this approach could give insights regarding the link between interest rate surprises and credit risk.

To begin however, we acknowledge that the data is not as generously populated as we would like. The German GC contracts contain a very liquid TN contract but a less liquid ON contract. The French case is the opposite in that there is a very liquid ON contract but an illiquid TN contract. We choose to use the French ON and German TN contracts as the basis of our ON-TN analysis. Obviously, this may be inappropriate for certain periods (e.g., when the French GCs reflected concerns about BNP's credit worthiness and solvency). However, on inspection of the data we believe that an analysis of these two contracts can give us most of the general insights about the uncertainty of overnight interest rates that we seek. The figure below shows the basis points difference between the one-period lead of the ON repo rate against the TN repo rate on a daily basis over time. This clearly indicates a rise in the volatility of the difference over time. The full sample mean is 2.7 with a t-statistic for difference from zero of 0.70, implying that there appears to be no systematic bias in the TN as a forecast of the next day's ON rate. However the statistics for the three phases of the dataset do not bear this out. In the pre-crisis phase there was a significantly negative mean (mean = -9.11, t-stat for zero mean = -3.51) implying that TN projections were systematically under-shooting the outcomes for the ON rate (indicating that rates were rising somewhat more than the market was expecting). By contrast, the first phase of the crisis was characterized by TN projections that were systematically below the ON outcomes (mean = 16.9, t-stat for zero mean = 2.56). This might reflect the expectation that there would be declines in ON rates sooner than actually occurred. The variances of this series in the three phases are, 2019.6, 10547.2 and 30375.1 respectively. The large rise over the three phases is consistent with what can be concluded from a casual glance of the time series itself.

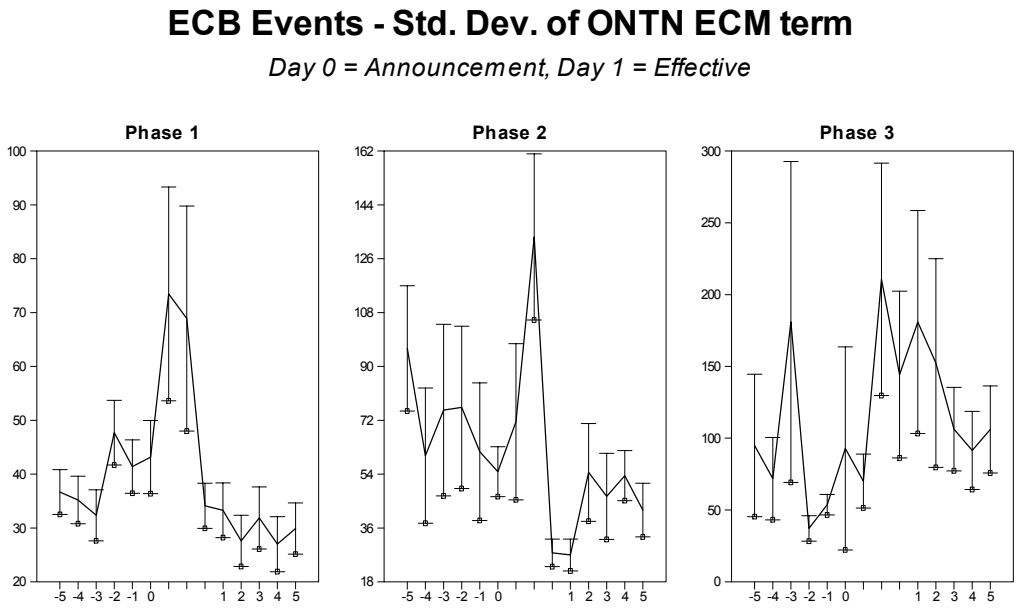


Allowing for different constants in each of the three phases, we regress the TN repo rate on the ON repo rate (one period lead). This produces residuals that we test for stationarity. The ADF(3) gives the following result, t-stat on lagged ECM residual = -8.17. This implies that the ON and TN rates are indeed cointegrated. In standard fashion, we then considered error correction mechanism (ECM) regressions involving the TN and ON rate changes as a function of the lags of both and the lagged disequilibrium between the two rates. In the case of the ON variable, we found that there was an insignificant positive relation between the changes in ON rates and the previous period's disequilibrium (the ECM term is in the form TN minus ON). There was however a significant negative relation between TN rate changes and the lagged disequilibrium. We tested for weak exogeneity of the ON rates and found them to be weakly exogenous. This simply implies that TN rates do all of the adjustment in response to disequilibrium between the two rates. It also implies that we can treat the ECM term (or the TN minus the one period lead of the ON adjusted for some phase related constants) as the forecast error that market participants make in their prediction of the one-period ahead ON rate.[5]

We now consider how the standard deviation of the TN-ON forecast error behaves around ECB interest rate events in each of the three phases. The figure below shows the average across ECB interest rate events of the squared error implied by the disequilibrium term from the cointegrating

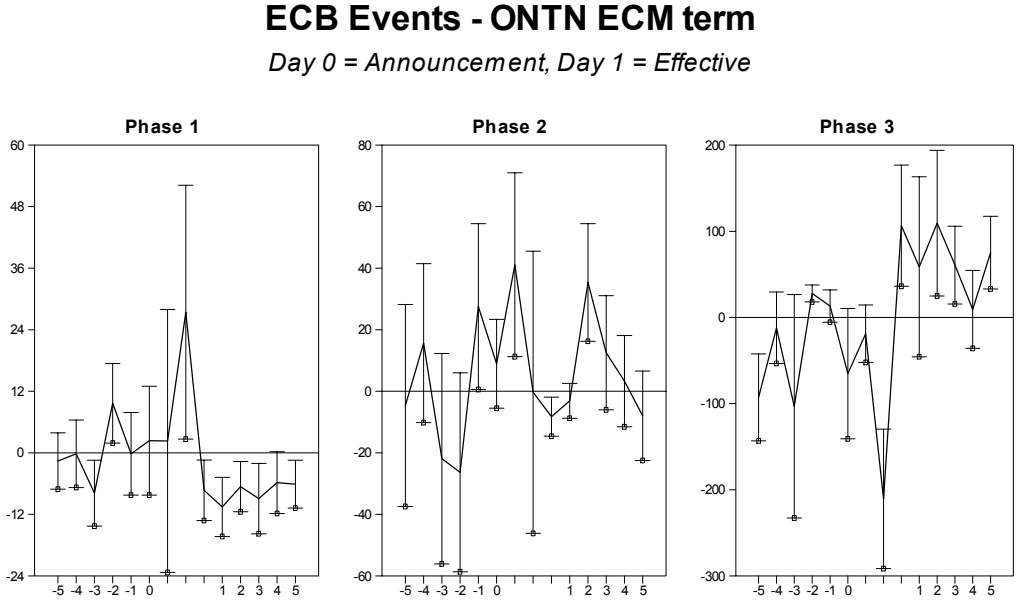
[5] The detailed cointegration regression results are available from the authors on request.

regression (1.96 standard error bounds are also provided). This shows that the three periods are very different risk environments in which interest rates are being set. The last phase is markedly more uncertain than the second phase and the same is true for the comparison of the second phase with the first. In each period it is clear that the uncertainty is greatest in the two days following the announcement. This simply reflects the fact that TN rates are set in advance of the announcement and apply to the two days after. The second day contains mostly TN contracts that are transacted before the policy announcement. What is more interesting, however, is the degree to which ECB interest rate decisions appear to contribute to or alleviate the uncertainty in the three phases. In both phase 1 and phase 2, it appears to be the case that uncertainty declines after interest rate decisions. In phase 3 this is not so clearly the case.



A clear picture of the effect of ECB interest rate decisions upon the uncertainty of ON repo rates is now considered. The following figure shows the ONTN ECM terms averaged across the interest rate events of the three phases. Thus the sign of the ECM term indicates whether the surprises were generally positive or negative. Recall that in the first phase interest rate changes were positive, in the second phase they were generally unchanged and in the last phase they were dramatically reduced. It is also worth recalling that our ECM variable is in the form TN minus ON. Thus a positive ECM residual implies that the TN was above the ON (outcome) and therefore that overnight interest rates were expected to rise more than they actually did. We see that in phase 1 the surprises just

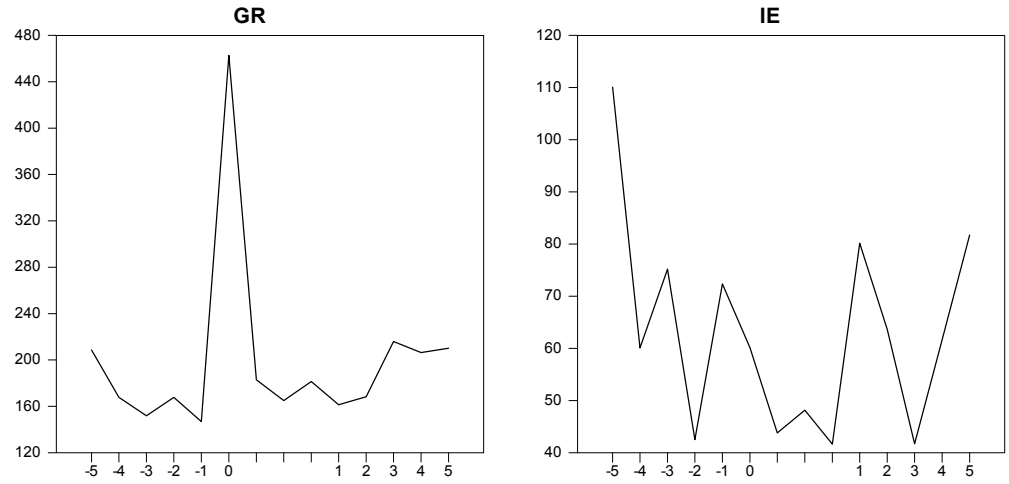
after announcement are positive implying that rate rises were expected to be somewhat greater than actually occurred. We prefer not to make any conclusions about the second phase because it is difficult to see any consistent pattern. In phase 3 the surprises are negative just after the event and this would seem to suggest that there were expectations of bigger declines than actually occurred. These findings are of course preliminary, and must not be given too much weight since they could be reflecting one or two extreme events (other than ECB interest rate events) that occur at the same time as the announcements. They are nevertheless indicative of what can be achieved by a deeper analysis of the data.



We now consider the change in the gap between repo rates on different country's collateral and that on the German collateral around ECB interest rate events. The following figure describes, for the last phase of the crisis, the gap between Greek and German TN repo rates and the gap between the Irish and German TN repo rates. Once again we stress that this is very preliminary analysis, but we conclude from it that Greek rates were adversely affected around ECB interest rate events in the sense that a gap widens at the time of the rate decisions and does not get reversed completely after the decision comes into effect. It is not clear that the same can be concluded for the Irish case.

ECB Events - Gap between country GC repo rate and German TN rate

Day 0 = Announcement, Day 1 = Effective



The Causal Relation between repo market stress and VDAX

An interesting question that can be addressed with repo market data is whether funding market stress contributed to (or caused) increased systemic risk or vice versa. We briefly address this issue here with the intention of addressing a fuller representation of the causal forces underlying the relationship in the near future. We measure repo market stress as the surprise element of deviations between the lagged expectation of overnight interest, namely TN(-1), and the ON rate itself. These surprises are auto-correlated and therefore, when larger than normal innovations occur, market participants are likely to be expecting more risk and uncertainty in repo funding in the future. We explore the interaction between such uncertainty and the VDAX index which we regard as a measure of more general risk. We test for two-way causality between these two variables using Granger causality tests.

We find that the absolute difference |TN(-1)-ON| is a good representation of the uncertainty of overnight repo rates (this is based on the mid price of closing quotes for both contracts on a daily basis). For a VAR regression involving 5 lags of the closing value of the VDAX and ABS(ONTN) it is not possible to reject the hypothesis that repo market stress granger causes the VDAX. The F-test for the dropping of ABS(ONTN) in the VDAX regression is easily rejected. The test for exclusion of the VDAX as a determinant of the ABS(ONTN) is not as clearly rejected. We therefore tentatively conclude that repo market stress was a causal factor in driving more general uncertainty.

F-Tests, Dependent Variable VDAXCLOSE			F-Tests, Dependent Variable ABS(ONTN)		
Variable	F-Statistic	Signif		F-Statistic	Signif
VDAXCLOSE	522.4921	0.0000000	VDAXCLOSE	2.4229	0.03525
ABS(ONTN)	11.4216	0.0000000	ABS(ONTN)	14.9263	0.00000

This preliminary exercise serves as an indication of the likely relation between the variables. Since the ultimate cause of the uncertainty may be ECB interest rate policy announcements or other policy actions, these variables could be included in a broader analysis that would identify the causal pattern in a more structural fashion.

Conclusion

This paper initializes a line of enquiry aimed at understanding the effects of ECB interest rate changes on credit and counterparty risk and generally outlines the changes that have occurred in the secondary repo market as a result of the financial crisis and the policy responses that it prompted. The evidence obtained from the pilot analysis suggests that there are many insights available from an analysis of this market and that this could be useful to policy makers in assessing how their actions are likely to affect risks in the post-crisis contraction of policy initiatives. Most obviously, the secondary repo market can provide insights about market expectations of future interest rates. Related to this, it appears possible to ascertain how policy announcements affect the quality of different collateral. If information about the ownership of sovereign bonds is made know it might also be possible to ascertain how policy shocks feed through to counterparty risk and back to sovereign risk. This pilot analysis paves the way for a more in-depth analysis of the causes and effects of the various changes identified.

References

Adrian, T., C. R. Burke & J. McAndrews (2008) "The Federal Reserve's Primary Dealer Credit Facility." Federal Reserve Bank of New York, Current Issues in Economics and Finance, 15(7) August 2009.

Adrian, T., & H. S. Shin (2008) "Financial Intermediaries, Financial Stability and Monetary Policy." Federal Reserve Bank of New York Staff Papers No. 346. http://ssrn.com/abstract=1266714.

Bank of England, Publications (2009) "Financial Stability Report," June 09, No. 25:58.

Brunetti, C., M. di Filippo & J Harris (2009) "Effects of Central Bank Intervention on ther Interbank Market: What Happened During the Sub-prime Crisis?" mimeo.

Brunnermeier, M. K. (2009) "Deciphering the Liquidity and Credit Crunch 2007-2008." Journal of Economic Perspectives, 23(1):77-100.

Cecchetti, S. G. (2008) "Crisis and Responses: The Federal Reserve and the Financial Crisis of 2007-2008." NBER Working Paper No. 14134.

Christensen, J. H. E., J. A. Lopez and G. D. Rudebusch (2009) "Do Central Bank Liquidity Facilities Affect Interbank Lending Rates?" Federal Reserve Bank of San Francisco, w/p 2009-13.

ECB, (2008) "General Documentation on Eurosystem Monetary Policy Instruments and Procedures," available at http://www.ecb.int/pub/pdf/other/gendoc2008en.pdf .

Eisenschmidt, J., A. Hirsch & T. Linzert (2009) "Bidding Behaviour in the ECB's Main Refinancing Operations During the Financial Crisis." European Central Bank Working Paper, No. 1052.

Ewerhart, C. & J. Tapking (2008) "Repo markets, counterparty risk and the 2007/2008 liquidity crisis", ECB w/p NO 909 / JUNE 2008

Fleming, M., W. B. Hrung & F. M. Keane (2009) "The Term Securities Lending Facility: Origin, Design and Effects." Current Issues in Economics & Finance, Federal Reserve Bank of New York, Vol 15(2):1-10.

Freixas, X. & J. Jorge (2008) "The Role of Interbank Markets in Monetary Policy: A Model with Rationing," Journal of Money, Credit and Banking, 40(6):1151-1176.

Heider, F., M. Hoerova & C. Holthausen (2009) "Liquidity Hoarding and Interbank Market Spreads: The Role of Counterparty Risk," European Banking Center Discussion Paper No. 2009-11S. Available at SSRN: http://ssrn.com/abstract=1362113.

Hördahl, P., & M. R. King (2008) “Developments in repo Markets During the Financial Turmoil.” BIS Quarterly Review pp 37-53, December.

Nyborg, K., U. Bindseil & I. A. Strebulaev (2002) “Bidding and Performance in Repo Auctions: Evidence from ECB Open Market Operations.” ECB Working Paper No. 157.

Taylor, J. B. and J. C. Williams (2009) “A Black Swan in the Money Market.” American Economic Journal: Macroeconomics, American Economic Association, 1(1):58-83.

Table 1. Events on Orderbook and Trades, by Term and Type, May 05 – Apr 09.

Term	Orderbook events	Trades
Overnights		
Overnight & O-Next	127,681	43,012
Tomorrow-Next	252,255	74,828
Settlement-Next	33,910	4,926
Corporate-Next	557	68
Sub-total:	414,403	122,834
% of Total of Column	86.8	95.2
1 Week		
Overnight-Week	76	2
Tomorrow-Week	2,518	276
Settlement-Week	21,514	2,870
Corporate-Week	7,394*	1,252
Sub-total:	31,501	4,400
% of Total of Column	6.6	3.4
2 & 3 Weeks		
O-2W,T-2W,S-2W or C-2W	5,345*	430
O-3W,T-3W,S-3W or C-3W	801*	84
Sub-total:	6,146	514
% of Total of Column	1.3	0.4
1 Month		
O-M,T-M,S-M or C-M	25,362*	1,298
% of Total of Column	5.3	1.0
Total	477,413	129,772

* Indicates that an adjustment was made to correct for a large number of orders in late 2006 that relate to a temporary testing of automated trading.

Table 2. Traded volume within phases of the crisis by contract and by maturity terms. Max highlighted.

PANEL 1: Phase 1 of crisis response										
Term	ON		TN		SN		Week		Month	
Country	Millions	Share	Millions	Share	Millions	Share	Millions	Share	Millions	Share
AT	3,600	0%	47,975	3%	1,475	2%	-	0%	200	1%
BE	21,375	2%	202,475	14%	6,725	9%	300	3%	2,125	14%
DE	109,250	12%	850,275	58%	52,875	72%	3,200	37%	3,300	22%
ES	100	0%	25,625	2%	3,400	5%	3,375	39%	2,575	17%
FR	750,450	84%	115,450	8%	50	0%	1,250	14%	6,600	44%
GR	-	0%	19,225	1%	175	0%	-	0%	-	0%
IE	-	0%	10,325	1%	6,750	9%	-	0%	-	0%
NL	8,225	1%	94,475	6%	1,175	2%	400	5%	-	0%
PT	-	0%	104,900	7%	500	1%	100	1%	250	2%
All	893,000		1,470,725		73,125		8,625		15,050	
PANEL 2: Phase 2 of crisis response										
AT	41,700	3%	52,100	3%	2,000	3%	2,175	1%	100	2%
BE	194,475	13%	222,900	15%	3,500	5%	4,500	2%	600	10%
DE	411,450	27%	751,575	49%	54,325	74%	234,725	93%	4,300	74%
ES	4,800	0%	3,725	0%	-	0%	200	0%	-	0%
FR	764,475	50%	197,300	13%	5,925	8%	6,700	3%	400	7%
GR	-	0%	173,875	11%	4,025	5%	2,575	1%	350	6%
IE	2,975	0%	6,775	0%	425	1%	375	0%	-	0%
NL	83,175	5%	78,775	5%	1,725	2%	1,775	1%	-	0%
PT	29,625	2%	42,450	3%	1,475	2%	450	0%	50	1%
All	1,532,675		1,529,475		73,400		253,475		5,800	
PANEL 3: Phase 3 of crisis response										
AT	83,250	6%	36,625	1%	1,350	1%	9,200	4%	4,425	12%
BE	283,075	22%	296,750	12%	7,725	3%	12,975	6%	2,050	5%
DE	165,850	13%	1,601,375	65%	154,175	69%	169,925	72%	22,975	60%
ES	22,325	2%	14,175	1%	200	0%	825	0%	50	0%
FR	516,000	40%	181,650	7%	16,550	7%	14,725	6%	400	1%
GR	28,700	2%	147,275	6%	37,000	16%	1,825	1%	100	0%
IE	9,700	1%	18,275	1%	1,400	1%	950	0%	-	0%
NL	114,325	9%	111,900	5%	3,150	1%	19,100	8%	4,850	13%
PT	60,050	5%	63,100	3%	3,450	2%	5,075	2%	3,300	9%

All	1,283,275	2,471,125	225,000	234,600	38,150

Table 3. 'Orderflow' within phases of the crisis by contract and by maturity terms. Negatives highlighted

	PANEL 1: phase 1 of crisis response, Orderflow in EUR and orderflow relative to volume traded.									
Term	ON		TN		SN		Week		Month	
Country	Mil EUR	OF/Vol	Mil EUR	OF/Vol	Mil EUR	OF/Vol	Mil EUR	OF/Vol	Mil EUR	OF/Vol
AT	1750	49%	19375	40%	**-325**	**-22%**	0	0%	200	100%
BE	8375	39%	76125	38%	1175	17%	**-100**	**-33%**	1625	76%
DE	8650	8%	71825	8%	14925	28%	1100	34%	900	27%
ES	100	100%	7325	29%	1800	53%	525	16%	**-1175**	**-46%**
FR	205900	27%	21100	18%	**-50**	**-100%**	**-450**	**-36%**	2700	41%
GR	0	0%	**-575**	**-3%**	**-25**	**-14%**	0	0%	0	0%
IE	0	0%	5625	54%	3800	56%	0	0%	0	0%
NL	325	4%	33175	35%	**-275**	**-23%**	400	100%	0	0%
PT	0	0%	13150	13%	**-500**	**-100%**	**-100**	**-100%**	**-250**	**-100%**
All	225100	25%	247125	17%	20525	28%	1375	16%	4000	27%
	PANEL 2: Phase 2 of crisis response									
AT	8750	21%	**-250**	**0%**	500	25%	**-425**	**-20%**	**-100**	**-100%**
BE	73275	38%	18750	8%	**-800**	**-23%**	250	6%	0	0%
DE	**-37350**	**-9%**	**-130975**	**-17%**	**-8475**	**-16%**	**-116025**	**-49%**	2500	58%
ES	2300	48%	825	22%	0	0%	**-200**	**-100%**	0	0%
FR	**-37175**	**-5%**	3100	2%	975	16%	0	0%	**-200**	**-50%**
GR	0	0%	**-45275**	**-26%**	**-425**	**-11%**	**-575**	**-22%**	**-150**	**-43%**
IE	1475	50%	3175	47%	**-125**	**-29%**	**-275**	**-73%**	0	0%
NL	14575	18%	8125	10%	725	42%	425	24%	0	0%
PT	3225	11%	**-2600**	**-6%**	**-625**	**-42%**	450	100%	50	100%
All	29075	2%	**-145125**	**-9%**	**-8250**	**-11%**	**-116375**	**-46%**	2100	36%
	PANEL 3: Phase 3 of crisis response									
AT	18900	0.23	12825	35%	**-500**	**-37%**	1150	13%	**-1125**	**-25%**
BE	41425	0.15	124950	42%	**-25**	**0%**	6875	53%	150	7%
DE	11850	0.07	**-58375**	**-4%**	**-17925**	**-12%**	**-41375**	**-24%**	6725	29%
ES	6325	0.28	2125	15%	**-200**	**-100%**	175	21%	50	100%
FR	**-11400**	**-0.02**	**-6150**	**-3%**	**-13600**	**-82%**	9775	66%	200	50%
GR	2100	0.07	**-31625**	**-21%**	**-9700**	**-26%**	525	29%	100	100%
IE	7150	0.74	9525	52%	**-900**	**-64%**	**-750**	**-79%**	0	0%
NL	29225	0.26	34800	31%	**-350**	**-11%**	**-5250**	**-27%**	**-3050**	**-63%**
PT	6500	0.11	13750	22%	350	10%	**-325**	**-6%**	**-2700**	**-82%**
All	112075	0.09	101825	4%	**-42850**	**-19%**	**-29200**	**-12%**	350	1%