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Effectiveness of ECB monetary policy in reducing interbank risk premia during financial crisis

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Perinteinen rahapolitiikka nojautuu vahvasti korkokanavan toimivuuteen, jossa keskuspankin politiikkakoron muutosten odotetaan välittyvän rahamarkkinakorkoihin ja edelleen pankkien asiakkaille annettujen luottojen korkoihin, jotka viime kädessä vaikuttavat kokonaiskysyntään ja hintatasoon. Vahva ja välitön korkojen välittyminen on erityisen tärkeää inflaatiotavoitteeseen tähtääville keskuspankeille, sillä inflaatiotavoitteeseen pääseminen tapahtuu perinteisesti talouden korkotasoa säätelemällä.

Vuonna 2007 alkaneen finanssikriisin jälkeen rahamarkkinat sekä Yhdysvalloissa että Euroopassa ajautuivat ongelmiin. Kasvaneesta vastapuoli- ja likviditeettiriskistä johtuen pankit eivät enää olleet halukkaita lainaamaan likviditeettiä toisilleen, jonka seurauksena keskuspankkien politiikkakorot eivät enää välittyneet rahamarkkinakorkoihin. Tästä syystä keskuspankit joutuivat turvautumaan epätavallisiin (unconventional) politiikkatoimenpiteisiin rahamarkkinoiden tasapainottamiseksi ja korkokanavan toimivuuden palauttamiseksi.

Tässä tutkielmassa keskitytään korkokanavan toimivuuteen tarkastelemalla Euroopan keskuspankin (EKP) epätavallisten politiikkatoimenpiteiden vaikuttavuutta rahamarkkinoiden tasapainon palauttamisessa. Tutkimusmetodeina käytetään yhteisintegraatiolähestymistapaa ja virheenkorjausmallia; empiiristen tulosten mukaan EKP:n epätavallinen rahapolitiikka on lokakuun 2008 jälkeen onnistunut pienentämään pankkien välisessä lainanannossa esiintyvää riskipreemiota ja näin jossain määrin palauttamaan korkokanavan toimivuutta.

Contents

1. INTRODUCTION

In recent decades the financial industry has been under significant changes, both in terms of its size and structure. Size of financial sector has increased significantly in advanced countries, as measured by its percentage of GDP. The explanation for financial sector growth lies largely in deregulation of financial markets. Since the 1980s western governments have systematically worked towards removing regulation as the prevailing view was that markets are efficient in allocating resources and risk, and that they work best when they are not interfered with. However, recent crisis has shown that this is not always the case. In fact, it can be argued that financial innovation combined with inadequate regulation largely contributed to the build-up of systemic risk that realized and led to a global recession in late 2008.

The financial crisis starting in August 2007 deeply affected particularly the credit market. As a result of materializing credit risk from subprime loans initiated in the U.S., market participants around the world were affected via two dimensions. Firstly, financial innovation had brought new securities to the market such as credit default swaps and collateralized debt obligations that were derived from subprime mortgages. Direct losses from holding these derivative contracts were largely responsible for tightening credit. Secondly, as the losses from these securities were experienced by most market participants, even healthy banks found it hard to obtain funding from the market because banks lost confidence in counterparties' ability to repay loans. Lack of confidence arose from a widespread uncertainty concerning the risk positions held by counterparty banks. As consequence of increased risk aversion in bank lending, interest rates charged for interbank loans skyrocketed. Reduced interbank lending spilled over to retail lending, causing companies around the world to experience funding difficulties. Suddenly, funding that was needed to secure continuation of their everyday business, such as covering payrolls and paying for purchases, was no longer available. This had severe real effects as investment and consumption were postponed and assets were sold at fire sale prices in order to service obligations that fell due. A spiral of falling asset prices and increasing uncertainty was born.

Developments in banking sector activities during recent decades reveal why bank lending behavior was severely affected. Traditionally banks have collected short term deposits from the public and acted as maturity transformers by making long term loans. This meant that in order to issue loans, banks needed a sufficient amount of deposits to finance the loan. However, in the 21st century there has been two important changes in banking activities. Firstly, emergence of a shadow banking sector has brought new near-bank entities to the field such as securities brokers and dealers, finance companies and asset-backed security issuers. Financing model of these entities is completely based on short term market financing as their business model is mainly to issue securities that are sold to banks and other institutions. Secondly, traditional banks have also become increasingly reliant on wholesale market funding as compared to traditional retail deposits. Starting from the 1990s, short term money markets have become significant funding sources for banks and near-banks because the general view is that they provide a more flexible way to manage asset and liability structures.

In this thesis, special attention is given to the interbank market, which is a subsection of the wider money market. In the interbank market, banks lend and borrow funds to one another for a specified term. In current fractional reserve banking system, banks are required to hold an adequate amount of liquid assets, such as cash, to manage any potential deposit withdrawals by clients. If a bank cannot meet these liquidity requirements, it will need to borrow money from the market to cover the shortfall. Some banks, on the other hand, may have excess liquid assets exceeding liquidity requirements. These banks usually lend the excess money in order to avoid the opportunity cost of not receiving interest. As a result, supply and demand for money in the interbank market determine the interbank rate, which is the rate for uncollateralized loans between banks with maturity ranging from one day to 12 months.

Normally, banks use the interbank market for funding purposes because the banking system design provides banks with incentives to allocate funds provided by the central bank between each other, rather than using central bank facilities for funding. The design gives the central bank direct control of intermediate targets, such as the policy rate. Usually central banks determine the short interest rate by supplying such amounts of reserves to banks that the policy rate settles to a desired level. However, level of policy rate as such is of restricted economic importance. Economic decisions are typically made based on other financial market prices, such as long term interest rates, equity prices, and exchange rates, which are linked to the policy rate. Therefore, the effectiveness of monetary policy depends on whether desired changes in the policy rate are transmitted to other financial prices, which ultimately affect consumption, employment and economic growth. In this thesis, particular attention is given to the link between the policy rate and longer term interbank rates in the European context.

Interbank rates are important for two main reasons. Firstly, interbank rates represent the marginal cost of funding for banks, which in turn determine the cost of short term bank loans and deposit rates. Moreover, interbank rates determine the cost of longer term loans made to households and firms, thereby affecting financing conditions for households and businesses. Secondly, interbank rates serve as a benchmark for pricing fixed income securities, such as short term interest rates futures, forward rate agreements and interest rate and currency swaps. Therefore, the level of interbank rates, and particularly the central banks' control over interbank rates, is of particular importance in assessing the effectiveness of monetary policy. Interbank markets are a key factor in transmitting monetary policy decisions to real economy particularly via the interest rate channel of monetary policy.

The purpose of this thesis is to study the tensions in the European interbank market and evaluate the European central bank's (ECB) ability to reduce risk premia incorporated in Euro Interbank Offered Rates, or EURIBOR rates, during recent financial crisis. The thesis is inspired by the credit freeze of 2008 and its adverse effects to monetary transmission and real economy. More specifically, special attention is given to interest rate transmission which seems to have lost some of its power during recent crisis. An empirical assessment is provided in order to evaluate the extent to which the ECB has been able to reduce risk premia in the interbank market, and consequently, to restore proper functioning of the interest rate channel of monetary policy.

This thesis is organized as follows. Chapter 2 provides a theoretical framework for monetary transmission and explains how interbank rates are determined. Unconventional tools of monetary policy are also discussed, as the traditional interest rate channel has met its limits during current crisis. Some empirical evidence is also provided on interest rate pass-through before the crisis. Chapter 3 studies the risk premium incorporated in EURIBOR rates in more detail. Theoretical framework is provided to better understand the sources of risk premium in interbank lending. Unconventional measures of the ECB during current crisis are also presented as they are relevant in reducing tensions in the interbank market. Chapter 4 provides a brief overview of literature studying interbank spreads and empirically evaluates whether the ECB’s unconventional liquidity provision has reduced interbank risk premia in the euro area. Chapter 5 provides conclusions and discusses potential disadvantages of unconventional monetary policy.

2. THEORETICAL FRAMEWORK FOR MONETARY TRANSMISSION AND INTERBANK RATES

2.1. Monetary policy transmission channels

One of the pillars of making monetary policy is good understanding of different monetary transmission mechanisms that transmit central bank actions to the real economy and allows the central bank to steer the economy in the desired direction. This section describes the functioning of different channels of monetary policy transmission. The categorization of channels is based on Mishkin (1996). A common feature of all the channels is that they all transmit policy decisions to aggregate demand or supply through financial markets.

2.1.1. Exchange rate channel

The exchange rate channel refers to the central bank's ability to manipulate exchange rates. To see this, consider an interest rate cut which leads to higher money supply. The interest rate cut leads, through the term structure of interest rates, to lower interest paid on deposits denominated in domestic currency relative to deposits denominated in foreign currencies. As a consequence, deposits denominated in domestic currency decline relative to foreign currency denominated deposits. This leads to a depreciating currency, which makes domestic goods cheaper than foreign goods, causing net exports to expand and domestic aggregate output to rise. (Mishkin, 1996) Naturally, the exchange rate channel does not exist for countries with a fixed exchange rate. Conversely, the more open an economy is in terms of trade, the stronger this channel is.

Exchange rate fluctuations may also influence aggregate demand by affecting the balance sheets of domestic firms whose balance sheets include a large share of debt denominated in foreign currency. If the asset side of the balance sheet is mainly denominated in domestic currency, then a depreciating currency raises the debt burden but leaves the asset side of the balance sheet unchanged, causing the net worth of the firm decline.

At the early stages of financial development, the exchange rate channel is thought to play a key role. In countries with undeveloped capital and money markets, foreign exchange is perceived as the single most liquid and inflation proof asset. The price of this asset, the exchange rate, quickly reacts to changes in monetary policy, which ultimately leads to changes in output and prices. (Gigineishvili, 2011)

2.1.2. Asset price channel

The asset price channel refers to the central bank's ability to raise asset prices, such as stocks and real estate. To see this, consider an interest rate decrease by the central bank which causes all interest rates to decrease along the term structure. Lower interest rates make bonds less attractive as investment than stocks and result in increased demand for stocks, causing stock prices to rise. Conversely, interest rate reductions make it cheaper to finance housing, causing real estate prices to rise. (Mishkin, 1996)

To see the effect more precisely, consider the following demonstration. Theoretically, stock prices are net present values of all expected future cash flows that they provide to the holder. Future cash flows are discounted to the present by using some discount rate. In finance, the discount rate is usually the Weighted Average Cost of Capital (WACC), which includes a component describing required return for equity. The required return for equity is usually determined by Capital Asset Pricing –model (CAPM), which can be written as:

$$E(r_i) = r_f + \beta_i[E(r_m) - r_f] , \qquad (1)$$

in which $E(r_i)$ is the required (or expected) return on the capital asset, r_f is the risk free rate, β_i is beta of capital asset, and $E(r_m)$ is expected return on the market portfolio. The term $\beta_i[E(r_m) - r_f]$ describes the risk premium for the security. Traditionally government bond yields have been used as the risk free rate. As described above, an expansionary monetary policy lowers yields on all bonds. If the risk premium for the security, $\beta_i\left[E(r_m) - r_f\right]$, is assumed to be constant, then the reduction in the risk free rate lowers the expected return $E(r_i)$ for the security. Since the price of the capital asset is the discounted NPV of all future cash flows, the lower discount rate therefore increases the NPV, or the price of the capital asset.

There are three different types of transmission mechanisms that involve asset prices: investment effects, wealth effects and balance sheet effects. *Investment effects* are explained by Tobin's q theory (1969). Tobin's q is defined as the market value of firms divided by the replacement cost of capital. If q is high, the market price of firms is high relative to the replacement cost of capital, which means that new plant and equipment is cheap relative to the market value of the firm. Firms can then issue stock and get a high price for it relative to the cost of the plant and equipment. Investment spending therefore rises because firms can now buy a relatively large amount of new investment goods with only a small issue of stock. (Mishkin, 1996)

Wealth effects are explained by the Modigliani's life cycle hypothesis (1954), which states that consumption is determined by lifetime resources of consumers. These life cycle resources consist primarily of financial assets, mostly stock and real estate. Interest rate cuts cause a rise in stock and real estate prices which raises households' wealth. This means that consumers' life cycle resources increase, thereby lifting consumer spending and aggregate demand.

Balance sheet effects arise when increases in stock and real estate prices improve corporate and household balance sheets, raising their net worth. Higher net worth translates into higher collateral when borrowing money. This in turn increases lending, investment spending and ultimately aggregate demand.

2.1.3. Credit channel

The credit channel mechanism of monetary policy refers to the theory that a central bank's policy changes affect the amount of credit that banks issue to firms and consumers, which in turn affects the real economy. The credit channel emphasizes the concept of asymmetric information in financial markets, which makes it possible to separate two different channels; bank lending channel and balance sheet channel (Mishkin, 1996).

The bank lending channel is based on the view that banks are particularly well suited to solve asymmetric information problems in credit markets. In the real world, many borrowers do not have access to credit markets because market participants do not know whether the borrower is creditworthy or not. Banks play a special role in assessing the creditworthiness of potential borrowers, which leaves many borrowers dependent on the bank as source of financing. If there is no perfect substitute to retail bank deposits as source of funding, then expansionary monetary policy increases bank reserves and bank deposits, leading to a higher quantity of bank loans available. This will cause more borrowing leading to higher investment spending and ultimately, higher aggregate demand. An important implication of this view is that small firms should benefit the most because they are the ones who are often dependent on bank loans. Bigger firms often have direct access to bond and stock markets which they can use to collect financing. (Mishkin, 1996)

The balance sheet channel refers to a theory which states that banks' willingness to lend is dependent on the borrowers net worth. With adverse selection, firms that have a low net worth are exactly those who seek bank loans because they do not have access to other type of credit. Lower net worth of borrowers also translates into lower collateral for lenders. Therefore, a decline in borrowers' net worth worsens the adverse selection problem and thus leads to decreased bank lending. Lower net worth of borrowers also increases the moral hazard problem because it means that owners have a lower equity stake in their firms, giving them incentives to engage in risky investment projects. Since riskier investment projects mean that lenders are less likely to be paid back, a decrease in firms' net worth leads to a decrease in lending and ultimately in investment spending. (Mishkin, 1996)

Monetaty policy can affect firms' balance sheets in many ways. Firstly, as described in section 2.1.2, expansionary monetary policy can cause equity prices to rise, which raises borrowers' net worth. Higher net worth lowers the adverse selection and moral hazard problems, leading to increased loanable funds available and ultimately higher investment spending. Secondly, if the expansionary monetary policy reduces nominal interest rates, then firms' balance sheets improve because of higher cash flows which are the result of lower financing costs. Higher cash flow raises net worth, leading to higher investment spending. Thirdly, because debt payments are often fixed in nominal terms, an expansionary monetary policy that raises the price level causes real net worth of firms to rise, leading to higher investment spending. (Mishkin, 1996)

2.1.4. Interest rate channel

Interest rate channel of monetary policy is the most traditional mechanism and it is of particular interest in this thesis. In general, interest rate channel transmission can be split to two pieces. First phase of the interest rate channel refers to the idea that changes in central bank policy rates cause movements in money market rates, starting from short maturities and moving to longer maturities through the yield curve. In the second phase, changes in money market rates are expected to pass through to commercial bank lending and deposit rates, which in the final phase of monetary transmission affect savings, consumption, investment and ultimately aggregate demand and prices. According to Gigineishvili (2011), the impact of policy changes on money market rates is usually strong and immediate, because central banks normally operate at the lower end of the yield curve. The second phase of the process, market-to-retail interest rate pass-through, is more diverse.

Traditional Keynesian view of interest rate transmission can be characterized by the schematic displayed in figure 1. When the central bank decides to conduct expansionary monetary policy that is targeted to reducing the policy rate, the reduction in policy rate is expected to transmit to term interbank rates. In the second phase of interest rate transmission, lower interbank rates are expected to be transmitted to bank lending rates. However, the interest rate channel does not rely on nominal rate changes to have effects on consumption and investment; rather, it is the real interest rate that affects economic decisions. In a traditional Keynesian framework, prices are sticky which means that reductions in policy rate do not cause an immediate rise in price level. Therefore, *real* interest rates also decrease, causing the opportunity cost to consume and invest to decrease. Reductions in real interest rates are expected to lead to higher consumption and investment, and ultimately to higher aggregate demand. (Mishkin, 1996)

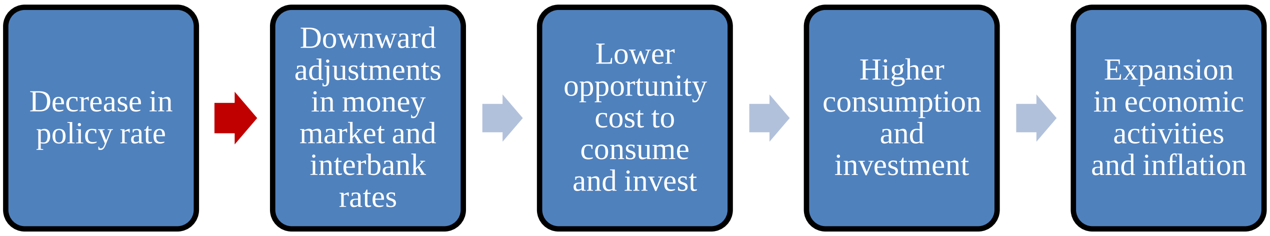

Figure 1. The interest rate channel of monetary policy

The interest rate channel is based on multiple assumptions. Firstly, it is assumed that the central bank has the ability to steer the nominal short rate (usually the overnight rate) by conducting open market operations. Secondly, price stickiness in the short run is assumed in order to explain why lower nominal rates also lead to lower real rates. Thirdly, it is assumed that lower short real rates also lead to lower long real rates. Finally, long real rates are assumed to stimulate consumption and investment spending, ultimately raising aggregate demand and output.

Intuitively one would expect that in current crisis the interest rate channel has lost all its power because nominal rates are at or near zero lower bound. However, Mishkin (1996) reminded that the central bank can affect the real interest rate without changing the nominal rates if it is able to manage inflation expectations. Fisher (1930) theoretized that there is a link between nominal rates, real rates and inflation expectations. A simplified presentation of the Fisher equation can be expressed as:

$$i \approx r + \pi^e \tag{2}$$

where i is the nominal interest rate, r is the real interest rate and π^e is expected rate of inflation. By rearranging the equation, we get

$$r \approx i - \pi^e \tag{3}$$

Equation (3) shows how the real rate is determined under Fisher's Theory of Interest (1930). This form of presentation reveals that the central bank has two variables that it can try to manipulate in order to achieve desired changes in the real interest rate. Firstly, by using open market operations it can set the level of nominal rate, i.e. the overnight rate. In current environment, however, the nominal rate is constrained because nominal rates are already at or close to the zero lower bound. Therefore, the central bank can potentially further affect the real rate if it is able to control inflation expectations. As Mishkin (1996) stated, the zero lower bound does not necessarily eliminate the functioning of the interest rate channel.

2.2. Determinants of overnight rate

The overnight rate is determined in the overnight market where large banks lend and borrow funds to one another with maturity of one day. In the Eurozone the overnight rate is called EONIA (Euro OverNight Index Average). It represents an effective overnight interest rate computed as a weighted average of all overnight unsecured lending transactions undertaken by participating panel banks. According to Välimäki (2006), although the ECB has not explicitly announced an operational target for its monetary policy (contrary to the Fed), it is clear that the monetary policy implementation in the euro area aims at stabilizing short interest rates to a level close to the main ECB policy rate, which is the rate for main refinancing operations (MROs) with a maturity of one week.

2.2.1. Open market operations and reserves

Open market operations (OMOs) refer to an activity by a central bank to buy or sell government bonds in the open market. The usual aim of open market operations is to control the short term interest rate and monetary base MB, which can be written as:

$$MB = C + R \tag{4}$$

where C is currency in circulation and R is reserves supplied. By buying bonds in the open market the central bank increases the monetary base and thus lowers the overnight rate. Monetary base is always increased by the amount of the open market purchase. However, effect of reserves depends whether the seller of the bonds keeps the proceeds in currency or in deposits. If the proceeds are kept in currency, the open market purchase has no effect on reserves, only to currency in circulation. If the proceeds are kept as deposits, reserves in the banking system increase by the amount of the open market purchase. (Mishkin, 2004)

Demand for reserves consists of required reserves and excess reserves. Cost of holding excess reserves is their opportunity cost, which is the overnight rate. If the overnight rate decreases, banks are more willing to keep excess reserves as insurance against deposit outflows because of lower opportunity cost. Therefore, demand curve slopes downwards. Supply of reserves consist of non-borrowed reserves R_n and loans from the central bank. Because borrowing in the interbank market is a substitute for taking out loans from the central bank, the supply curve is vertical if the overnight rate is below the lending rate; there is no lending from the central bank. However, if the overnight rate rises above lending rate, then reserves demanded will be satisfied by borrowing straight from the central bank, implying a flat supply curve. Market equilibrium occurs at the intersection of demand and supply curve shown in figure 2 (Mishkin, 2004)

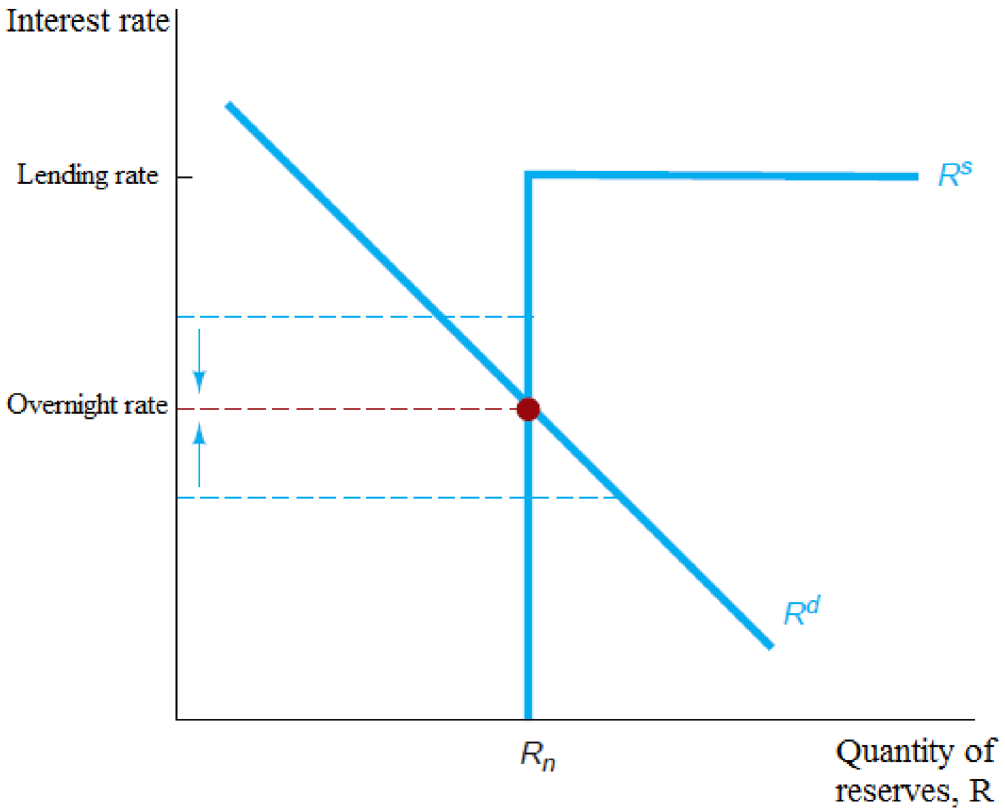

Figure 2. Equilibrium in market for reserves (Mishkin, 2004)

By conducting OMOs, the central bank can shift the supply curve; an open market purchase causes the overnight rate to fall, whereas an open market sale causes the overnight rate to rise (Mishkin, 2004). By shifting the supply curve, the central bank can respond to changes in demand. For example, if demand curve shifts to the right because of a liquidity shock, the central bank can offset the rise in overnight rate by increasing open market operations. Since the central bank has a monopoly position in supplying reserves, it can effectively set the level of overnight rate by conducting OMOs (Mishkin, 2004).

In the euro area, regular open market operations are conducted via refinancing operations, which are repurchase agreements where banks put up accepted collateral with the ECB and receive a cash loan in return. OMOs consist of main refinancing operations (MRO) with maturity of one week and longer term refinancing operations (LTRO) with maturity of three months. MROs serve to steer short term interest rates, to manage the liquidity situation, and to signal the stance of monetary policy in the euro area, while LTROs aim to provide additional, longer term refinancing to the financial sector. In addition to MROs and LTROs, ECB conducts fine-tuning operations which are aimed at smoothing the effects of unexpected liquidity fluctuations on interest rates.[1]

2.2.2. Interest rate corridor system

In the euro area, the ECB has adopted features of an interest rate corridor system which sets limits to the overnight rate. In a corridor system, a central bank sets up two standing facilities: a lending facility which supplies money overnight at a fixed lending rate against collateral and a deposit facility where banks can make overnight deposits at the central bank in order to earn a deposit rate[2]. The deposit rate provides a floor for the overnight rate, because no bank will lend money in the overnight market if it receives higher return by depositing the money to the central bank. Similarly, the lending rate provides a ceiling for the overnight rate, because no bank will borrow money from the overnight market at a rate higher than what the central bank charges. (Mishkin, 2004) The corridor system is illustrated in figure 3.

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[1] For further information, see http://www.ecb.int/mopo/implement/omo/html/index.en.html

[2] Marginal lending facility of the Eurosystem can be used by counterparties to receive overnight credit from a national central bank at a pre-specified marginal lending rate against eligible assets. Similarly, the deposit facility can used to make overnight deposits at a national central bank that are remunerated at the deposit rate.

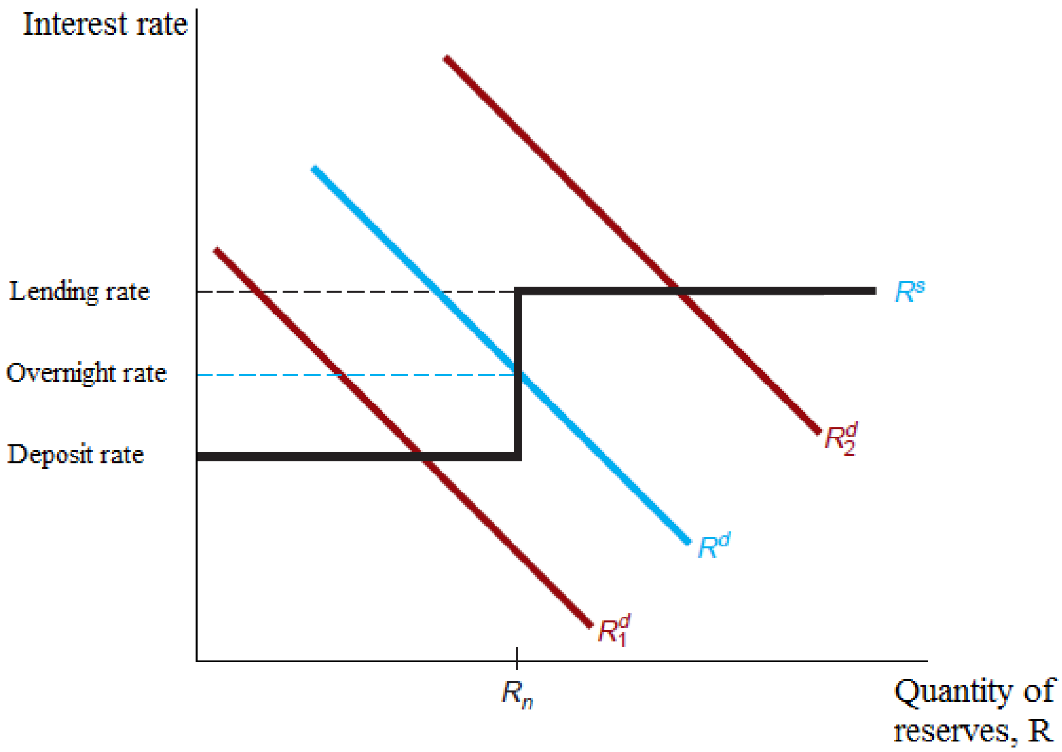

Figure 3. Interest rate corridor system (Mishkin, 2004)

Figure 3 shows that if the demand curve shifts between R_1^d and R_2^d, the overnight interest rate always remains between deposit and lending rates. Reserve supply curve is a step function because the central bank is ready to supply any amount banks want at lending rate and similarly accept any amount of deposits and pay the deposit rate. R_n stands for non-borrowed reserves that are determined by open market operations. In a corridor system, central bank has the ability to set the overnight rate whatever the demand for reserves, including zero demand. By increasing (decreasing) open market operations the central bank shifts the supply curve to the right (left), thereby lowering (raising) the overnight rate. (Mishkin, 2004) Naturally, by narrowing the interest rate corridor the central bank can reduce the volatility of the overnight rate in case of sudden changes in demand for reserves.

In the euro area, design of the monetary policy operational framework implies that the overnight market rate usually fluctuates around the middle of the corridor given by the standing facilities rates. Figure 4 shows that before the crisis the EONIA has moved closely with the MRO rate. In 2008, ECB adopted a fixed rate full allotment policy (FRFA) which allowed banks to raise as much liquidity as they want with a fixed rate. The FRFA policy and extraordinary long term refinancing operations (LTRO) have substantially increased liquidity in the market, which may explain why EONIA has clearly fluctuated under the MRO rate after 2008. Before the start of the crisis, EONIA has been in line with the MRO rate.

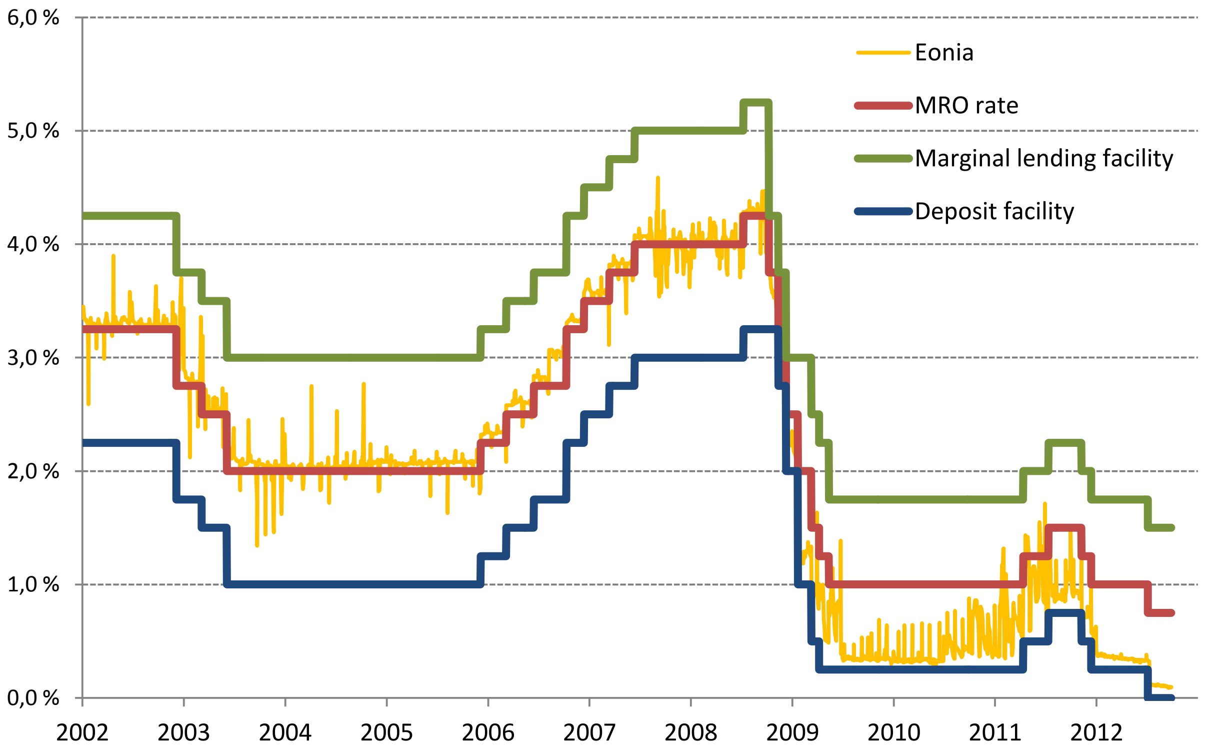

Figure 4. ECB key rates between January 2002 and September 2012. *Data source: ECB statistics, Bloomberg*

2.3. Determinants of term interbank rates

2.3.1. Expectations hypothesis

Expectations hypothesis (EH) was first introduced by Fisher (1896) and it is one of the oldest theories in finance aiming to explain the relationship between yields of different maturities. According to Guidolin et al. (2008), there are several versions of the theory and which been statistically tested and rejected using a wide variety of interest rates, over a variety of time periods and monetary policy regimes. Despite the fact that there exist little empirical support for full explanatory power of the EH, it provides a theoretical basis which can be used to explain determination of term interbank rates.

According to the pure expectations theory (PEH), long term interest rate will equal an average of short term interest rates that the market expects to occur over the life of the long term bond. This is based on the assumption that bonds with different maturities are perfect substitutes. Arbitrage arguments are used to explain why this is the case. Consider two investment strategies. One could invest in a two period bond or alternatively in a one period bond and roll over the investment after the first year. EH states that yields for both strategies must be the same. In general form, this can be written as:

$$(1 + y_n)^n = (1 + y_{n-1})^{n-1}(1 + f_n)^n \qquad (5)$$

where y_n is the annualized yield for n period investment and f_n is the one period forward rate at time n. Equation 5 shows that the expected yield for a n period investment can be derived using the yield for a n-1 period investment and the forward rate for period n. For example, consider a two period investment. If the spot rate for a one period investment is 4 % and the market expects that the one period spot rate (=current forward rate) for the second period will be 6 %, then using arbitrage arguments we are able to calculate what the spot rate for a two period investment must be:

$$(1 + r_1)(1 + f_2) = (1 + y_2)^2 \Leftrightarrow (1{,}04)(1{,}06) = (1 + y_2)^2$$
$$(1 + y_2) = \sqrt[2]{(1{,}04)(1{,}06)} \Leftrightarrow y_2 = 4{,}995\ \% \qquad (6)$$

Equation 6 shows that annualized yield for a two period investment must be 4,995 %. Otherwise there would be arbitrage which would be exploited immediately in an efficient market. Equation 6 also shows that we are able solve the one period forward rate that is implied by the yield curve because we know what annualized yields for one and two period investments are.

By applying the EH to interbank rates, we should be able to derive term interbank rates from the overnight rate by repeatedly rolling over the overnight investment (Abbassi and Linzert, 2011). However, this is not the case because term interbank rates include a maturity-specific risk premium (Litterman et al. 1991). Still, the basis for EURIBOR rates is determined by the overnight rate and ECB policy rates. For a historical presentation of EURIBOR rates, see appendix A.

2.3.2. Risk premium

In general, risk premium in term interbank rates is the result of mainly three factors: term premium, liquidity premium and credit premium. The EH does not consider these factors as relevant for term rates since the theory is based on the assumption that bonds with different maturities are perfect substitutes. To fill the gap, other theories have been developed that are based on the EH but incorporate the missing factors in order to better describe the determination of term rates.

Segmented markets theory of the term structure sees the market for bonds of different maturity as completely separate and segmented. The interest rate for each bond with a different maturity is then determined by the supply of and demand for that bond with no effects from expected returns on other bonds with other maturities, implying that the expected return from holding a bond of one maturity has no effect on the demand for a bond of another maturity. By allowing investors to prefer one maturity over another, the theory can explain why the yield curve might slope upwards but cannot explain why yields of different maturities tend to move together. (Mishkin 2004)

Liquidity preference theory (Keynes 1936) *and preferred habitat theory* of the term structure state that the interest rate on a long term bond will equal an average of short-term interest rates expected to occur over the life of the long term bond plus a liquidity premium (referred to as a term premium in preferred habitat theory). Both theories assume that bonds of different maturities are not perfect substitutes. Also, investors are allowed to prefer one maturity over another. Generally investors tend to prefer shorter term bonds because they bear less interest rate risk. For these reasons, investors must be offered a positive liquidity premium to induce them to hold longer term bonds. (Mishkin 2004)

It is worth noticing that EURIBOR rates are not *annualized* yields; they are simply rates for specific term loans between banks. For example, government bond yields are annualized yields calculated as average returns received each year by buying the bond at current market price and holding it until maturity. Still, term structure theories provide reasons why longer term investments include a risk premium. The risk premium that is incorporated in EURIBOR rates can be measured by the spread between EURIBOR rates and OIS rates of corresponding maturity. A detailed rationale of this measurement will be provided in section 3.1. Figure 5 shows the term structure of the risk premium on different year end dates, including 1M, 3M, 6M and 12M maturities.

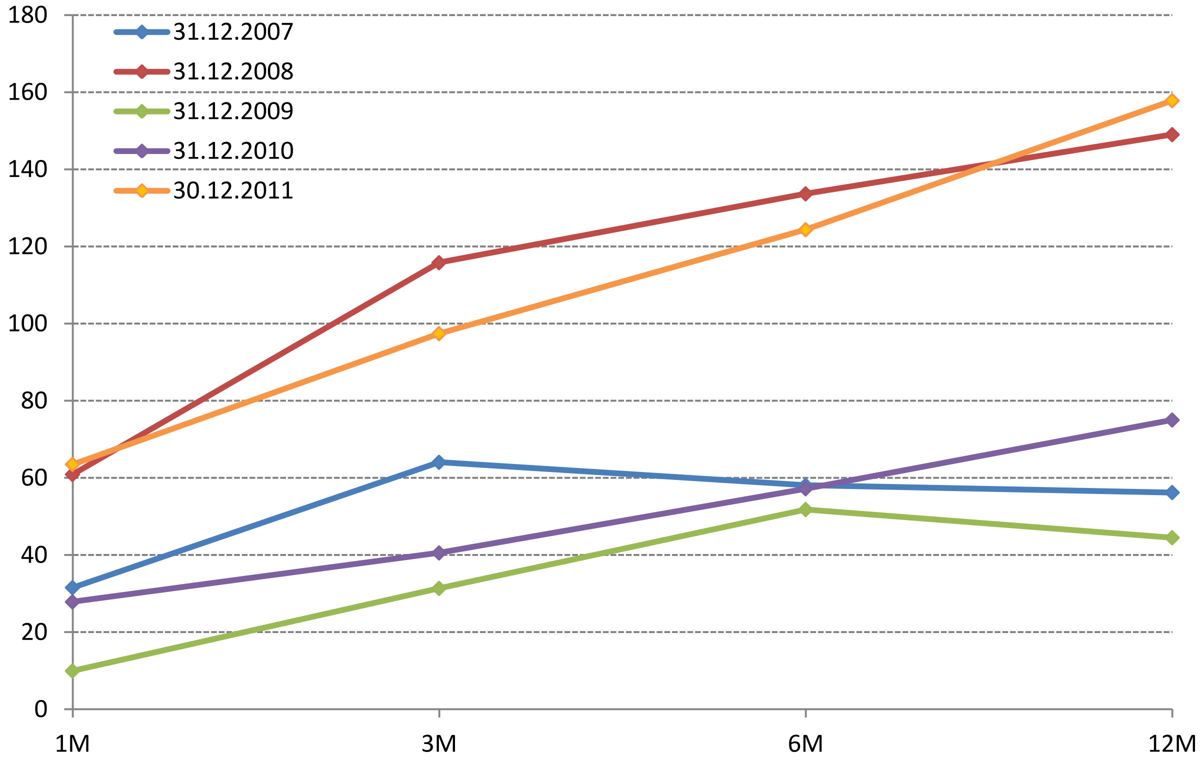

Figure 5. Term structure of the EURIBOR-OIS spread (as basis points) in different year ends.

When considering interbank rates, term and liquidity premia are also accompanied by credit premia. Since interbank rates are rates for uncollateralized loans between banks, there is a possibility of a bank defaulting on its liabilities.

2.4. Unconventional monetary policy near zero lower bound

Conventional monetary policy refers to the implementation of monetary policy via the interest rate channel. As presented in section 2.1.4, the central bank expects that changes in its policy rate are transmitted to money market rates, and further, to retail lending rates, which should affects consumer and investment decisions. However, in current market environment, central bank policy rates are at or near the zero lower bound, which constrains the use of further policy rate changes as a tool to achieve an expansion in economic activities and inflation. For the purpose of stimulating the economy at or near zero lower bound, the central bank can use unconventional tools that work through other channels of monetary transmission that were presented in section 2.1. Such unconventional tools are categorized by Bernanke et al. (2004) into three categories; (1) expectation management strategy, (2) expansion of monetary base and (3) changes in composition of central bank balance sheet.

2.4.1. Expectations management strategy (signaling)

Expectations hypothesis presented in section 2.3.1. described how expected short term rates form the basis for longer term rates. However, it is not the short rate itself that is important in affecting economic decisions; rather, other asset prices such as longer term rates, equity prices and exchange rates are more important in affecting economic decisions. As these other asset prices are linked to the short rate, it follows that the ability of a central bank to influence economic decisions is critically dependent upon its ability to influence market expectations about future path of overnight interest rates, not the current level. (Woodford, 2003) If market participants expect that the nominal rate will be kept low, they will bid down longer term yields and boost up equity prices.

At most basic level, implementation of monetary policy has two core elements. The first consists of signaling the desired policy stance. The second consists of operations that are used to make this policy stance effective. To see the importance of signaling, consider a policy rate announcement, which defines the desired level of the reference rate. To make the announcement effective, the central bank designs liquidity management operations to ensure that the reference rate tracks the desired policy rate closely. As such, liquidity management operations only play a technical and supportive role in achieving the target. Because the central bank has monopoly over the price of reserves, it is able to set the price to any level simply because it could stand ready to buy and sell unlimited amounts at the chosen price. This is the source of credibility for the signal. (Borio and Disyatat, 2009) Therefore, if the public believes that the central bank can set the price of reserves, the signal should become self-fulfilling, giving the central bank an important tool to conduct monetary policy.

In addition to signaling, central banks can affect expectation formation by committing in public to some policy rule. By committing to a policy rule market participants will update their expectations whenever desired target variables fluctuate from policy rule levels. However, in practice there are limits to central banks' ability to fully commit to a specified policy rule, as the central bank could find it very difficult to describe the details of its actions to highly unusual circumstances. Because the ability to commit to precisely specified rules is limited, central bankers have found it useful in practice to supplement their actions with talk, communicating regularly with the public about the outlook for the economy and for future policy. Communication has been thought to be particularly important near the zero lower bound. (Bernanke et al., 2004)

2.4.2. Expansion of monetary base (quantitative easing)

Central banks normally lower their policy rate through open market purchases of securities, which increase the supply of bank reserves and put downward pressure on the rate that clears the reserves market. A sufficient injection of reserves will bring the policy rate close to zero, so that further interest rate reduction are not possible. However, nothing prevents the central bank from adding liquidity to the system beyond what is needed to achieve a policy rate of zero. (Bernanke et al., 2004)

Quantitative easing refers to the action of a central purchasing financial assets, such as government bonds, from the private sector. These assets are paid with new central bank money, which should boost the amount of central bank money held by banks and the amount of deposits held by firms and households, because the central bank pays for the assets via the seller's bank. This additional money then works through different channels to increase spending. First effect works through the asset price channel. When asset prices go up, lower yields reduce the cost of borrowing for households and companies. This should lead to higher consumption, investment spending and inflation. Second effect works through the bank lending channel. When assets are purchased from non-banks, banks gain both new reserves and new customer deposit. Higher level of liquid assets should encourage banks to extend more new loans, leading to higher consumption and investment. Third effect works through inflation expectations. By demonstrating that the central bank will do whatever it takes to meet the inflation target, inflation expectations should remain anchored to the target if there was a risk that they might otherwise have fallen. Even with very low nominal interest rates this would imply that real interest rates are kept at a low level, which should encourage greater spending. Higher inflation expectations could also influence price-setting behavior by firms, leading to a more direct impact on inflation. (Benford et al., 2009) Effects of quantitative easing are described in figure 6.

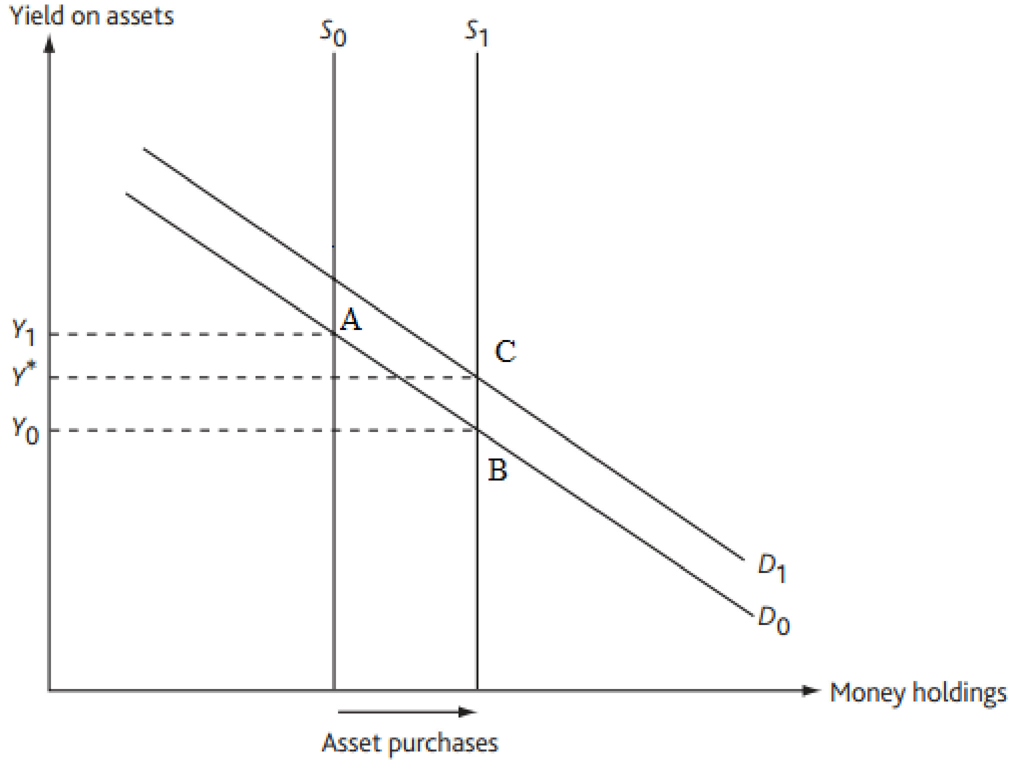

Figure 6. Effects of quantitative easing (Benford et al., 2009).

Figure 6 shows the overall impact of quantitative easing. Demand curve is downward-sloping because yields on other assets represent the opportunity cost of holding money. If opportunity cost declines, then money holdings are expected to rise. Asset purchases shift the supply curve to the right, leaving markets at point B in which yields have fallen from Y_1 to Y_0. If markets are efficient, all asset prices are be expected to adjust quickly to news about asset purchases because of substitutability of different types of assets under market efficiency. As asset prices rise, nominal spending should increase and the demand for money should shift to the right from D_0 to D_1. This will reduce the initial effect of a change in asset prices and yields, causing yields to rise from Y_0 to Y*. The overall effect of asset purchases depends on the elasticity of money demand to changes in yields, i.e. the slope of the demand curve, and the elasticity of money demand to changes in spending caused by higher asset prices, i.e. the extent of the shift of the demand curve. (Benford et al., 2009)

Quantitative easing is sometimes confused with "credit easing", a term coined by US Federal Reserve chairman Bernanke. According to Bernanke (2009), the focus of quantitative easing policy is on bank reserves, while the focus of credit easing is more targeted to relief credit pressures by purchasing specific securities from the private sector.[3]

2.4.3. Changes in composition of central bank balance sheet (qualitative easing)

Composition of assets held by the central bank offers another potential tool for monetary policy without changing the size of central bank balance sheet.[4] By buying and selling securities of various maturities or other characteristics in the open market, the central bank could influence the relative supplies of these securities. If asset purchases and sales are targeted to assets that differ only in maturity, the central bank can try to manipulate the term structure of interest rates of that particular asset. Depending on whether the purchases are targeted to the short or long end of the yield curve, the central bank can shorten or lengthen the average maturity of the asset in question. (Bernanke et al., 2004)

These changes in supplies should be effective only if financial markets are not perfect. This is because in a frictionless market, pricing of any financial asset would depend only on its state- and date-contingent payoffs. However, when markets are incomplete, the central bank might be able to affect term, liquidity and risk premiums that are related to the purchased securities. (Bernanke et al., 2004)

2.5. Real interest rates

As presented in section 2.1.4, the interest rate channel emphasizes the real rather than the nominal rate as being more important in determining consumer and business decisions.

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[3] Speech given at Stamp Lecture, London School of Economics, January 2009. Available at: http://www.federalreserve.gov/newsevents/speech/bernanke20090113a.htm

[4] Changing the composition of central bank's balance sheet is often referred as "qualitative easing".

According to the Fisher equation (2), central banks can affect the real interest rate by changing the nominal rate or by managing inflation expectations. Section 2.2.1. provided arguments that central banks have direct control over the short nominal rate, which also affects longer term rates as described by theories explaining the term structure of interest rates. However, at or near the zero lower bound, the Fisher equation (2) implies that the central bank's ability to steer real interest rates depends on whether it is able to steer inflation expectations. If the central bank has a published inflation target, then proper anchoring of inflation expectations is necessary to conduct credible and effective monetary policy.

Increases in money supply should eventually lead to a rise in prices, as there is a well-documented long run empirical relationship between broad money growth and inflation across a variety of countries and monetary regimes[5]. However, there is considerable uncertainty about the pace with which injections of money will be transmitted to prices[6].

2.5.1. Inflation expectations

Inflation expectations are widely recognized to have a strong macroeconomic significance as wage negotiations, consumption and investment are affected by people's expectations of future prices. A good starting point for analyzing expectation formation of future variables is the concept of rational expectations originally presented by Muth (1961), which has been widely incorporated in many modern macroeconomic models and is regarded as an underlying force that drives decision making. According to Mishkin (2004), the concept of rational expectations states that expectations are formed using all available information, not just past information as stated by adaptive expectations. Therefore, expectations will be affected by predictions of future monetary policy as well as by current and past monetary policy. Market participants are thought to change their expectations quickly when new publicly available information arrives to the market; as a result, economic variables should reflect all publicly available information correctly and without delay.

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[5] See for example Benati (2005) and King (2002).

[6] Benford et al. (2009)

For the central bank's monetary policy, management of inflation expectations can be a very useful tool at least in two situations, which often coincide; deflationary environment and a liquidity trap. Mishkin (1996) explained that even without the assumption of sticky prices, the central bank can affect real interest rates by raising inflation expectations via an increase in money supply. However, it is important to notice that if nominal rates are at or near the zero lower bound, an increase in money supply is not purposed to lower them further. Also, in the European scope, it is worthwhile to keep in mind that because the ECB has an inflation target, raising inflation expectations support ECB's credibility only if inflation falls below the central bank's target or turn negative.

Krugman (2010) explained why a deflationary environment is bad for the economy. Firstly, when the public expects falling prices, people become less willing to spend and to borrow. When prices are expected to fall, just holding cash becomes an investment with a real positive yield. Expectations of deflation can also cause a deflationary trap in which the economy stays depressed because people expect deflation. Secondly, falling prices worsen the position of borrowers by increasing the real burden of their debts. Fisher (1933) showed that although one might think that this is offset by a corresponding gain that lenders experience, borrowers are likely to be forced to cut their spending more than lenders are likely to increase their spending. Lastly, deflation has potential to cause high unemployment because of nominal wage rigidities; in a deflationary economy, wages should fall with the price level so that producers would not have to cut employment as their revenue decreases.[7]

In addition to a being important in a deflationary environment, inflation expectations have been at the centre of the "liquidity trap debate" which is concerned about the effectiveness of monetary policy in such an environment. Keynes (1936) represented the traditional view of the matter. He described the liquidity trap as a situation which occurs when people hoard cash because they expect an adverse event such as deflation. Consequently, Keynes (1936) argued that in an environment of low nominal rates and cash hoarding, the economy is trapped in the sense that an expansion of the money supply does not succeed in stimulating inflation and economic activity. However, this argument has been challenged, for example, by Krugman (2000) and by Eggertsson and Woodford (2003) who represent the modern view of the matter. They have argued that near the zero lower bound, the central bank can escape the liquidity

[7]Available at: http://krugman.blogs.nytimes.com/2010/08/02/why-is-deflation-bad/#

trap by creating inflationary expectations which do not lower nominal rates, but can lower the real interest rate. If the public expects that the real value of their cash holdings decreases, an incentive to stop hoarding cash is created which is an essential key that should restore economic activity.

Krugman (2000) argued that a credible commitment to expand the future money supply will be expansionary even in a liquidity trap, because it changes inflation expectations of the public. He suggested that this could be achieved if the central bank loosened its commitment to price stability. Furthermore, Eggertsson and Woodford (2003) argued that the current level of the short rate is not relevant for stimulating the economy; rather, what actually matters is the private sector's expectation of the future path of short rates, as this path determines longer term interest rates, exchange rates and other asset prices that are relevant for current spending decisions. Consequently, Eggertsson and Woodford (2003) argued that the central bank can increase inflationary expectations by committing to keep nominal rates low. This can be interpreted as a form of expectation management strategy (or signaling).

Eggertsson and Woodford (2003) model also provided justification for quantitative easing, which should lead to higher inflationary expectations. If the central bank has a published inflation target and actual inflation falls below its respective target, the central bank has justification to expand the monetary base. In addition to providing justification for quantitative easing, Eggertsson and Woodford (2003) argued, in line with Krugman, that the central bank could raise inflationary expectations by starting to make announcements of the monetary policy that it intends to conduct in the future. One way to do this would be to commit to sustain monetary expansion even after the liquidity trap was over, and simultaneously, to commit to keep future nominal rates low so that expectations of nominal rates do not change in response to a monetary expansion.

As the topic is quite fresh, there is very little empirical evidence exists on whether the central bank can actually change the public's inflation expectations by conducting unconventional monetary policy. Szczerbowicz (2011) seems to be the only paper that studied how long run inflation expectations were affected by the two QE programs conducted by the Fed. The author used a market-based measure of inflation expectations and found that QE1 had very little effect, but QE2 much more effective in raising long run inflation expectations. She believed that the difference between the effectiveness of these programs were related to different economic outlooks at the time of the operations; according to her, QE1 was implemented when the U.S. was still in a recession while the decision about QE2 was undertaken when the economic recovery was proceeding. As an intuitive consideration, this makes sense because QE1 may have been more effective in reducing deflationary concerns, rather than actually contributing to higher inflationary expectations, contrast to QE2.

2.5.2. Persistence of real interest rates

According to the Fisher (1930) hypothesis, nominal interest rates should vary one-for-one with expected inflation in the long-run; for example, if inflation rises from a constant level of 2 % to a constant level of 4 %, the Fisher equation (2) shows that nominal rates should rise 2 percentage points. Thus, real interest rates, which represent the difference between nominal interest rates and expected inflation, must be stationary. However, the stationary properties of real interest rates have been questioned in several studies starting from Rose (1988). Real interest rate persistence means that when, for example, inflation expectations rise, the real interest rate falls and does not immediately revert to its previous level (i.e., is not stationary) because the nominal rate does not react immediately to changes in expected inflation. For the functioning of the interest rate transmission channel, persistence of real interest rates demonstrates that by changing inflation expectations the central bank can affect real interest rates, which should praise the effectiveness of the interest rate channel in transmitting monetary policy decisions to the real economy.

Neely and Rapach (2008) reviewed the empirical literature on real interest rate persistence. Their conclusion based on existing research was that real interest rates are highly persistent when nominal rates are adjusted for both actual and expected inflation; the real rate is found to be substantially above or below the sample mean. This implies that nominal rates and inflation (expectations) do not move one-for-one, causing doubts on validity of economic theory, as the real interest rate plays a central role in many important financial and macroeconomic models, including the consumption-based asset pricing model, neoclassical growth model, and models of the monetary transmission mechanism.

2.6. Empirical evidence of interest rate pass through in euro area

As presented in section 2.1.4., interest rate pass through can be split to two phases; transmission from central bank policy rate to money market rates and transmission of money market rates to bank lending rates. These changes should ultimately affect decisions in real economy. According to Gigineishvili (2011), the impact of policy changes on money market rates is usually strong and immediate, but evidence of transmission from money market rates to retail rates is more diverse.

2.6.1. Transmission from policy rates to market rates

Busch and Nautz (2010) provided empirical evidence on controllability and persistence of money market rates in the euro area. They defined the *expectations-adjusted policy spread* as the difference between market rates and expected average policy rate (overnight rate) over corresponding maturity. Interbank rates are directly observable from the market; expected average overnight rate is reflected in EONIA swap rates[8]. According to Busch and Nautz (2010), controllability of longer term interbank rates requires that the persistence of their deviations from the central bank's policy rate (i.e. the policy spreads) remain sufficiently low. A persistent policy spread means that longer term interbank rates do not adjust immediately to changes in central bank policy rate. As EONIA swap rates adjust without delay to central bank communications and actions, the pace of transmission should be reflected in the persistence of policy spreads.

According to empirical evidence by Busch and Nautz (2010), the controllability and persistence of longer term rates depend on the predictability and communication of monetary policy. Unclear policy signals about future interest rate decisions should lead to larger forecast errors and more persistent policy spreads. According to empirical evidence by Busch and Nautz (2010), from 2000 to 2007 the average policy spreads for 14 different maturities have varied between 1 to only 7 basis points with standard deviations of about 3 basis points for corresponding maturities, suggesting lower persistence when compared to policy spreads

[8] EONIA swap rates are the main instrument for speculating on and hedging against interest rate movements and therefore give a very good approximation for market's expectations of the average overnight rate over the duration of the swap. For a more detailed rationale of EONIA swap rates, see section 3.2.

that are not adjusted for expectations (i.e., market rate less *current* policy rate). According to Busch and Nautz (2010), the lower persistence of expectations-adjusted policy spreads is largely attributable to the ECB's new operational framework implemented in 2004, because it significantly improved communication of monetary policy. However, Busch and Nautz (2010) estimates show that the expectations-adjusted policy spreads exhibit long memory, which means that shocks such as policy rate changes do not cause an immediate adjustment in market rates. According to Busch and Nautz (2010), this provides evidence that the ECB's control of longer term interbank rates might be weaker than expected.

In addition to policy spread persistence, transmission from policy rates to market rates can be affected by investors' (banks') risk tolerance. If investors are risk-neutral and markets efficient, long term rates can be derived from average short term rates that are expected to prevail, as stated by the expectations hypothesis. If investors are risk averse, the yield curve would be steeper because investors demand a liquidity premium on longer maturities, as suggested by the liquidity preference theory. Finally, if markets for different maturities were segmented as stated by segmented markets theory, interest rates at the two ends of the yield curve could be disconnected, resulting in the breakdown of the transmission mechanism. (Gigineishvili, 2011)

2.6.2. Transmission from market rates to retail rates

According to Gigineishvili (2011), transmission from market rates to bank lending rates can be explained using the cost of funds approach. In this approach, money market rates represent opportunity costs of funds because banks rely on them for short term borrowing. They also represent opportunity the cost for firms and households, because they represent the yield of investing in the money market. In addition to the cost of funding, banks' retail product pricing will also include a premium for maturity and risk transformation involved in their activities. Therefore, there is positive long run relationship between money market rates and retail rates, which can be formalized as in equation (7):

$$i^R = \alpha + \beta * i^M \quad (7)$$

where i^R is the retail rate, α is the premium (markup charged by the bank), β is the long run pass-through coefficient and i^M is the money market rate. If markets were perfect and banks risk-neutral, β would equal 1, implying complete pass-through. However, according to Gigineishvili (2011), empirical evidence usually suggests that pass-through is incomplete with $\beta < 1$; the long run pass-through varies widely by countries and markets. Equation (7) can also be modified in order to better account short run pass-through. As a general conclusion from estimates of Gigineishvili (2011), more advanced economies appear to have stronger pass-through in the long-run. However, in the short-run there seems to be some persistence of market interest rates, as the short run pass-through coefficients are systematically smaller than long run estimates. It is also worth noticing that Gigineishvili (2011) estimates show that the long run pass-through coefficient in euro area is significantly smaller than in USA; coefficients were approximately 0,3 and 0,7 for euro area and USA, respectively.

Gigineishvili (2011) also provided a brief literature overview on structural determinants of interest rate pass through, which has received less attention in empirical literature. In general terms, existing literature has found evidence that a higher inflationary environment, capital mobility, money market development and competition in the banking sector result in a stronger pass-through. Gigineishvili (2011) estimates highlight that higher inflation and market interest rates result in better pass through. A potential explanation is that since high inflation and interest rates are associated with larger uncertainty, banks are passing the risk to borrowers. It is also notable that similarly to some previous evidence, excess liquidity in the banking sector is found to weaken pass-through, which is particularly relevant in current market environment.

Findings of Gigineishvili (2011) and previous literature have significant implications for monetary policy. Gigineishvili (2011) concluded that if pass-through is weak and cannot be improved, for example by developing stronger financial markets, increasing capital mobility and competition in banking sector, a monetary framework that relies on strong interest rate pass-through, such as inflation targeting, may not be an optimal choice. This is very interesting for central banks in most advanced countries, including the euro area; since the ECB has adopted an inflation targeting framework, it is in its own interests to strengthen interest rate transmission. However, the positive relationship between inflation and the strength of pass-through found in empirical studies suggests that by being successful in achieving its key target of reducing inflation close to 2 %, the ECB actually seems to contribute to the weakening of interest rate transmission. Although this is naturally controversial, Gigineishvili (2011) pointed out that a strong interest rate pass-through and an inflation target need not to be viewed as policy tradeoffs; a weakened pass-through attributable to successful control of inflation could be compensated with other means presented above that contribute to a better pass-through.

3. EUROPEAN INTERBANK MARKETS IN CRISIS OF 2007-2012

Starting in August 2007, losses from subprime mortgages in USA started to affect bank lending behavior in the interbank market as realization of risks led banks to became more careful in their lending activities. In order to restore confidence in the interbank market, central banks reacted by conducting unconventional monetary policies as the traditional interest rate transmission was not the best mechanism to calm money markets. This chapter focuses on interbank market functioning in crisis. Before moving on to measurement of interbank risk and unconventional measures taken by the ECB, some theoretical background is provided to shed light on potential problems that the banking sector might have with respect to proper functioning or contributing to its social welfare function.

3.1. Theoretical framework for interbank markets in crisis

There are several different aspects that can be used to identify potential problems in the interbank market. Starting from theoretical works that explain interbank market functioning through market participation, Flannery (1996) proposed a model of competitive lending with asymmetric information. He categorized borrowers as “good” and “bad” and allowed banks to differ in their ability to assess borrowers’ creditworthiness. During "normal" times, private lenders are assumed to assess one another's financial conditions with reasonable accuracy. However, if the financial system incorporates systemic risk and a large shock hits the system, normal lending may become insufficient in funding all illiquid banks. If it is feared that financial conditions of other banks have weakened, a lender's assessment of its own underwriting abilities and that of its competitors may become less certain, even for most accurate lenders. Thus the model implies that private loan markets can fail not because the average borrower's credit quality deteriorates, but because lenders become less certain about how to identify risks. Higher rates can occur without even without some lenders retreating from the market, which means that full participation can exist. (Flannery, 1996)

Flannery (1996) also considers to role of lender of last resort (LLR) in bank lending. A government LLR has two advantages over private lenders: its size and its immunity to bankruptcy. A government LLR can finance the entire banking sector's liquidity needs, and it can do so quickly without coordination problems. Moreover, in order to protect itself against adverse selection, the LLR can afford to lend at a rate below any rate prevailing in private lending. However, if some private lender's remain sufficiently confident of their underwriting abilities, then without LLR intervention, they could charge lower rates than the LLR. The LLR should therefore evaluate whether lending below the market rate produces lower social costs than those associated with letting "good" banks pay the LLR rate, which is higher than the rate "good" banks would have gotten from the market without LLR intervention. In normal times, the model provides no justification for LLR lending to individual banks; once the LLR has provided sufficient aggregate liquidity through open market operations[9], it should rely on private lending to channel funds so that solvent but illiquid firms are funded. The model justifies LLR intervention only in crisis times. However, Rochet and Tirole (1996) pointed out that the bad incentive effects of this "too big to fail" policy can be avoided by subsidizing the troubled institution's counterparties instead of bailing out the troubled institution itself.

Freixas and Holthausen (2005) studied international interbank market integration under unsecured lending when cross-country information is noisy. They consider peer monitoring as a key factor in improving interbank market efficiency; banks monitor each other by obtaining signals concerning their peers' solvency probabilities. A critical assumption of their model is that cross border information or signals about banks is less precise than home country information. Consequently, when a bank tries to borrow funds from a foreign bank, it does so either because of a liquidity shortage in home country or because it has created a "bad" signal and is thereby unable to borrow funds in home country. Their model argues that a perfect liquidity smoothing cannot exist between countries, because cross-border lending involves interest rate premia which reflect the adverse selection of borrowers in the international market. Although interbank market imperfections could be related to exchange risk, the Freixas and Holthausen (2005) model argued that the main barrier to an integrated international market is the existence of asymmetric information between banks in different countries. Only if cross-border information is sufficiently precise, the integration of markets is possible.

[9] Sufficient amount of liquidity can also be called "neutral" amount of liquidity. According to Nikolaou (2009), "neutral" amount of liquidity is the amount that satisfies the liquidity demand of the system, to the extent that interbank rates are in line with policy rates.

In addition to above models explaining interbank market functioning via market participation, there are some theoretical guidelines explaining market functioning through alternative lender behavior. Dudley (2008) suggested that during the current crisis banks with low equity capital were forced to decrease interbank lending in order to avoid excessive leverage. Acharya et al. (2008) suggested that interbank markets are characterized by moral hazard, asymmetric information, and monopoly power in times of crisis; banks with excess liquidity do not necessarily provide it to the interbank market because they might strategically try to gain market share at expense of illiquid banks that are forced to sell assets at fire sale prices. These two views yield opposite predictions concerning the relationship between lender's liquidity and the lending rate. In Dudley (2008), lower liquidity leads to higher lending rates offered; in Acharya et al. (2008), high liquidity may coincide with high lending rate. Still, both views provide justification for central bank lending in crisis times.

In contrast, there are theoretical works that do not support LLR intervention because it may dilute the social welfare enhancement role of the interbank market. Calomiris and Kahn (1991) argued that demandable-debt banking can be understood as optimal means of intermediation, because in an environment of asymmetric information and possible moral hazard behavior by the bank, depositors have incentives to monitor banks. As deposits can be withdrawn anytime in demandable-debt banking, bankers should fear that deposits are withdrawn if invested in risky projects that enhance the welfare of bankers at the expense of depositors' interests. Therefore, because depositors monitor banks on how they use their deposits, bad banks are liquidated because deposits should roll from bad banks to good banks. This process should thereby enhance social welfare by allocating funds to effective use and maintain market discipline.

In the context of interbank markets, and based on theoretical framework by Calomiris and Kahn (1991), Calomiris (1999) argued that banks should be required to issue subordinated debt, so that potential holders of the debt, other financial institutions, were incentivized to monitor the issuer. In his view, the interbank market should be an alternative mechanism for depositor monitoring in order to achieve and enhance market discipline. The need for alternative mechanism stems from the fact that retail deposits are usually guaranteed by adeposit insurance scheme, which removes depositors' incentives to monitor banks. As interbank claims, on the other hand, are generally unsecured, banks should have strong incentives to monitor their counterparts.

However, there are also some theoretical works arguing that incentives for banks to monitor each other may be low. Huang and Ratnovski (2008) extended the framework by Calomiris and Khan (1991) so that the signals received by financiers on counterpart solvency are noisy. They show that this simple alteration can significantly lower financiers' efforts to monitor counterparts and gives them excess incentives to withdraw funding, thus triggering inefficient liquidations of the counterparts. On the other hand, Rochet and Tirole (1996) argue in favor of another mechanism that destroys market discipline. They argue that "…the current system of interbank linkages suffers from its hybrid nature: On one hand, banks engage in largely decentralized mutual lending. On the other hand, government intervention, voluntary or involuntary, destroys the very benefit of a decentralized system, namely, peer monitoring among banks" (p. 735). In other words, if banks believe that the LLR is unable to commit not to rescue troubled banks, they may have no incentives to take costly efforts to monitor their counterparts.

Very little empirical evidence exists on whether banks do monitor their counterparts or not. Furfine (2001) found that banks do monitor their interbank market counterparts in normal circumstances, charging higher rates to riskier borrowers. On the other hand, Angelini et al. (2011) results suggest that borrower characteristics were not an important determinant of the interest rate charged on interbank loans before the current financial crisis. They believe that this may be because of low incentives to monitor counterparts as described above. However, after the start of current financial crisis in August 2007, they found that riskier institutions did pay higher rates so as to reflect their lower creditworthiness. Based on these two pieces of evidence, precise conclusions cannot be drawn.

3.2. EURIBOR-OIS spread

Because maturities of deposit and marginal lending facilities is one day, the interest rate corridor system only binds the interest rate with corresponding maturity, i.e. the overnight rate. As presented in section 2.3.2, term interbank rates include a risk premium. In order to quantify the risk premium in term interbank rates, a measure of risk free rate is necessary. The maturity of the risk free rate needs to be the same as the comparable EURIBOR rate.[10] For this purpose, fixed rates from overnight index swaps (OIS) are commonly used because they involve very little default risk[11].

OIS contracts are interest rate swaps that involve two parties who agree to swap their interest rate payments, but not the principal, for an agreed period. The fixed interest rate is agreed at the time of the trade while the floating rate will be known when the contract period ends. The floating rate in OIS contracts is the overnight rate. At the end of the agreed period, parties look up how much did each party pay in interest. The floating rate is determined by compounding the overnight rate every day over the contract period and calculating an average overnight rate that has been paid under the contract period. The procedure is similar to one used in equation (5). If the compounded average interest rate in the end of the contract period paid by party A was, for example l,5 %, and the fixed rate paid by party B was 2 %, then party A will pay the difference of 0,5 % to party B, because they agreed to swap interest rate payments. Similarly, if the compounded average interest rate was be 2,5 %, then party B would pay the difference of 0,5 % to party A.

Following the above example, let's assume that the current overnight rate is 1 % and that the market expects that the overnight rate will continue to be 1 % on each day over 30 days. In this setting, the average floating rate paid by party A will be $\sqrt[30]{1,01 * 1,01 * 1,01 * ... * 1,01}$ = $\sqrt[30]{1,01^{30}}$ =1,01 or 1 %. However, if the market expects that the overnight rate rises to 2 % after the first 15 days, then the average floating rate will be $\sqrt[30]{1,01^{15} * 1,02^{15}}$ =1,0149 or 1,49 %. By entering into an OIS contract, the party which has a 30 day loan at a fixed rate of 2 % can take a speculative position that the overnight rate will not rise over the 30 day period so much that the compounded average interest rate would exceed 2 %. This leads party B to offer a 30 day OIS contract in which it commits to swap a fixed rate of 2 % to the

[10] The EURIBOR rate is the rate at which Euro interbank term deposits are offered by one prime bank to another within the Eurozone. EURIBOR rates for different maturities are published at 11.00 a. m. CET. It is quoted for spot value (two Target days) and on actual / 360 day basis. A representative panel of banks is asked to quote those rates at which, to the best of their knowledge, euro interbank term deposits are being offered within the euro area. The calculation of EURIBOR rates includes eliminating the highest and lowest 15% of all quotes collected. The remaining rates will be averaged and rounded to three decimal places.

[11] OIS contracts do not involve the exchange of principal. Therefore, only the interest payment, which is exchanged at the end of the contract period, can be defaulted.

compounded average interest rate. However, if party A also expects that the overnight rate rises to 2 % after the first 15 days, then party A would not accept the OIS contract at fixed rate of 2 % because it would expect to make a loss (2-1,49 = 0,51 %) in the deal. Therefore, party A forces party B to cut the offered fixed rate so that it better reflects party A's expectations of the future evolution of overnight rates. Taken to the market level, OIS rates are determined so that they best reflect market participants' expectations of future overnight rates.

In the euro area, OIS contracts are called EONIA swaps. They are the main instrument used by market participants to take speculative positions on expected central bank actions. Similarly to all swaps, EONIA swaps are also used for hedging purposes. Because OIS rates are a good proxy for the risk free rate, they can be used to quantify the risk premium incorporated in term interbank rates. The EH implies that without a risk premium involved, term interbank rates should be the same as OIS rates with corresponding maturity. Otherwise there would be an arbitrage possibility[12]. Because central bank policy rate expectations are included in both rates, the spread is stripped from policy rate expectations, leaving a measure of risk premium that banks pay when they borrow funds for a pre-determined period relative to the expected cost from repeatedly rolling over funding in the overnight market. (Abbassi and Linzert, 2011)

Since the adoption of a single currency, EURIBOR-OIS spreads have been very close to zero throughout the decade; for example, the three-month 3M EURIBOR has evolved very close to the respective 3M OIS rate with an average spread of around 6 basis points in the period between January 2000 and August 2007. The levels of the spreads have all been close to zero with very low volatility prior to the crisis.[13] Developments after 2007 are displayed in figure 7.

[12] For example, if 3M EURIBOR was 3 % and 3M OIS rate was 2 %, then a bank could make a 3M loan of €100 in the interbank market, fund the loan by borrowing €100 each day in the overnight market, and hedge the interest rate risk related to borrowing in the overnight market by purchasing a 3M OIS contract, thereby locking its funding costs at 2 % while receiving 3 % in interest.

[13] For a historical presentation of the spreads, see appendix B.

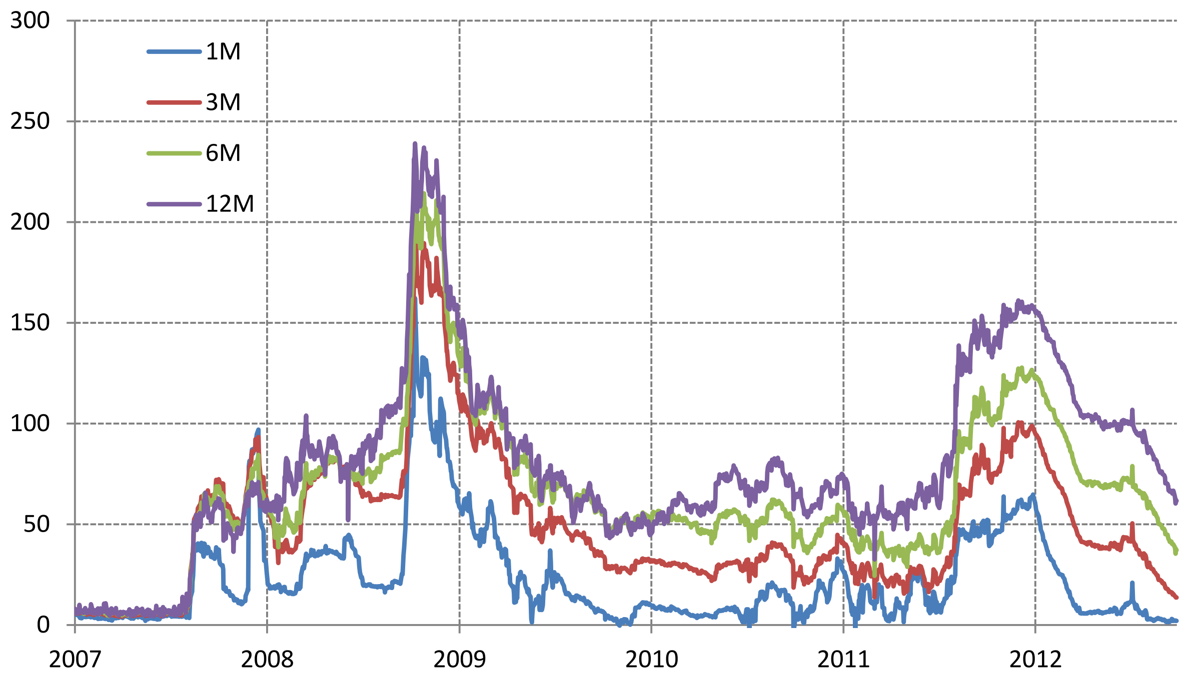

Figure 7. EURIBOR-OIS spreads for different maturities (in basis points). *Data Source: Bloomberg*

Figure 7 clearly shows that the levels of EURIBOR-OIS spreads rose substantially after the start of financial crisis in August 2007. The spreads reached their highest levels after Lehman Brothers collapsed in September 2008. The 12M spread was at its maximum of 239 basis ponits in 10 October 2008, a few weeks after Lehman Brothers collapsed. In addition, the spreads have become highly volatile and the risk premium clearly rose with maturity. Empirical literature generally views that the risk premium in longer EURIBOR rates reflects banks' reluctance to engage in longer term lending. This is because banks may need excess funds themselves or because they have lost confidence on counterparts' solvency.

3.3. Causes of high interbank spreads

A general view among academic literature is that the risk premium incorporated in term interbank rates is the result of counterparty credit risk, liquidity risk or some combination of the two. In this section, different sources of risk are considered.

3.3.1. Credit risk

First source of risk associated in bank lending is the risk that counterparty of an agreement is not able to or does not want to pay back the loan it has received. This risk stems from the fact that most loans between banks are uncollateralized. In this thesis, counterparty credit risk is defined as in Cecchetti et al. (2009): counterparty credit risk refers to “the risk that a counterparty will not settle an obligation in full value, either when due or at any time thereafter.” (p. 57)

Heider et al. (2009) studied the functioning and possible breakdown of the interbank market in order to explain observed developments before and during recent financial crisis. They provided a model of how the risk in long term assets of banks can increase the likelihood of liquidity hoarding. The key factor in the model is counterparty risk which is amplified by adverse selection. Counterparty risk stems from the asset quality of counterparties. Each bank is assumed to know the distribution of risk in the banking sector and is privately informed about the risk of their own assets; however, banks cannot observe the risk of their counterparties’ asset quality. Depending on the level and distribution of counterparty risk, Heider et al. (2009) model allows various interbank market regimes to arise.

In the first regime, when the level and dispersion of risk are low, the unsecured interbank market functions smoothly despite counterparty risk and asymmetric information. The interest rate for unsecured loans is low and all banks manage their liquidity using the interbank market. Under asymmetric information, riskier banks pose an externality on safer banks because all banks pay the same rate; under asymmetric information, it is not possible for lenders to recognize riskier borrowers in order to charge higher rates for higher risk. But the externality is small compared to the cost of obtaining liquidity outside the unsecured market. Therefore, the first regime implies full participation and a low interbank spread.

In the second regime, the level of counterparty risk is high; safer banks with a liquidity shortage may find the mispricing (externality) caused by riskier borrowers too large, causing them to leave the unsecured market and to lend elsewhere. This destroys the full participation equilibrium, as good risks are driven out of the market, allowing adverse selection to arise. Liquidity is still traded but the interest rate rises to reflect the presence of riskier banks.

In the third regime, the interbank market may break down if the dispersion of risk is high. Once the safest banks with a liquidity shortage drop out of the interbank market, liquidity hoarding can occur; banks prefer to hoard liquidity instead of lending it out to the market because only riskier banks are present. Although the interest rate increases to reflect higher counterparty risk, it may not rise enough to encourage lenders, who still are present at the market, to lend to an adverse selection of borrowers. This potentially causes a breakdown in the interbank market. Therefore, Heider et al. (2009) model implies that the interest rate rises because creditworthiness of the average borrower deteriorates due to lower market participation. Finally, it is possible that even riskier borrowers find the unsecured interest rate too high and prefer to obtain liquidity elsewhere.

3.3.2. Liquidity risk

Second source of risk associated in interbank lending is liquidity risk. According to Nikolaou (2009), liquidity can be classified into three different types: central bank liquidity, market liquidity and funding liquidity. The first relates to liquidity provided by the central bank, the second to the ability of trading in the markets, and the third to the ability of banks to fund their positions. According to Nikolaou (2009), central bank liquidity can be defined as the liquidity supplied by the central bank that satisfies liquidity needs of the financial system. Central bank liquidity is typically measured by the flow of base money supplied in open market operations. Because the central bank is always able to supply sufficient amounts of base money due to its monopoly position, there is no definition of central bank liquidity risk.

Following the consensus reached in studies, Nikolaou (2009) defined market liquidity as “the ability to trade an asset at short notice, at low cost and with little impact on its price.” (p. 14) The author continued that it therefore follows those three different aspects can be used to evaluate market liquidity, from which the ability to trade is most important. According to Nikolaou (2009), two different types of market liquidity can be distinguished: interbank market liquidity, which refers to liquidity traded among banks such as interbank loans, and asset market liquidity, which refers to assets that are traded among financial agents. These two types are the main sources for banks to acquire funding liquidity from the markets, and therefore help to explain the interactions between market liquidity and funding liquidity.

Following the Basel Committee of Banking Supervision, Nikolaou (2009) defined funding liquidity as “the ability of banks to meet their liabilities, unwind or settle their positions as they come due”. (p. 13) References to funding liquidity have also been made from point of view of investors and traders, where funding liquidity refers to the ability to raise cash or capital at short notice. It consists of four different sources of funding: customer deposits, interbank loans, securitization of illiquid assets and central bank loans. Interbank market funding is arguably the most important source of funding for banks.

According to Nikolaou (2009), there are several interconnections between all three forms of liquidity risk and their significance varies in time. In normal times, liquidity flows easily among the three liquidity types, thereby creating a circle that stimulates the stability of the financial system. With efficient markets and a “neutral” amount of liquidity supplied by the central bank, liquidity should be efficiently distributed to agents who need it most. However, in turbulent times, the linkages may produce a spiral of illiquidity in the financial system. Nikolaou (2009) argued that the liquidity risk spiral can be caused by asymmetric information and incomplete markets that result in coordination problems between depositors, banks or traders. Because banks have an intermediation role as maturity transformers, i.e. taking short term (liquid) deposits and turning them into long term (illiquid) loans, they are considered fragile due to the maturity mismatch. Given the fragility, banks are subject to bank runs, which represent the extreme form of bank funding liquidity risk. (Nikolaou, 2009). Eisenschmidt and Tapking (2009) provided further examples on funding liquidity risk. According to them, funding liquidity risk refers to the risk that lenders face a liquidity shock before term loans mature. Alternatively, the probability of higher funding costs for the lender may increase when such a liquidity shock arrives.

Funding liquidity risk of a single bank, however, is of limited concern. The real issue arises when funding liquidity risk is transmitted to more than one bank, becoming systemic and therefore transforming to market liquidity risk through interbank markets. As banks are linked by a common market for liquidity, individual bank failures can potentially shrink the common pool of liquidity and therefore spread the shortage to other banks. Furthermore, liquidity shortages can stimulate fears of counterparty insolvency because of incomplete markets, i.e. there is no perfect hedge against future liquidity shortages, and because of information asymmetries about solvency of banks, i.e. it is not possible to distinguish whether counterparty banks are illiquid or insolvent. Funding liquidity risk can also transmit to market liquidity risk through asset markets; if the interbank market liquidity-providing channel is disrupted, banks may need to use fire-sales of assets to obtain liquidity. (Nikolaou, 2009)

In addition to funding liquidity risk transmitting to market liquidity risk, there may also be second round effects working in opposite direction because of market-valued balance sheets, creating an endogenous loop between funding and market liquidity risks. Nikolaou (2009) proposed that in order to prevent second round effects, the central bank could break the loop with emergency liquidity provision in the market, thereby possibly avoiding contagion and spillover effects.

3.4. Unconventional measures of ECB during crisis of 2007-2012

Cecioni et al. (2011) provided an excellent overview on unconventional monetary policy that summarizes all unconventional actions taken by the ECB between August 2007 and September 2011. The actions are relevant for relieving stress in the interbank market and consequently may have the potential, to some extent, to restore functioning of the interest rate channel. As a general note, unconventional monetary policies have been conducted since the start of the crisis in 2007. However, they have not always been effective as the interbank markets were dysfunctional despite several unconventional interventions before Lehman Brothers collapsed. A potential explanation is that the interventions were initially too small and that their effectiveness was to be seen only after the scope of interventions were brought up to a higher level.

Table 1 provides a summary on unconventional actions conducted by the ECB. The table is based on Cecioni et al. (2011). However, it has been simplified and updated to match actions taken as of 30 September 2012. Updated information in table 1 is compiled from ECB press announcements and ECB website. [14]

[14] Press releases by year can be found at : http://www.ecb.int/press/pr/date/2012/html/index.en.html

Table 1. Unconventional measures taken by the ECB between August 2007 and September 2012.

	Fixed rate full allotment policy (FRFA) in MROs and LTROs	6M LTROs	12M LTROs	36M LTROs	Special term refinancing operations	Fine tuning operations	Currency swap agreements	Covered Bond Purchase Programme (CBPP)	Covered Bond Purchase Programme 2 (CBPP2)	Securities Markets Programme (SMP)	Outright Monetary Transactions (OMT)
Announcement date	9.10.2008	27.3.2008	7.5.2009	8.12.2011	29.9.2008	Quick tender	12.12.2007	7.5.2009	3.11.2011	10.5.2010	6.9.2012
Start date	15.10.2008	28.3.2008	24.6.2009	22.12.2011	30.9.2008	-	17.12.2007	4.6.2009	Nov 2011	May 2010	Conditional
End date/last date conducted	Ongoing	12.5.2010	27.10.2011	1.3.2012	Ongoing	-	Ongoing	30.7.2010	Ongoing	6.9.2012	-
Participants	All banks that have access to Eurosystem credit operations	All banks that have access to Eurosystem credit operations	All banks that have access to Eurosystem credit operations	All banks that have access to Eurosystem credit operations	All banks that have access to Eurosystem credit operations	All banks that have access to Eurosystem credit operations	All banks that have access to Eurosystem credit operations	Counter-parties	Counter-parties	Counter-parties	Counter-parties
Collateral	Collateral eligible for Eurosystem credit operations	Collateral eligible for Eurosystem credit operations	Collateral eligible for Eurosystem credit operations	Collateral eligible for Eurosystem credit operations	Collateral eligible for Eurosystem credit operations	Collateral eligible for Eurosystem credit operations	Collateral eligible for Eurosystem credit operations	-	-	-	-
Term of the loan	1 week, 1, 3, 6, 12, and 36 months	6M	12M	36M	Same as the lenght of maintenance period	From overnight to 5 days	7, 28, 35 and 84 days	Purchases in primary and secondary markets	Purchases in primary and secondary markets	Purchases in primary and secondary markets	Purchases in secondary markets
Objective	Assure the provision of liquidity to all euro area banks	Support normalisation of the functioning of euro area banking system	Encourage the provision of credit by banks to the private sector	Encourage the provision of credit by banks to the private sector	Improve the overall liquidity position of the euro area banking system	Assure orderly conditions in the euro money market	Assure liquidity in foreign currencies to euro area banks	Restore the covered bonds market segment	Ease funding conditions for credit institutions and encourage lending to the private sector	Address the malfunctionin g of securities markets and restore appropriate monetary policy transmission	Safeguarding appropriate monetary policy transmission and the singleness of monetary policy

As response to first signs of interbank market stress after August 2007, the ECB started to increase the frequency and the liquidity allotted in its long term refinancing operations. Moreover, in order to control the excessive volatility of EONIA within maintenance periods, the ECB provided a relatively larger volume of funds in the first part of the maintenance period so that preferences for early fulfillment of reserve requirements (front-loading) were satisfied[15]. Also, the increased volatility in liquidity demand and the larger demand for US dollars were offset by fine-tuning operations and through auctions of US dollar liquidity. Finally, these measures were also supplemented by an effort to clearly communicate the separation between monetary policy decisions and liquidity provision operations (the "separation principle"). (Cecioni et al., 2011)

After the collapse of Lehman Brothers in September 2008, the biggest change in ECB's operational framework was the decision to conduct all refinancing operations with fixed rate and full allotment (FRFA) in October 2008, thereby allowing banks to raise unlimited liquidity from the ECB. To guarantee full access to refinancing operations and to prevent fire sales of assets, which according to Cecioni et al. (2011) would have contributed to further deleveraging in bank balance sheets, the ECB also decided to widen the set of assets accepted as collateral in its refinancing operations. In addition, US dollar funding strains were addressed by providing further liquidity in dollars. Overall, in line with Cecioni et al. (2011) suggestions, the purpose of liquidity provision via FRFA policy and supplementary LTROs was to restore monetary transmission by preventing spillover effects in the money market and encouraging bank lending to private sector (i.e., stimulating the credit channel of monetary policy).

In addition to liquidity provision measures described above, the ECB has announced four asset purchase programs aimed at reviving selected markets[16]. In May 2009, the ECB started its first Covered Bonds Purchase Programme (CBPP), in which it purchased covered bonds issued by euro area banks. These bonds have traditionally been major sources of bank funding.

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[15] According to ECB website, Eurosystem counterparties must fulfill reserve requirements by holding non-negative current accounts with the respective national central bank during the reserve maintenance period (around one month), in such a way that the daily average of current accounts is at least the amount of the reserve requirements.

[16] Asset purchase counterparties include all banks that have access to Eurosystem credit operations and euro area based counterparties used by the Eurosystem for the investment of its euro-denominated portfolios.

CBPP was ended as planned in June 2009, but re-introduced in November 2011 with a view to ease funding conditions for credit institutions and enterprises and to encourage lending[17]. These programmes were expected to stimulate the credit channel of monetary policy.

In addition to CBPP programmes, the ECB has purchased securities in the Securities Markets Programme (SMP). Purchases were addressed to relief tensions in certain market segments which have weakened monetary policy transmission mechanism. Under SMP, Eurosystem central banks could purchase the following: "(a) on the secondary market, eligible marketable debt instruments issued by the central governments or public entities of the Member States whose currency is the euro; and (b) on the primary and secondary markets, eligible marketable debt instruments issued by private entities incorporated in the euro area."[18] The SMP program was terminated in 6 September 2012 as the ECB announced a new bond purchase program. According to the press release of the new program (OMT), the securities purchased under SMP will be held until maturity[19].

In 6 September 2012, the ECB announced a new (sovereign) bond purchase program (OMT) which is addressed to relief tensions in sovereign bond markets. According to the press release[18], the aim of the program is to safeguard an appropriate monetary policy transmission and the singleness of the monetary policy. The bond purchases will be known as Outright Monetary Transactions (OMTs) and they will be executed in secondary markets. The purchases will focus on the shorter part of the yield curve, and in particular on sovereign bonds with a maturity of between one and three years. No quantitative limits were set on the size of OMTs. The liquidity created through OMTs will be fully sterilized.

The press release reveals that there are two important features of OMTs. The first is that the OMT program has a strict conditionality; sovereign states must provide an official help request for the EFSF/ESM mechanism if they wish to receive support. The second feature is that the Eurosystem is willing to accept the same treatment as private creditors with respect to

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[17] See: http://www.ecb.int/mopo/liq/html/index.en.html#portfolios

[18] Decision of the European Central Bank to establish a securities markets programme, 14 May 2010. Document available at: http://www.ecb.int/ecb/legal/pdf/l_12420100520en00080009.pdf

[19] Available at: http://www.ecb.int/press/pr/date/2012/html/pr120906_1.en.html

bonds issued by euro area countries and purchased by the Eurosystem. Thus, the ECB will not have seniority on bonds purchased under the OMT program. As of 9 October 2012, no purchases had been made under the new OMT program as no country had asked for help from the EFSF/ESM mechanism.

3.5. Descriptive analysis on the effects of unconventional measures

3.5.1. Outstanding amount of liquidity

In October 2008 the ECB decided to conduct all refinancing operations with fixed rate and full allotment (FRFA) which allowed banks to raise unlimited liquidity from the ECB. The ECB also decided to widen the set of assets accepted as collateral in these operations. Figure 8 shows how the outstanding amount of liquidity created through MROs and LTROs has evolved from 2002 to the beginning of October 2012.

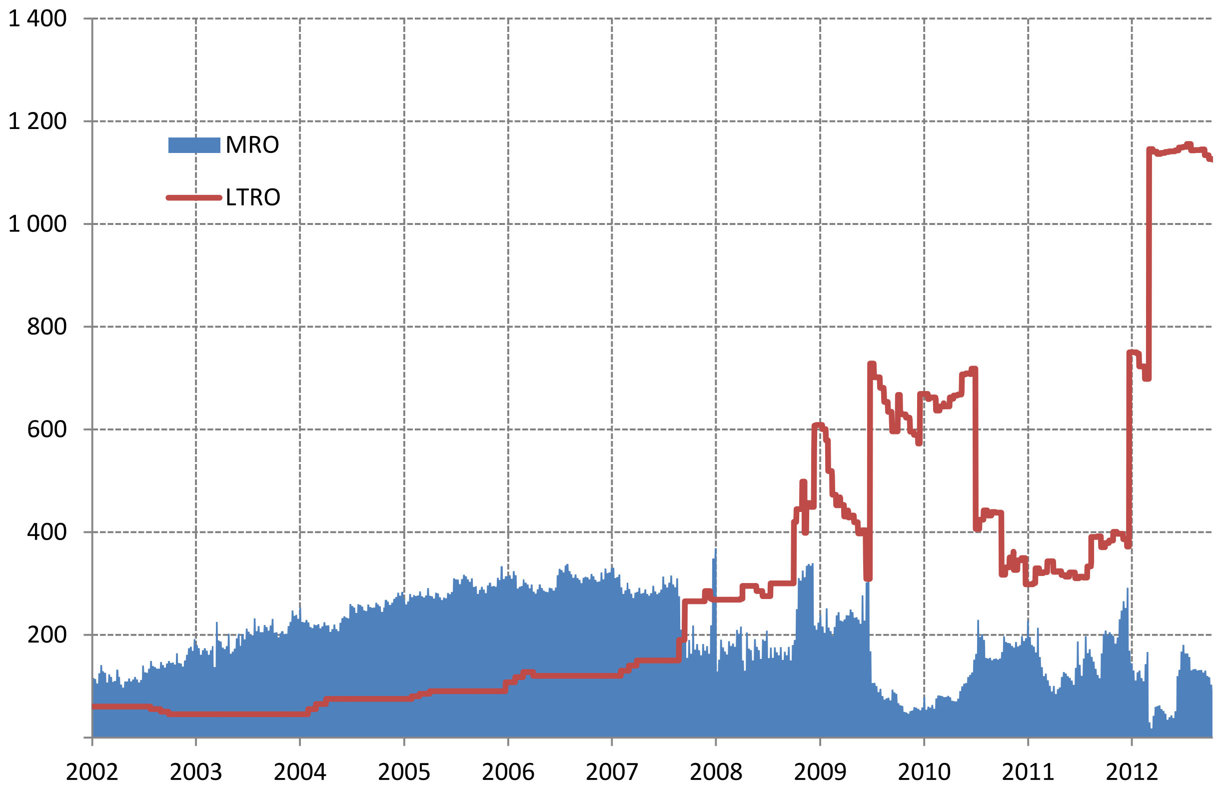

Figure 8. Outstanding amounts of liquidity allotted in refinancing operations (in billions of euro). *Data Source: ECB Statistics*

Figure 8 shows that the adoption of FRFA policy has significantly increased the outstanding amount of liquidity allotted in refinancing operations to the banking system. It also seems that the adoption of FRFA policy has reduced the use of MROs relative to LTROs as source of central bank liquidity. Particularly the two 36 month LTRO operations have substantially increased the outstanding amount of liquidity in the market.

3.5.2. Use of ECB's deposit and marginal lending facilities

In 9 October 2008, the ECB reduced the corridor of standing facilities from 200 basis points to 100 basis points around the interest rate on main refinancing operations. The rate of the marginal lending facility was reduced from 100 to 50 basis points above the interest rate on the main refinancing operation, while the rate of the deposit facility was increased from 100 to 50 basis points below the interest rate on main refinancing operations. The corridor was increased back to 200 basis points in January 2009, but again reduced to 150 basis points in May 2009. As of October 2012, the corridor stood at 150 basis points.

As described in section 2.2.2, if interbank markets function smoothly and risks related to interbank lending are small, banks should have no incentive to use deposit and marginal lending facilities. Figure 9 shows the evolution of deposit and marginal lending facilities set up by the ECB from 2007 to the beginning of October 2012.

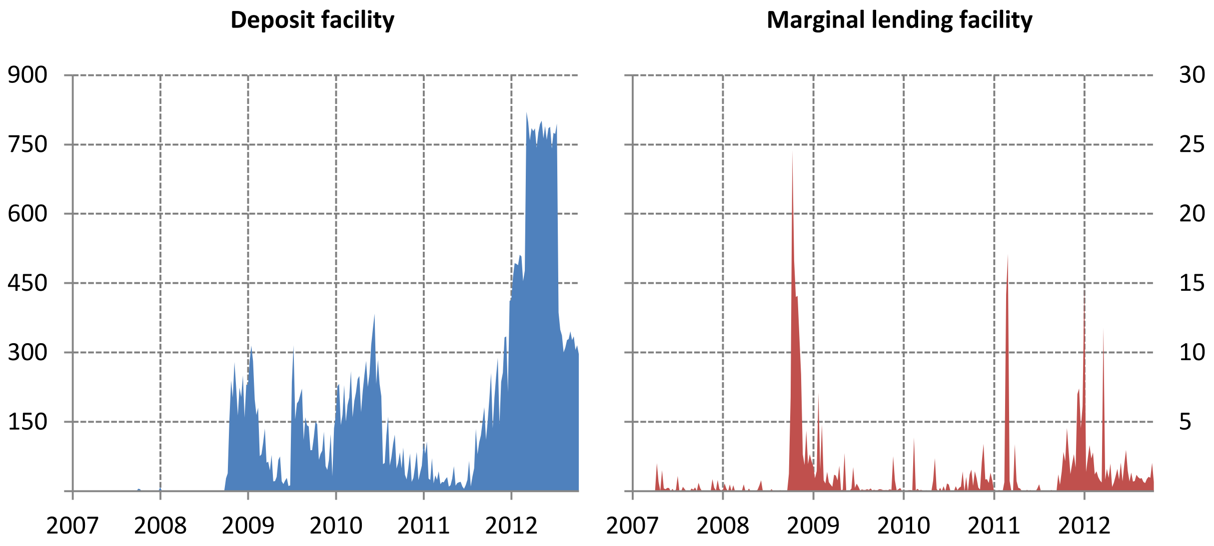

Figure 9. Deposit and lending facilities (in billions of euro). *Data source: ECB Statistics*

The left hand side of figure 9 reveals that overnight deposits at the ECB were close to zero before the collapse of Lehman Brothers. After that, deposits at the ECB have considerably increased. In early stages of the crisis, the observation is most likely consistent with risk aversion; when perceived creditworthiness of counterparties is low, banks may choose not to participate in interbank lending. As a result, it seems that a large part of excess reserves has been deposited at the ECB. In later stages of the crisis, overnight deposits have increased substantially particularly after the ECB conducted two 36 month LTROs. This observation could indicate both risk aversion and a lack of demand for money in the interbank market. By conducting two 36 moth LTROs the ECB flooded the interbank market with liquidity with an amount that is most likely much more than is demanded by banks to solely fund their positions.

The right hand side of figure 9 shows that the use of ECB's marginal lending facility has been quite moderate during the crisis, despite a few spikes in 2009 and 2011. As the marginal lending facility charges a penalty rate, it is likely that banks use it only when they cannot obtain funding from the interbank market. Liquidity squeeze in interbank market is most likely related to risk aversion; when systematic risk is high, banks with excess funds may retreat from the market.

3.5.3. Inflation expectations

As unconventional operations of the ECB have grown, it is a natural that some market participants may become worried about future inflation because there is a well-documented long run empirical relationship between broad money (M3) growth and inflation, as already mentioned in section 2.4. However, the excess liquidity in the financial system may not necessarily produce inflation as banks may *choose* to hold a significant amount of excess reserves in order to protect themselves from future liquidity shortages.[20] If banks choose not to lend out a significant part of the excess liquidity, inflationary pressures may be limited as credit creation process is not fully initiated.

According to the ECB (2012), developments in longer term inflation expectations play an important role in central banks' monitoring and assessment activities, because well-anchored expectations are central to the functioning of the monetary transmission mechanism. The ECB monitors long term inflation expectations derived from surveys and financial market instruments. The focus is on longer term rather than shorter-term expectations, because inflation in the short term can be heavily affected by shocks, such as commodity price developments or changes in indirect taxes. Longer term inflation expectations should be a more fundamental measure of expectations about the credibility of monetary policy.

Market-based indicators of longer term inflation expectations are derived from inflation-linked bonds and inflation-linked swaps. According to the ECB (2012), for the purpose of monitoring longer-term inflation expectations, the five-year inflation-linked swap rate five years ahead is used as one of the most suitable indicator.[21] It measures the expected inflation for a five-year period starting in five years and is therefore not affected by short-term shocks as much as spot five-year inflation swaps are. As a result, five-year forward inflation swap rates are more much more stable than five-year spot inflation swap rates. Figure 10 shows

[20] The ECB defines M3 to include (1) currency in circulation, (2) overnight deposits, (3) deposits with an agreed maturity of up to two years, (4) deposits redeemable at notice of up to three months, (5) repurchase agreements, (6) money market fund shares and units and (7) debt securities with a maturity of up to two years. Definition available at: http://www.ecb.int/stats/money/aggregates/aggr/html/hist.en.html

[21] In an inflation swap, one party pays a fixed rate on a notional principal amount, while the other party pays a floating rate linked to an inflation index, such as the Consumer Price Index (CPI). Just like plain vanilla interest rate swaps, the fixed rate in an inflation swap therefore provides information on private sector expectations of future inflation.

how inflation expectations derived from forward inflation swaps have evolved from 2007 to the beginning of October 2012.

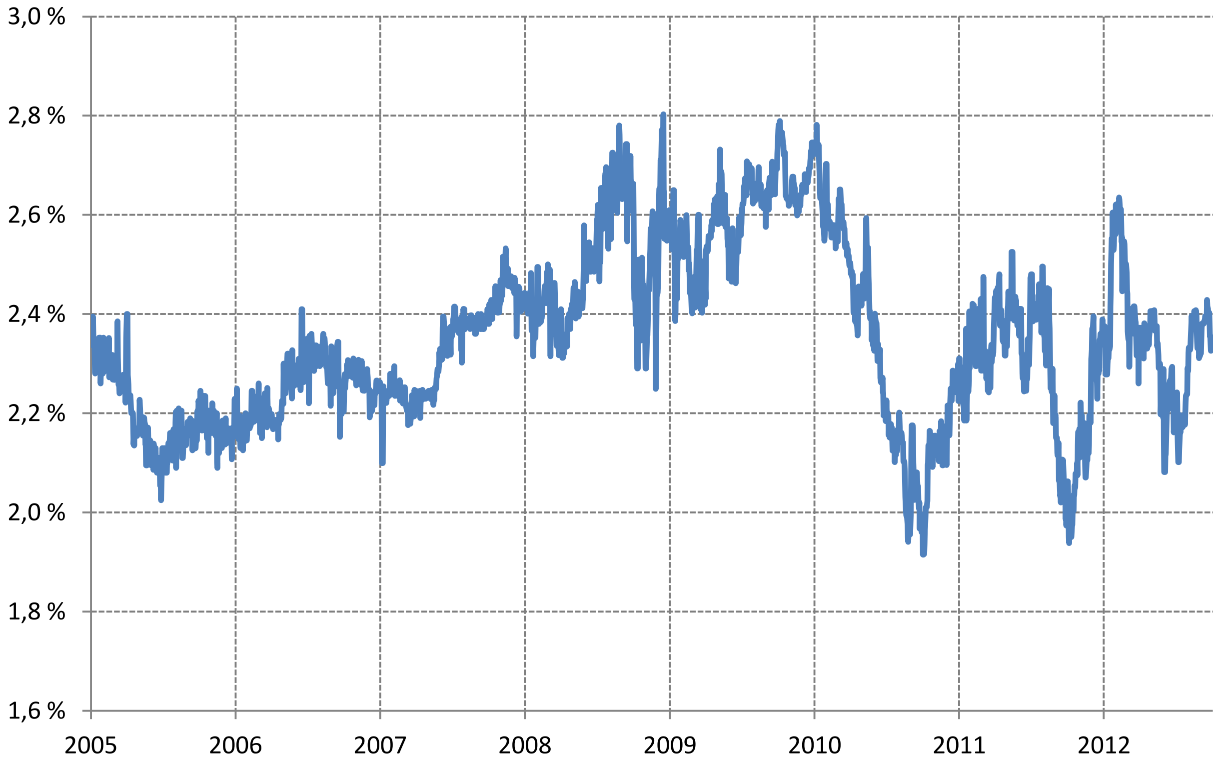

Figure 10. Eurozone 5y5y inflation expectations. *Data source: Bloomberg*

Interpretation of figure 10 is that, for example on 30 September, market participants expect that the average annual inflation between 30 September 2017 and 30 September 2022 will be slightly below 2,4 %, as the last observation in the series indicates.

According to figure 10, long term inflation expectations have been quite well anchored to the 2 % inflation target during the financial crisis despite worsening economic outlook in Europe. It seems that long term inflation expectations did slightly rise after the ECB announced that it would conduct two 36 month LTROs in December 2012, but the expectation of future inflation seems to be driven mainly by other factors as the effect LTROs disappeared quite fast. One potential reason for a surprisingly stable level of inflation expectations after the 36 month LTROs may be the very nature of liquidity operations. LTROs are simply loans that have to be paid back at maturity, which means that their expansionary effect on credit to businesses and households may be limited if, for example, there is low demand for money.

Also, it is likely that expected increase in banking regulation and higher capital requirements are simultaneously offsetting some of the expansionary effects on credit.

3.5.4. Evolution of ECB's balance sheet

Unconventional monetary policy operations conducted during financial crisis have varied in size and it is likely that the significance of each operation in reducing tensions is related to its size. As of 9 October 2012, the outstanding amount of asset purchases under the programmes were 54 billion euros in CBPP1, 16 billion euros in CBPP2 and 209 billion euros in SMP program, according to the ECB open market operations website[22]. As for the LTROs, the most important ones seem to have been the two rounds with maturities of 36 months. According to the ECB open market operations website, the size of the two rounds that were settled 22 December 2011 and 1 May 2012 were 489 billion euros and 530 billion euros, respectively. These numbers reveal that the previous asset purchase programmes have been relatively small compared to the two 36 month LTROs.

Unconventional asset purchases and LTRO operations have considerably increased the size of ECB's balance sheet. Figure 11 shows how the ECB's balance sheet has evolved on a weekly basis from 1999 to the beginning of October 2012. Biggest movements can be seen in asset item 5, which includes, for example, MROs, LTROs and overnight loans from the marginal lending facility. The effect of the asset purchase programmes (excluding OMT) that have been conducted are included in asset item 7; security holdings of the ECB have grown particularly in later phases of the crisis.[23] Asset purchases made under the two CBPP programmes have not been sterilized; therefore, they have increased the amount of liquidity in the Eurosystem. However, purchases made under SMP were sterilized so that liquidity conditions remained unchanged[24]. Possible bond purchases under the OMT program will also be sterilized.

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[22] Available at: http://www.ecb.int/mopo/implement/omo/html/index.en.html

[23] For a more precise structure of ECB's balance sheet and for explanations of each item, see Appendix C.

[24] One purpose of fine-tuning operations (included in asset item 5) is to re-absorb the liquidity injected through the SMP.

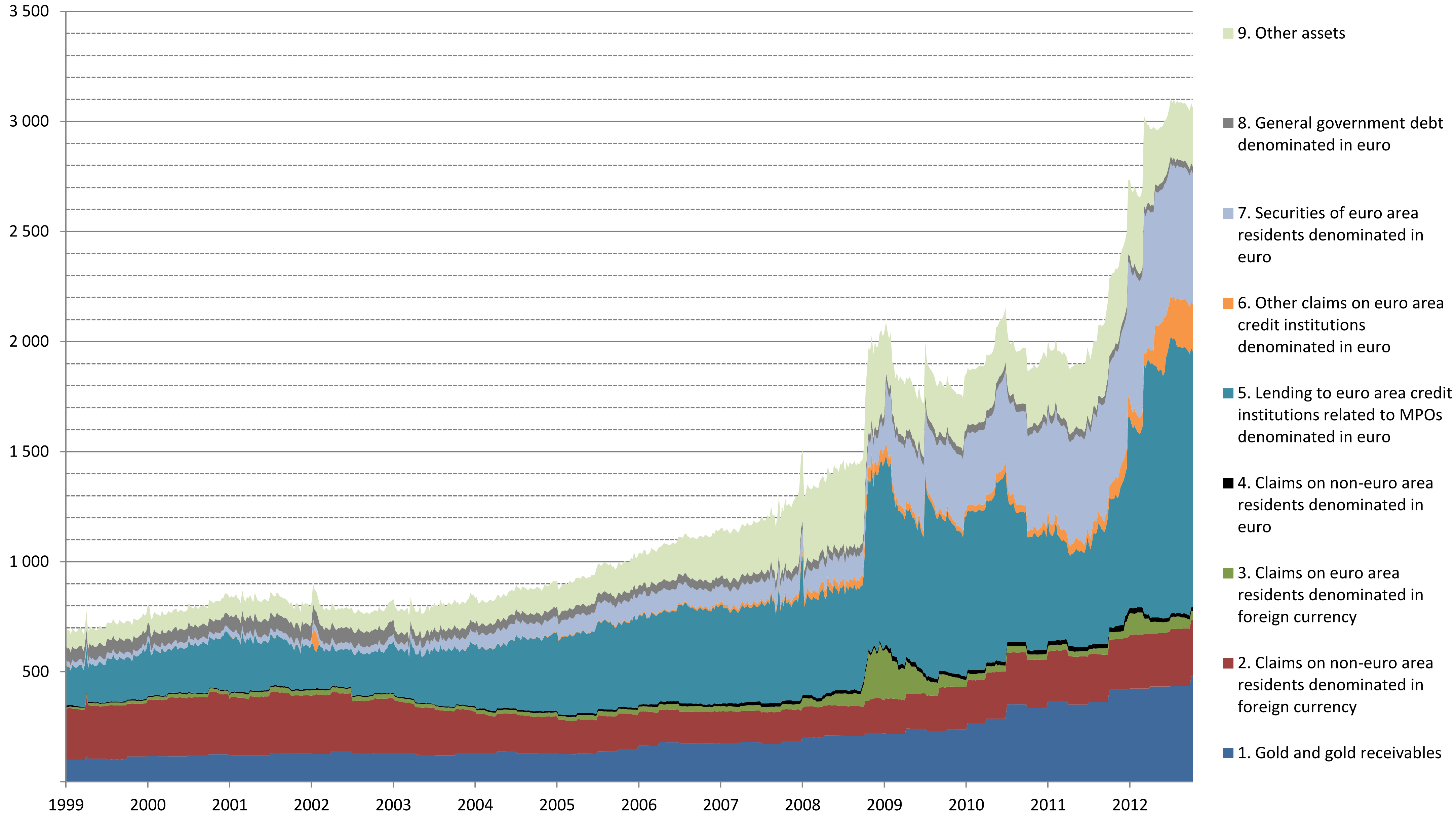

Figure 11. Asset side of ECB's balance sheet from 1999 to 2012 (in billions of euro). *Data source: ECB statistics*

4. EMPIRICAL STUDY ON EFFECTIVENESS OF ECB MONETARY POLICY IN REDUCING INTERBANK RISK PREMIA

After the start of the financial crisis in 2007, interbank spreads attracted interest in academic research as the spreads were recognized to be a good measure of health of the banking system. As the crisis was initiated in the U.S., US dollar LIBOR-OIS spreads were the main interest of academic studies. EURIBOR-OIS spreads were have been more interesting in later phases of the crisis as sovereign credit risk related to troubled European economies spilled over to the banking sector. High interbank spreads imply that policy rates are not fully transmitted to interbank rates; therefore, the central bank may not succeed in achieving its goals by conducting conventional monetary policy, as the first phase of interest rate transmission is impaired (see figure 1 and figure 7).

4.1. Overview of previous literature

As a starting point, not all empirical studies have been interested in the effectiveness of central bank actions on interbank spreads; some papers have only tried to explain the drivers of elevated interbank spreads by decomposing the spread into credit and non-credit related components. In addition, most studies have focused on U.S. LIBOR-OIS spreads whereas empirical evidence for the euro area is rather scarce.

The first to study the components was the paper by Bank of England (2007). The paper tried to decompose the LIBOR-OIS spread into a credit and non-credit component in order to assess their relative importance in explaining the funding pressure observed in the interbank market. The paper suggested that liquidity risk was more important in the early stage of the crisis, which may have been due to liquidity hoarding by banks.

Michaud and Upper (2008) examined the drivers of high LIBOR-OIS spreads in multiple currencies. They argued that CDS premia drove Libor-OIS spreads during the second half of 2007 as they found that the LIBOR-OIS spreads co-moved with measures of credit risk such as bank CDS premia. By contrast, they found that the relationship broke down in January 2008 as LIBOR-OIS spreads declined whereas CDS premia rose. They suggested that the somewhat loose relationship after January 2008 was due to liquidity factors taking the more dominant position in driving the spread. Overall, they suggested that both credit and liquidity factors were important in driving the spread, but the credit risk was more important to the long run behavior of the spread while liquidity factors better explain its day-to-day variations.

Taylor and Williams (2009) studied the effects of the Fed's Term Auction Facility (TAF) on the *level* of the US dollar LIBOR-OIS spread using the OLS method[25]. They found evidence that each of the credit risk proxies (including CDS premia) had positive signs and that they were usually significantly different from zero, implying to the importance of credit factors in explaining the spread. However, they found no empirical evidence that the TAF had reduced spreads as the sums of TAF auction date dummy coefficients were not negative or statistically significant. They concluded that because they found no evidence of TAF effects, the LIBOR-OIS spread must be driven mainly by increased counterparty credit risk between banks.

McAndrews et al. (2008) argued that the model specification in Taylor and Williams (2009) was not valid as the level of the spread was used as dependent variable.[26] McAndrews et al. (2008) argued that a specification with the level of the spread is valid only under the assumption that the effect of a TAF auction disappears immediately after the auction. When the change, rather than the level, of the LIBOR-OIS spread is used as the dependent variable in Taylor and Williams (2009) regression, the coefficient of the TAF dummy becomes negative, implying that the TAF was effective in reducing the LIBOR-OIS spread.

As explanatory variables McAndrews et al. (2008) used the lagged level of the spread, the daily change of the J.P. Morgan Banking Sector CDS Index and separate TAF announcement and operations date dummy variables. Their results showed negative and significant estimates for both types of TAF dummies but the level of significance was stronger for the announcement dummy variable. By using the change of the spread as dependent variable, the results showed that the TAF could be associated with a cumulative reduction of 50 bp in the LIBOR-OIS spread. They were also able to boost the R-squared of their regression by adding

[25] The Term Auction Facility (TAF) was a temporary program managed by the United States Federal Reserve designed to address elevated pressures in short-term funding markets. Under the program the Fed auctioned collateralized loans with terms of 28 and 84 days to depository institutions that were in sound financial condition and were expected to remain so over the terms of TAF loans. For further information, see: http://www.federalreserve.gov/newsevents/press/monetary/20071212a.htm

[26] Taylor and Williams (2009) paper was completed in 2008 before McAndrews et al. (2008) paper, but was not published in a journal until 2009.

additional variables to their regressions, such as the VIX Index and calendar dummies that accounted for market-wide risk aversion and quarter- and year-end effects.

There are also other papers that have tried to decompose the LIBOR-OIS spread and to study whether the TAF was effective in bringing down the spread. Overall, the results are more in favor of TAF efficiency in reducing the spread, implicitly suggesting that liquidity factors have played a key role in driving the spread. According to Abbassi and Linzert (2011), the common view acknowledges that both credit and liquidity factors are important.

As the ECB did not make any significant alterations to its operational framework in the pre-Lehman period, it did not attract the attention of researchers.[27] The first significant change in ECB's operational framework was the ECB's decision to conduct refinancing operations with fixed rate and full allotment (FRFA policy) in October 2008. Abbassi and Linzert (2011) were the first to study how the ECB's adoption of the FRFA policy affected money market rates. They modeled EURIBOR dynamics rather than the EURIBOR-OIS spread. However, their model was closely related to the ones used in LIBOR-OIS studies. The model was also expressed in difference form due to non-stationarity of the time series. Abbassi and Linzert (2011) were the first the use outstanding amounts of liquidity as explanatory variables instead of policy dummy variables that had been used in previous studies. Also, they were the first to provide empirical evidence for money market rates in the European context, as prior literature had only studied the effect of the ECB's unconventional policies to macroeconomic and financial aggregates.

Overall, the empirical results in Abbassi and Linzert (2011) documented a loss in the effectiveness of standard monetary policy during the crisis compared to the pre-crisis period: they found that policy rate expectations, which were proxied by using OIS rates, were less relevant for money market rates up to 12 months after August 2007 when compared to the pre-crisis period. The loss in policy effectiveness during the crisis was, according to the results, partly compensated by the use of non-standard monetary policy, as the ECB's net increase in outstanding open market operations as of October 2008 accounted for at least a

[27] According to Cecioni et al. (2011), the flexibility of ECB's operational framework ensured that the ECB was able to cope with the pre-Lehman crisis by modifying its framework only marginally. They summarize that during this period the ECB made some alterations to its fine-tuning operations, accommodated banks' desire to front-load the reserve requirement, increased the provision of longer term liquidity and offered US dollar funding to Eurosystem counterparties.

100 basis point decline in EURIBOR rates. The authors revised their earlier work in Abbassi and Linzert (2012), which suggested at least an 80 basis point decline in EURIBOR rates. The results therefore suggested that the ECB did have effective tools in conducting monetary policy in times of crisis.

According to Abbassi and Linzert (2011), almost all previous empirical studies have decomposed the spread into a credit and non-credit part in order to assess the relative importance of the risk factors. The decomposition has usually been done by using CDS premia (a proxy for the credit risk factor) as the only explanatory variable on EURIBOR-OIS spread, and then treating the residual as the non-credit component. Abbassi and Linzert (2011) argued that this approach is inaccurate because the two components cannot be fully separated due to joint variation. If the CDS premia is regressed on the EURIBOR-OIS spread, at least one of the coefficients will be biased because the joint variation of credit and liquidity risk is allocated to one of the decomposed risk factors. Therefore, the decomposition will not provide robust results about the relative importance of the risk factors. Rather, it seems that the decomposition is at best directional.[28] For this reason, the decomposition is not pursued in this study.

Michaud and Upper (2008) argued that there are at least two reasons why credit factors may correlate with liquidity factors. First, banks may exhibit risk aversion and hoard liquidity in times of high systematic risk. This idea is in line with theoretical considerations of Heider et al. (2009), who argued that banks may prefer to hoard liquidity instead of lending it out in a situation where good banks are driven out of the market and only riskier banks remain present. Second, Michaud and Upper (2008) argue that banks may default on their obligations because of both liquidity and solvency reasons. Banks may face a situation where they cannot obtain market funding even if they are fully solvent. This may occur when all or most lenders retreat from the market, possibly because they need liquidity themselves or because of symmetric information about the borrower's creditworthiness.

[28] Di Socio (2011) explained that if the interbank market was working perfectly, liquidity risk would be zero and the spread would represent solely credit risk. In this sense, the residual should represent liquidity risk, but the assumption of a perfectly working interbank markets is not realistic.

4.2. Data and sample period

The analysis uses daily data collected from Bloomberg and ECB Statistical Data Warehouse (SDW). Investigated sample period covers the period from 9 August 2007 to 27 September 2012. The length of the sample period is the most important enhancement to prior literature as it covers the effects of 36 month LTROs, which are believed to represent the most effective unconventional operations to reduce tensions in the interbank market.

Abbassi and Linzert (2012) divided their sample period (10 March 2004 – 31 December 2009) into three parts due to structural breakpoints in the data. By applying Chow breakpoint tests they were able to confirm that relevant breakpoints in their sample were 9 August 2007 (start of financial crisis in U.S.) and October 15 2008 (adoption of FRFA policy and consequent increase in allotted liquidity by the ECB, see figures 8 and 11). Because this study uses a longer sample period, a third breakpoint is suspected to be found in December 2011. On 8 December 2011, the ECB announced that it would conduct two rounds of 36m LTROs at the prevailing MRO rate, which at the time of first round of allotment was 1 %. Before December 2011, the maximum length of LTROs had been 12 months. As the length of these operations was three times the length of previous LTROs, they are believed to represent the most effective operations in reducing interbank tensions.

In order to confirm suspected breakpoints, Chow (1960) breakpoint test was used to test whether coefficients were different between sub-samples and the entire sample. Test results are presented in appendix D. Results indeed confirm that there is breakpoint on 8 December 2011. The first structural break (adoption of FRFA policy in 15 October 2012) found in Abbassi and Linzert (2012) was also confirmed. To sum up, investigated time periods are:

1. 9 August 2007 – 14 October 2008
2. 15 October 2008 – 7 December 2011
3. 8 December 2011 – 27 September 2012

4.3. Variables

Michaud and Upper (2008) argued that in theory, the risk premium in money market rates can be broken into variables reflecting both market-wide conditions and characteristics of the borrowing bank as follows:

$$Risk\ premium = tPrem + cPrem + bLiq + mLiq + micro \qquad (8)$$

where $tPrem$ is the term premium (reflecting uncertainty about the path of expected overnight rates), $cPrem$ is the credit premium (reflecting the risk of default), $bLiq$ is the funding liquidity premium (reflecting funding liquidity risk of the borrowing bank), $mLiq$ is the market liquidity premium (reflecting the ease of trading), and $micro$ is microstructure of the market. Michaud and Upper (2008) noted that disentangling of different components is tricky because there are no financial instruments whose payoffs are directly or uniquely related to any of the individual factors. Due to data constraints and lack of proper instruments, variables $tPrem$ and $micro$ are treated as unobserved variables. However, they should represent the smallest effects of the above components.

As proxy for credit risk premium ($cPrem$), this thesis uses the CDS spread of the Markit iTraxx Europe Senior Financials Index, which measures the average CDS premia on 5-year debt issued by 25 large European banks. According to BoE (2007), CDS prices (premia) reflect the default probability of the reference entity, the loss given default and some compensation for uncertainty about these factors. Michaud and Upper (2008) suggested that CDS premia are a good measure of credit risk as it much less affected by liquidity conditions than the unsecured-secured spreads. Overall, the existing empirical literature has converged to the view that bank CDS premia are the best available proxies for counterparty credit risk. De Socio (2011) argued that the CDS contracts with 5 year debt as reference are the best choice because they are of the most liquid maturity CDS contracts available. As the CDS index rises, the EURIBOR-OIS spread is also expected to rise.

Previous studies have often used the Chicago Board Options Exchange Volatility Index (VIX) as a measure for general risk aversion in financial markets. It has also been viewed as a proxy for market liquidity (mLiq), which is difficult to observe in the market. In this study, The

EURO STOXX 50 Volatility Index (VSTOXX) is used instead of VIX because it should better reflect the European context. VSTOXX measures the implied volatility of all EURO STOXX 50 Index options regardless of whether the options are in-, out- or at-the-money. VSTOXX is designed as a rolling index at a fixed 30 days to expiry. According to Abbassi and Linzert (2011), the VIX (and therefore VSTOXX also) may also be related to market liquidity premium, because it captures (expected) adverse price changes of market valued assets, thereby reflecting, at least indirectly, changes in market liquidity. Brunnermeier and Pedersen (2009) argued that in an environment of high stress, a potential dry up of funding liquidity can cause a fire sale of assets and as a result, market liquidity could dry up too. As VSTOXX rises, the EURIBOR-OIS spread is expected also rise (positive coefficient).

Figure 12 shows how CDS and VSTOXX indices have evolved from 2005 to the end of September 2012. Both indices were relatively stable before August 2007, but after the start of financial crisis they have become more volatile. The iTraxx Europe Senior Financials (5y) Index has risen throughout the crisis period, whereas the VSTOXX Index has had occasional spikes.

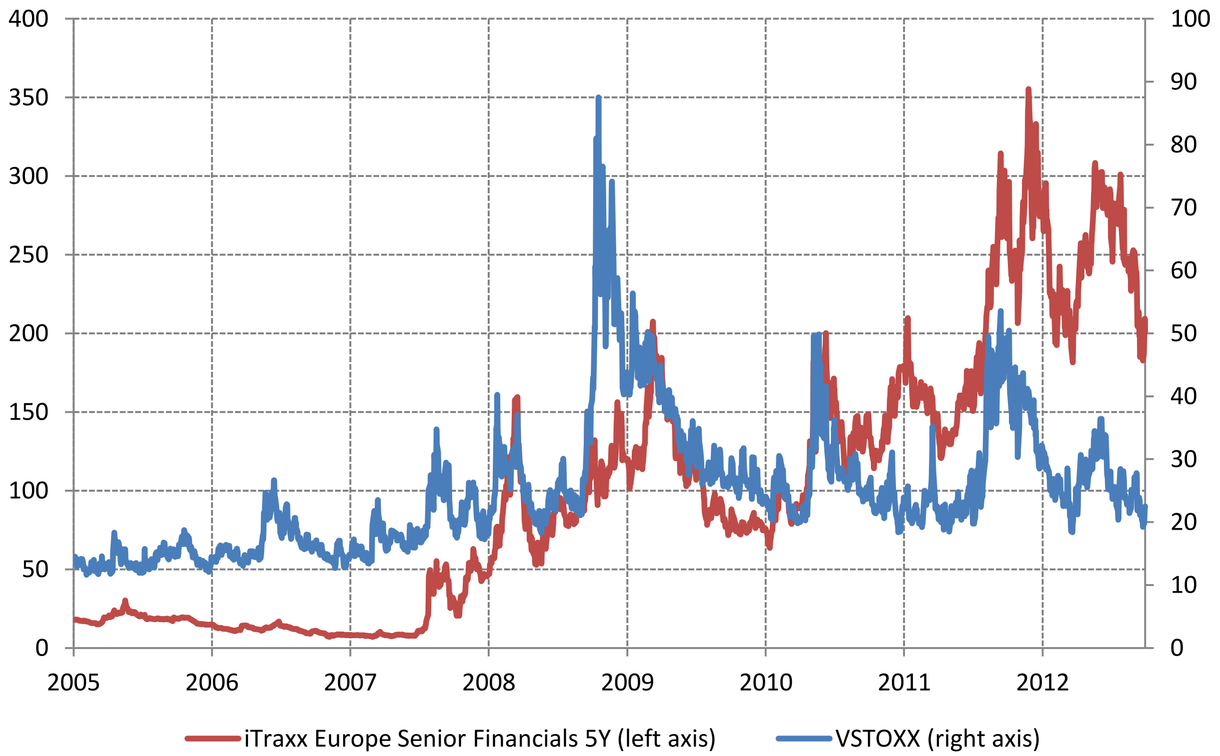

Figure 12. History of CDS and VSTOXX indices (as index points). *Data source: Bloomberg*

According to Michaud and Upper (2008), relevant information for assessing the funding liquidity of banks would include liquidity ratios and the size of potential commitments. Unfortunately, these variables are not available on a systematic basis and at a relevant frequency. Thus, as in Abbassi and Linzert (2011) and De Socio (2011), the spread between EUREPO and OIS rates are used as a proxy for funding liquidity risk. EUREPO rates are the cost for secured loans between euro area banks. The loans are backed by government bonds issued by euro area countries. Much like EURIBOR-OIS spreads reflects the risk premium in unsecured lending (incorporating both credit and liquidity risks), the EUREPO-OIS spread reflects the risk premium in secured lending, thus incorporating only liquidity risk.[29] As a result, EUREPO-OIS spread should reflect the liquidity premium charged by the lending party. It should mainly reflect funding liquidity risk ($bLiq$), but as noted earlier, it may also include effects of market liquidity risk ($mLiq$).

Figure 13 shows the evolution of 3M EUREPO-OIS spread. The spread was quite stable and close to zero before August 2007, after which it increased in volatility and rose substantially. At the end of 2009 the spread turned negative, indicating a liquidity discount rather than a premium. This possibly reflects a change in lender preferences towards lending in the secured market rather than in the unsecured market. As the EUREPO-OIS spread rises, the EURIBOR-OIS spread is also expected to rise.

[29] In a strict sense, Eurepo rates may not fully risk-free because the collateral provided by the borrower may be subject to default. Similarly, OIS rates may not fully risk-free because the interest payment at the end of contract period may also be subject to default. However, Eurepo rates represent the only reliable measure of risk-free term transactions between banks. Also, the default risk in OIS contracts concerns only the interest payment at the end of the contract period, as the the notional amount is not exchanged. Thus, the spread between these two rates should reliably reflect only the liquidity premium.

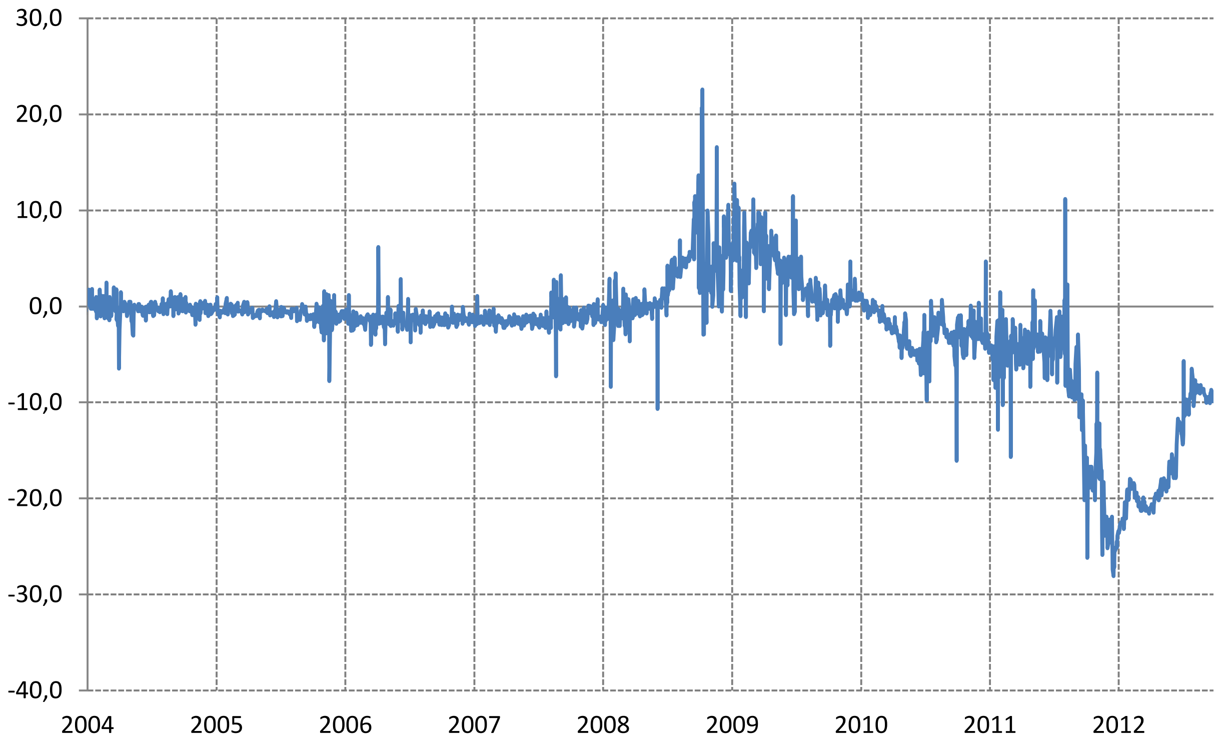

Figure 13. 3 month EUREPO-OIS spread. *Data source: Bloomberg*

According to Baba et al. (2008), an important aspect for many European financial institutions was that they faced a shortage of dollar funding as a result of increasing risk aversion by usual dollar suppliers. Traditionally U.S. dollar suppliers have included, for example, U.S. based banks and money market mutual funds that have investments in Europe. As an enhancement to prior literature, dollar funding pressures are controlled for by using the 1-year cross-currency basis swap spread.[30] According to Baba et al. (2008), cross-currency basis swaps have traditionally been employed to fund foreign currency investments and as a tool for converting currencies of liabilities. The pricing of a cross-currency basis swap indicates the premium received/penalty paid to exchange funds in one currency to another. The price of this

[30] For example, De Socio (2011) used the USD LIBOR-OIS spread as explanatory variable for EURIBOR-OIS spread in order to account for dollar funding pressures in the European interbank market. This study views that a regression using the LIBOR-OIS spread as explanatory variable may not be accurate in controlling dollar funding pressures, because the LIBOR-OIS spread only indicates that banks in London are reluctant to lend to other London-based banks. This does not necessarily imply that London-based banks are reluctant to lend dollars to Eurozone-based banks. Thus, the use of LIBOR-OIS may not be fully accurate because the LIBOR-OIS spread could include regional effects.

transaction (swap spread) contains information about funding pressures and thus reflects funding liquidity premium ($bLiq$).[31]

Figure 14 shows the evolution of 1-year EURUSD cross-currency basis swap spread as basis points from 2004 to the end of September 2012. The swap spread has been trading steady at a slight premium prior to August 2007, but since then it has turned negative and increased in volatility, indicating a that there has been significant dollar funding pressures because banks have agreed to swap euros into dollars with a considerable discount (negative premium). The observation therefore reflects a surge in demand for dollar term funding relative to that of the euro. As the level of EURUSD cross-currency basis swap rises (dollar funding eases), EURIBOR-OIS spread is expected to fall.

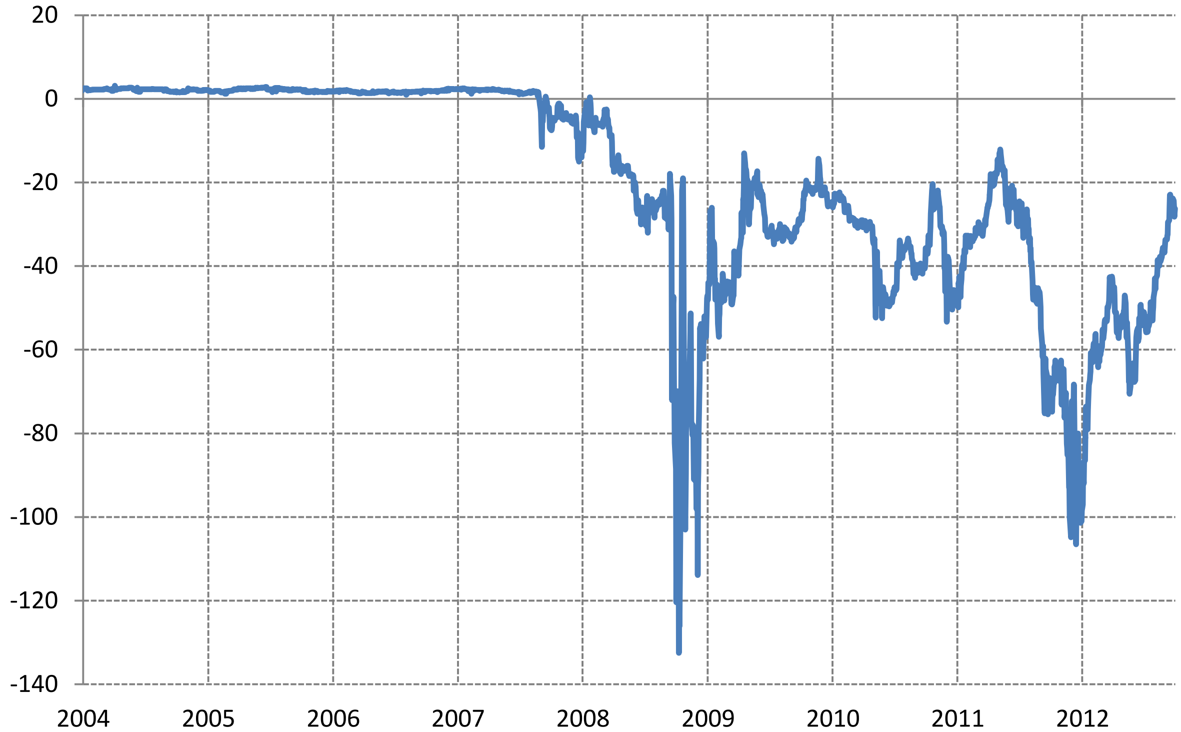

Figure 14. EURUSD cross-currency basis swap (1y). *Data source: Bloomberg*

[31] To see this, consider the following example modified from Baba et al. (2008). Suppose that a European bank want to swap 100 euros to dollars for three months and that the current EURUSD exchange rate is 1,35. At the start of the contract, the European bank borrows 100 *1,35 USD from, and lends 100 EUR to an American bank. During the contract term, the European bank receives 3M EURIBOR + α from, and pays USD 3M Libor to the American bank, where α is the price of the basis swap agreed upon at the start of the contract. When the contract expires, the European bank returns 100·1,35 USD to the American bank, and the American bank returns 100 EUR to the European bank. The exchange rate does not change during the contract period, making the swap pricing immune to movements in the exchange rate (unlike in normal FX swaps). Thus, funds are swapped but both still receive interest rates in their initial currencies. As a result, the price of the basis swap (α) turns negative if there is a strong demand for dollars and consequently a willingness to receive less in interest rate on euros.

Market liquidity premium will, unfortunately, be reflected only indirectly. According to Michaud and Upper (2008), an accurate measurement of market liquidity risk would include data on transactions between banks, such as number of trades, volume and bid-ask spreads. Unfortunately, such data is not available for public use and thus market liquidity risk will only be reflected in the VSTOXX Index and in EUREPO-OIS spreads.

To measure the effect of unconventional liquidity provision by the ECB, outstanding amounts of OMOs are used to account for relieving effects in the interbank market. OMOs contain liquidity provided through both conventional and unconventional operations. It includes the liquidity injected through MROs, LTROs, covered bond purchase programmes (CBPP and CBPP2) as well as from foreign exchange swap operations. As the SMP is sterilized, it will not be included in OMOs. However, the liquidity-absorbing operations that are carried out to sterilize the liquidity provided through the SMP are included in OMOs. Figure 15 shows how open market operations excluding SMP have affected liquidity conditions in the euro area.

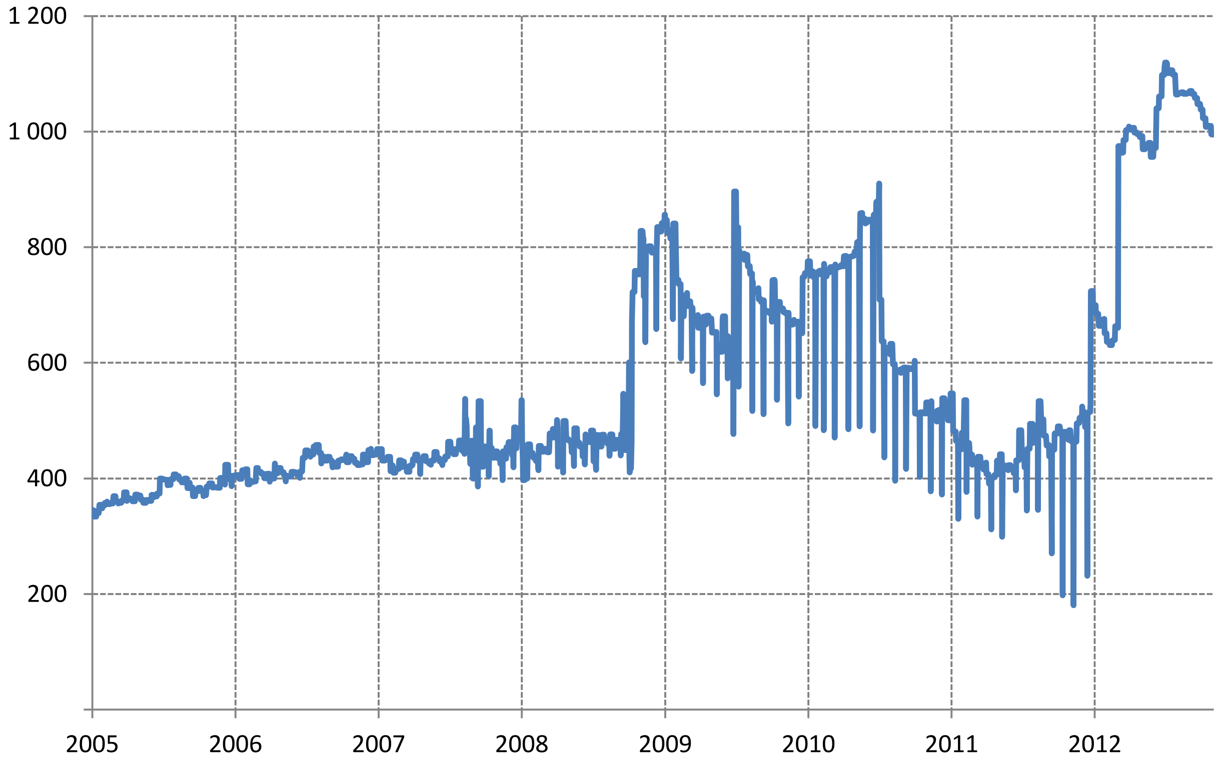

Figure 15. Open market operations (excl. SMP) in billion of euro. *Data Source: ECB Statistical Data Warehouse*

Figure 15 shows that the outstanding amount of liquidity increased substantially in October 2008 when the ECB decided to adopt the FRFA policy. Other significant spikes include the two rounds of 36m LTROs late 2011 and early 2012. The length of downward spikes between 2009 and 2012 is one day and they are caused by end of reserve maintenance periods. In a long run examination, it seems that the series could exhibit level-dependent variance and occasional trend-like behavior. For these reasons, estimations are carried out by transforming OMOs to logarithmic form.

To summarize, each variable with notations, explanations and expected signs are presented in table 2. k refers to maturity and t to time. Descriptive statistics on each time series is provided in appendix E.

NOTATION	EXPLANATION	REFLECTS	SIGN
$R_t(k)$	Spread between EURIBOR and OIS rates	Risk prem. in interbank lending	
CDS_t	iTraxx Europe Senior Financials Index	Counterparty credit risk	+
$EUREPO - OIS_t(k)$	Spread between EUREPO and OIS rates	Funding/market liq. risk	+
$VSTOXX_t$	Implied volatility of Euro Stoxx 50 Index	Market liq. risk	+
$XCCY\_SWAP_t$	1-year cross-currency basis swap spread	Dollar funding liquidity risk	-
$Ln(OMOs)_t$	Open market operations (excl. SMP)	Outstanding amount of liquidity	-

Table 2. Summary of variables

By using multiple maturities (represented by k) the analysis should also reveal whether ECB actions have had maturity-specific effects in the money market.

4.4. Methods

Prior empirical literature has usually employed a regression model in first differences due to non-stationary time series. This study should be the first to use a cointegration approach to study EURIBOR-OIS spreads. This should be an enhancement to prior literature because cointegration allows to estimate long run coefficients in level from, which means that information about the level of each time series will not be lost as in difference form representation.

4.4.1. Stationarity of time series

The analysis starts with unit root tests in order to verify whether the time series are stationary or not. Each time series have to be stationary in order for the OLS to produce unbiased estimates. By looking at figures 8, 12, 13, and 14 one can observe that the time series are unlikely to be stationary. In order to verify this, unit roots are tested by applying the augmented version of the Dickey-Fuller (1979) test for each sub-sample period. Test results are presented in appendix F.

Overall, t-statistics for level form variables suggest that the variables are non-stationary. By transforming the series into first difference form, the issue of non-stationarity disappears, thus revealing that the time series are I(1). This suggests that the model should be expressed in differences, unless the time series are cointegrated. If the time series are in fact cointegrated, the Error Correction Model (ECM) is an appropriate choice for the model form. Before testing for cointegration, some theoretical background is provided to understand the logic behind cointegration.

4.4.2. Spurious regressions and cointegration

To understand the logic behind cointegration, the concept of spurious regressions should be examined. The following theoretical background is based on Verbeek (2004).

Suppose that two I(0) processes, Y_t and X_t, are generated by two independent random walks:

$$Y_t = Y_{t-1} + \varepsilon_{1t}\,, \qquad \varepsilon_{1t} \sim IID(0, \sigma_1^2)$$
$$X_t = X_{t-1} + \varepsilon_{2t}\,, \qquad \varepsilon_{2t} \sim IID(0, \sigma_2^2)$$

where ε_{1t} and ε_{2t} are mutually independent. In this setting, there is nothing that should lead to a relationship between Y_t and X_t. However, if we estimate the following regression:

$$Y_t = \alpha + \beta X_t + \varepsilon_t \qquad (9)$$

According to Verbeek (2004), the results from regression (9) are likely to be characterized by a fairly high R^2 statistic, highly auto-correlated residuals and a significant value for β. This phenomenon is a well-known problem of *spurious regressions*, where two independent non-stationary variables are spuriously related due to the fact that they are both trended. In this case, the OLS estimator does not converge in probability as the sample size increases, the t- and F-statistics do not have well-defined asymptotic distributions, and the DW statistic converges to zero. The reason is that with Y_t and X_t being I(1) variables, the error term ε_t will also be a non-stationary I(1) variable.

According to Verbeek (2004), an important exception to this rule arises when Y_t and X_t share a common stochastic trend. If there is a linear relationship between Y_t and X_t, a proposition states that there must exist some value β such that a linear combination of the variables, $Y_t - \beta X_t$,is I(0), although Y_t and X_t are both I(1). In such case, Y_t and X_t are said to be *cointegrated* as they share a common stochastic trend. In a more general case, If two or more series are individually integrated but some linear combination of them has a lower order of integration, then the series are said to be cointegrated.

According to Verbeek (2004), if Y_t and X_t are cointegrated, it can be shown that one can consistently estimate β from an OLS regression of Y_t on X_t. In addition, the OLS estimator is said to be super consistent, because the OLS estimator converges to β at a much faster rate than with conventional asymptotics. If there exist a β such that $Z_t = Y_t - \beta X_t$ is I(0), the β is called the cointegrating parameter, or more generally, $(1, \beta)'$ is called the cointegrating vector. Z_t measures the extent to which the value of Y_t deviates from its long run equilibrium value $\alpha + \beta X_t$. Z_t is stationary when Y_t and βX_t have long run components that cancel out to produce values for Z_t that systematically differ from zero.

If Y_t and X_t are cointegrated, the error term ε_t will be I(0). If not, ε_t will be I(1). Hence, the cointegrating relationship can be tested by applying a unit root test for ε_t. This can be done using the Augmented Dickey-Fuller (1981) test. The test equation is:

$$\Delta e_t = \gamma_0 + \gamma_1 e_{t-1} + \sum_{i=1}^{p} \delta_i \Delta e_{t-i} + u_t \qquad (10)$$

The specification of the lag length p assumes that u_t is white noise. The null hypothesis states that $\gamma_1 = 0$. Rejection of this hypothesis implies that e_t is I(0). A failure to reject implies that Δe_t is stationary, so e_t is I(1).

In order to test whether the time series used in this study are cointegrated, the cointegrating regression is defined as follows:

$$R_t(k) = \beta_0 + \beta_1 EUREPO\_OIS_t(k) + \beta_2 CDS_t + \beta_3 VSTOXX_t + \beta_4 XCCY\_SWAP_t + \beta_5 Ln(OMOs)_t + e_t \qquad (11)$$

where $R_t(k)$ represents the EURIBOR-OIS spread with maturity k. The error term e_t in cointegrating regression (11) is estimated and tested for the presence of a unit root by applying equation (9) with null hypothesis of $\gamma_1 = 0$. The test results for are presented in appendix F. According to the test results, the variables are cointegrated for each maturity k, which means that there exists a long run equilibrium between the variables in equation (11).

4.4.3. Error Correction Model

A good time series model should describe both short run dynamics and the long run equilibrium simultaneously. For this purpose the error correction model (ECM) has been popularized after the introduction of Engle and Granger (1987) representation theorem. The theorem states that if a set of variables are cointegrated, then there exists a valid error-correction representation of the data. Using the two variable example in section 4.4.2., the error-correction representation with $Z_t = Y_t - \beta X_t$ can be written in a simple form as follows:

$$\Delta Y_t = \delta + \varphi \Delta X_{t-1} + \gamma Z_{t-1} + \varepsilon_t, \quad (12)$$

where ε_t is white noise and Z_{t-1} is the error term. In the case of cointegration the following Engle and Granger two-step procedure can be used:

1. Run the cointegrating regression (9) and save the residuals $Z_t = Y_t - \beta X_t$
2. Run an ECM regression of ΔY_t on ΔX_{t-1} and Z_{t-1}.

According to Verbeek (2004), the Engle-Granger representation theorem should hold because if Y_t and X_t are both I(1) but have a long run relationship, then there must be some force which pulls the equilibrium error back towards zero. To see this, consider a case where $\Delta X_{t-1} = 0$ and the error correction term $Z_{t-1} > 0$. This means that Y_{t-1} is too high above its equilibrium value, so in order to restore equilibrium, ΔY_t must be negative. This intuitively means that the error correction coefficient γ must be negative such that (11) is dynamically stable. In other words, if Y_{t-1} is above its equilibrium, then it will start falling in the next period so that the equilibrium error will be corrected in the model.

Coefficients in equation (12) are interpreted as follows. β in Z_t is called the long run parameter and it can be estimated super consistently from cointegrating regression (9), whereas φ and γ are short run coefficients estimated from the error correction model (12). Because all variables in the ECM are stationary, the ECM therefore has no spurious regression problem.

In time series analysis the explanatory variable may influence the dependent variable with a time lag. Furthermore, the dependent variable may be correlated with lags of itself. This often raises the need to add lags of both explanatory and dependent variables in the regression. The Engle-Granger representation theorem does not specify how many lags of ΔX_{t-1} or ΔY_{t-1} should be added to the ECM. In practice, the appropriate number of lags is chosen so that auto-correlation is removed from the error term. The ECM can be stated in a more general form as follows:

$$\Delta Y_t = \delta + \gamma Z_{t-1} + \sum_{j=1}^{q-1} \varphi_j \Delta X_{t-j} + \sum_{j=1}^{p-1} \omega_j \Delta Y_{t-j} + u_t, \qquad (13)$$

where q and p are lag lengths, which in practice are chosen so that autocorrelation is removed from u_t.

4.5. Results of modeling interbank spreads

As stated in the previous section, the cointegrating regression (10) considers the long-run balance between variables. Tables 3,4 and 5 show the long run coefficients β for 3, 6 and 12 month spreads. Overall, test results seem to be quite well in line with expectations.

Table 3. Long run dynamics of 3 month EURIBOR-OIS spread.

$EURIBOR\_OIS_t(3M)$	COEFF.	T-VALUE		COEFF.	T-VALUE
$EUREPO\_OIS_t(3M)$			$VSTOXX_t$		
Aug 2007 – Oct 2008	-1.21*	-2.49	Aug 2007 – Oct 2008	0.05	0.13
Oct 2008 – Dec 2011	1.07**	3.26	Oct 2008 – Dec 2011	2.24**	11.97
Dec 2011 – Sep 2012	-0.18	-1.00	Dec 2011 – Sep 2012	-0.83*	-2.43
CDS_t			$XCCY\_SWAP_t$		
Aug 2007 – Oct 2008	-0.19**	-2.66	Aug 2007 – Oct 2008	-1.00**	-6.95
Oct 2008 – Dec 2011	-0.16**	-4.45	Oct 2008 – Dec 2011	-1.02**	-7.53
Dec 2011 – Sep 2012	-0.11*	-2.57	Dec 2011 – Sep 2012	-1.13**	-11.60
$Ln(OMOs)_t$					
Aug 2007 – Oct 2008	45.65*	1.99			
Oct 2008 – Dec 2011	-23.50**	-3.12			
Dec 2011 – Sep 2012	-32.46**	-4.40			
Adj. R^2			***No. of observations***		
Aug 2007 – Oct 2008	0.69		Aug 2007 – Oct 2008	303	
Oct 2008 – Dec 2011	0.87		Oct 2008 – Dec 2011	809	
Dec 2011 – Sep 2012	0.93		Dec 2011 – Sep 2012	210	

Note: t-values are heteroskedasticity and autocorrelation consistent (HAC). ** and * indicate statistical significance at 1 % and 5 % level, respectively.

Table 4. Long run dynamics of 6 month EURIBOR-OIS spread.

$EURIBOR\_OIS_t(6M)$	COEFF.	T-VALUE		COEFF.	T-VALUE
$EUREPO\_OIS_t(6M)$			$VSTOXX_t$		
Aug 2007 – Oct 2008	0.16	0.42	Aug 2007 – Oct 2008	0.21	0.62
Oct 2008 – Dec 2011	0.99**	3.39	Oct 2008 – Dec 2011	2.27**	12.87
Dec 2011 – Sep 2012	-0.27	-1.16	Dec 2011 – Sep 2012	-0.77*	-2.17
CDS_t			$XCCY\_SWAP_t$		
Aug 2007 – Oct 2008	-0.05	-0.97	Aug 2007 – Oct 2008	-1.00**	-7.02
Oct 2008 – Dec 2011	-0.16**	-4.71	Oct 2008 – Dec 2011	-1.08**	-8.69
Dec 2011 – Sep 2012	-0.12*	-2.12	Dec 2011 – Sep 2012	-1.17**	-8.78
$Ln(OMOs)_t$					
Aug 2007 – Oct 2008	37.65	1.58			
Oct 2008 – Dec 2011	-19.16**	-2.62			
Dec 2011 – Sep 2012	-30.20**	-3.72			
Adj. R^2			***No. of observations***		
Aug 2007 – Oct 2008	0.82		Aug 2007 – Oct 2008	303	
Oct 2008 – Dec 2011	0.89		Oct 2008 – Dec 2011	809	
Dec 2011 – Sep 2012	0.92		Dec 2011 – Sep 2012	210	

Note: t-values are heteroskedasticity and autocorrelation consistent (HAC). ** and * indicate statistical significance at 1 % and 5 % level, respectively.

Table 5. Long run dynamics of 12 month EURIBOR-OIS spread.

$EURIBOR\_OIS_t(12M)$	COEFF.	T-VALUE		COEFF.	T-VALUE
$EUREPO\_OIS_t(12M)$			$VSTOXX_t$		
Aug 2007 – Oct 2008	0.62**	2.85	Aug 2007 – Oct 2008	0.33	1.03
Oct 2008 – Dec 2011	0.65**	2.72	Oct 2008 – Dec 2011	2.47**	12.70
Dec 2011 – Sep 2012	-0.54	-1.76	Dec 2011 – Sep 2012	-0.70	-1.90
CDS_t			$XCCY\_SWAP_t$		
Aug 2007 – Oct 2008	0.25**	5.99	Aug 2007 – Oct 2008	-1.04**	-8.25
Oct 2008 – Dec 2011	-0.07	-1.84	Oct 2008 – Dec 2011	-1.14**	-8.92
Dec 2011 – Sep 2012	-0.14**	-2.08	Dec 2011 – Sep 2012	-1.27**	-8.03
$Ln(OMOs)_t$					
Aug 2007 – Oct 2008	26.32	1.10			
Oct 2008 – Dec 2011	-34.52**	-5.06			
Dec 2011 – Sep 2012	-30.68**	-3.52			
Adj. R^2			***No. of observations***		
Aug 2007 – Oct 2008	0.88		Aug 2007 – Oct 2008	303	
Oct 2008 – Dec 2011	0.89		Oct 2008 – Dec 2011	809	
Dec 2011 – Sep 2012	0.92		Dec 2011 – Sep 2012	210	

Note: t-values are heteroskedasticity and autocorrelation consistent (HAC). ** and * indicate statistical significance at 1 % and 5 % level, respectively.

The EUREPO-OIS spread does not have expected explanatory power between August 2007 and October 2008, but does indicate statistically and economically important effects between October 2008 and December 2011. In the period between December 2011 and September 2012, the EUREPO-OIS spread does not provide explanatory power. In addition, the relative importance of EUREPO-OIS spreads seem to decrease slightly when moving on to longer maturities.

Coefficients for CDS Index provide rather mixed results. In most cases, the coefficients for CDS Index have negative sign which is the opposite of what was expected. However, the effects are not economically important; for example, during October 2008 and December 2011, the level of CDS Index rose the most from 100 to 267 index points, which accounts for a 27 basis point decline in the 3 month and 6 month EURIBOR-OIS spreads (-0.16*(267-

100)). Although this is against expectations, it should be noted that the coefficients in tables 3,4 and 5 represent long run equilibriums between EURIBOR-OIS spreads and the CDS Index. If counterparty credit risk is not in fact important in driving EURIBOR-OIS spreads, as previous literature often suggests, the variables reflecting liquidity conditions should then have statistically and economically important effects on EURIBOR-OIS spreads.

As expected, dollar funding liquidity risk seems to be a key driver of EURIBOR-OIS spreads. The cross-currency basis swap spread provides statistically and economically important effects; for example, between August 2007 and October 2008, the cross-currency basis swap spread widened from -2 to -75, which accounts for approximately 73 basis point rise in 3 month, 6 month and 12 month. Furthermore, tightening of the cross-currency basis swap spread accounts for over 50 basis point decline in EURIBOR-OIS spreads between December 2011 and September 2012. These observations shed light on the importance of dollar funding pressures, which has been neglected in prior literature, as key drivers of EURIBOR-OIS spreads.

Lastly, the liquidity provided through open market operations has significant effects on EURIBOR-OIS spreads after October 2008. Before October 2008, open market operations do not provide robust explanatory power, which is similar to the results of Abbassi and Linzert (2012). This could be explained by the fact that only after October 2008, the ECB conducted open market operations without absorbing the excess liquidity at the end of the reserve maintenance period. Between October 2008 and December 2011, however, the outstanding amount of liquidity provided by the ECB decreased from 760 billion to 490 billion (-36 %)[32]. Between December 2011 and September 2012, liquidity increased from 490 billion to 1040 billion euros (112 %). Table 6 presents the effects of OMOs as well as the change in each maturity spread during investigated time periods. Effect of OMOs is calculated as follows: $(\beta_5/100) * chg(\%)$.

[32] After the collapse of Lehman Brothers, the ECB conducted US dollar liquidity-providing operations, supplementary LTROs and announced that it would adopt the FRFA policy starting in 15 October 2012. Furthermore, in 8 October 2012, the ECB lowered its key rates by 50 basis points, all of which led to a significant increase of liquidity in the market just before 15 October 2012. Thus, the level of liquidity was very high in 15 October 2012, which is the start date of the second time period investigated.

	3 month spread	6 month spread	12 month spread
Effect of OMOs			
Oct 2008 – Dec 2011	8.5 bp	6.9 bp	12.4 bp
Dec 2011 – Sep 2012	-36.4 bp	-33.8 bp	-34.4 bp
Changes in spreads			
Oct 2008 – Dec 2011	-70.3 bp	-65.9 bp	-54.8 bp
Dec 2011 – Sep 2012	-86.6 bp	-90.6 bp	-98.6 bp

Table 6. Effect of OMOs after the adoption of FRFA policy.

Table 6 shows that between October 2008 and December 2011, a 36 % reduction in outstanding amount of liquidity accounts for 8.5, 6.9 and 12.4 rise in EURIBOR-OIS spreads. Similarly, between December 2011 and September 2012, a 112 % increase in outstanding amount of liquidity accounts for a 36.4, 33.8 and 34.4 decline in EURIBOR-OIS spreads. When this is compared to the changes in each spread during the same time period, the estimation results show that between December 2011 and September 2012, the increase in OMOs accounts for over one-thirds of the decline in EURIBOR-OIS spreads. Thus, the results suggest that the Eurosystem's net increase in the outstanding amounts of liquidity has significantly reduced the risk premium in interbank lending.

Moreover, results from estimating the ECM in equation (13) provides further information whether EURIBOR-OIS spreads adjust or not to correct for the equilibrium error. The results from estimating equation (13) are provided in table 7. The appropriate number of lags in equation (13), q and p, are chosen so that autocorrelation is removed from the error term u_t.

	3 month spread	6 month spread	12 month spread
Speed of adjustment			
Aug 2007 – Oct 2008	-0.04	-0.06	-0.08
Oct 2008 – Dec 2011	-0.01	-0.00	0.00
Dec 2011 – Sep 2012	-0.04*	-0.04**	-0.04**

Note: t-values are heteroskedasticity and autocorrelation consistent (HAC). ** and * indicate statistical significance at 1 % and 5 % level, respectively.

Table 7. Speed of adjustment parameters for EURIBOR-OIS spreads.

In most cases, autocorrelation was removed from u_t with $q = p = 1$. For those cases where autocorrelation was still present, it was removed by raising $p = 2$. However, heteroskedasticity was present in each of the nine regression. Thus, HAC t-values were used to correctly assess the statistical significance of the speed of adjustment coefficients.

In most cases, the speed of adjustment coefficients (γ) have a negative sign as expected and their absolute values are quite small, which indicates slow adjustment. However, their statistical significance is verified only in three out of nine cases, between December 2011 and September 2012. During this time period, the results show that EURIBOR-OIS spreads adjust to correct for the equilibrium error. In addition to EURIBOR-OIS spreads adjusting, there could be other variables which also adjust. However, they are not recognized in the analysis.

In each of the other six cases, some combination of the X_t variables have to adjust to correct for the equilibrium error. In each of these six cases, at least one φ_j differed significantly from zero (not reported), which provides evidence of cointegration but not about which of the X_t variables adjust to correct for the equilibrium error [33].

4.6. Potential problems in empirical analysis

Such as previous studies, the empirical analysis potentially suffers from a number of limitations. The first problem in the empirical part of the thesis has to do with the lack of proper variables. Prior academic literature has done a good job at identifying the most important theoretical factors driving the tensions in interbank markets. Unfortunately, these factors are often difficult or impossible to measure. For this reason, studies have had to rely on proxies that are not fully reliable. Firstly, in the case of some proxies, prior literature has recognized that they may not solely reflect the desired factor, but could also include effects from other factors. Thus, the coefficients need to be interpreted cautiously. Secondly, the study could to suffer from the omitted variable bias, because some variables are simply impossible to measure or because desired data is not available at relevant frequency.

[33] According to Enders (1995), a necessary condition for cointegration to exist is that γ and φ_j in equation (13) cannot simultaneously be equal to zero. If both coefficients equal zero, then it could be said that the ΔX_t sequence does not Granger cause ΔY_t sequence. However, if one or both coefficients significantly differ from zero, then the variables are cointegrated.

The econometric methods used in this study may also be subject to criticism. In time series analysis, the concept of cointegration is well recognized and widely used particularly after pioneering work by Engle and Granger (1987). However, cointegration among variables as such does not provide information about causality nor about the number of cointegrating relations when there are more than two variables. When there are more than two explanatory variables, there could be more than one cointegrating relations among them, which cannot be identified using the Engle and Granger (1987) procedure. As there are six time series investigated in this study, it may be that there are up to five cointegrating vectors among the variables. Without having information about the number of cointegrating vectors, the analysis is not able to econometrically prove that causality runs as it is specified in equation (13). Thus, causality in equation (13) is based on theoretical considerations of prior literature reviewed in section 4.1.

Moreover, the Engle Granger (1987) analysis is based on the assumption that that the variables in equation (13) are exogenous. According to Enders (1995), the long run coefficients in tables 3,4 and 5 do not have asymptotic t-distributions unless the variables in equation (13) are actually independent and there exist only one cointegrating vector. Appendix H presents simple correlation matrices, which do not point to any systematically high correlations between variables. However, a simple correlation analysis does not provide a reliable assessment about the exogeneity of variables.

Furthermore, the Engle Granger (1987) analysis cannot reveal which of the set of cointegrated variables adjust to correct for the equilibrium error. Although this not in the scope of this study, an analysis of the full system of equations should be able to recognize which variables adjust to the long-run cointegration relation. According to Enders (1995), a Vector Autoregressive process (VAR) would be an appropriate description of this system. In a VAR, each variable is “explained” by its own lagged values, and the lagged values of all other variables in the system. It treats variables as endogenous and could provide more information about the direction of causality without making assumptions. Overall, a VAR system and the use of Johansen (1988) procedure, which is able to detect the existence of multiple cointegrating vectors, would be an enhancement to the analysis.

5. IMLICATIONS OF UNCONVENTIONAL MONETARY POLICY TO THE FUNCTIONING OF THE INTEREST RATE CHANNEL

5.1. Interbank market

After the adoption of the FRFA policy in October 2008, outstanding amount of liquidity allotted through OMOs increased significantly and EURIBOR-OIS spreads started to fall, continuing their downward trend throughout 2009, 2010 and the first half of 2011. In the second half of 2011, the spreads started to rise again. The ECB responded by conducting new unconventional measures, of which the 36 month LTROs were the most important. After late 2011, the spreads have been steadily declining throughout 2012. Prior empirical evidence presented in section 4.1 has suggested that reductions in interbank market tensions have been affected by unconventional actions conducted by central banks. Keeping in mind the potential problems with the empirical analysis, this study also provided empirical support to the effectiveness of the ECB actions in reducing interbank market tensions.

It is clear that low levels of EURIBOR-OIS spreads are highly desirable. When the spreads are low, money market rates follow the expected path of overnight rates, which of course is a necessary condition for conducting effective monetary policy through the policy rate. When interbank spreads are low, future changes in the ECB policy rate should be fully transmitted to interbank rates, thereby lowering wholesale funding costs. Lower funding costs should then be transmitted to lending rates. If this has occurred, then the unconventional measures of the ECB have potentially helped to restore the proper functioning of the first phase of the interest rate channel. However, a proper assessment of whether the functioning of the interest rate channel has been restored requires some analysis about developments in the retail market, which ultimately transmits monetary policy to the real economy.

5.2. Retail market

As banks should have no inventive to lend money at the retail market at cost that is lower than the prevailing funding cost, high levels of EURIBOR-OIS spreads thus imply that changes in the ECB policy rate are not fully transmitted to money market rates nor retail rates. However, the determination of retail rates is not solely explained by the funding cost (EURIBOR rates), because there are other factors which may reduce retail lending. These other factors could include, for example, increased banking regulation, higher capital requirements and increased bank taxation. Thus, the strength of pass through can significantly differ between the two steps of interest rate pass through.

To examine the pass through from money market rates to retail rates, some descriptive analysis is provided about euro area retail rates. According to the ECB website, MFI interest rate statistics cover those interest rates that resident monetary financial institutions (MFIs, i.e. "credit institutions") apply to euro-denominated loans granted to households and non-financial corporations which are residents of the euro area. These statistics can be used for the analysis of monetary developments and the monetary transmission mechanism as well as for the monitoring of financial stability.

Figure 16 shows selected interest rates spreads against the 12 month EURIBOR for new loans on a monthly basis.[34] The period considered spans from January 2006 to October 2012 and the geographic area taken into account is the Euro area (changing composition). All retail rates used to calculate the spread against 12 month EURIBOR are annualized agreed rates, which the ECB has defined as "the interest rate that is individually agreed between the reporting agent and the household or non-financial corporation for a deposit or loan, converted to an annual basis and quoted in percentages per annum".[35] Original maturities are used to calculate the average interest rate for each of the selected series.

[34] Selected interest rates for households and non-profit institutions serving households include: Loans for consumption (excluding revolving loans and overdrafts, convenience and extended credit card debt, and lending for house purchase (excluding revolving loans and overdrafts, convenience and extended credit card debt). Interest rates for non-financial firms include: loans other than revolving loans and overdrafts, convenience and extended credit card debt, with amounts up to and including EUR 1 million and over EUR 1 million.

[35] Manual on MFI interest rate statistics is available at: http://www.ecb.int/stats/pdf/money/mfi-intrestratestatisticsmanual.pdf?ecf300083643da72431de53429e7cc68

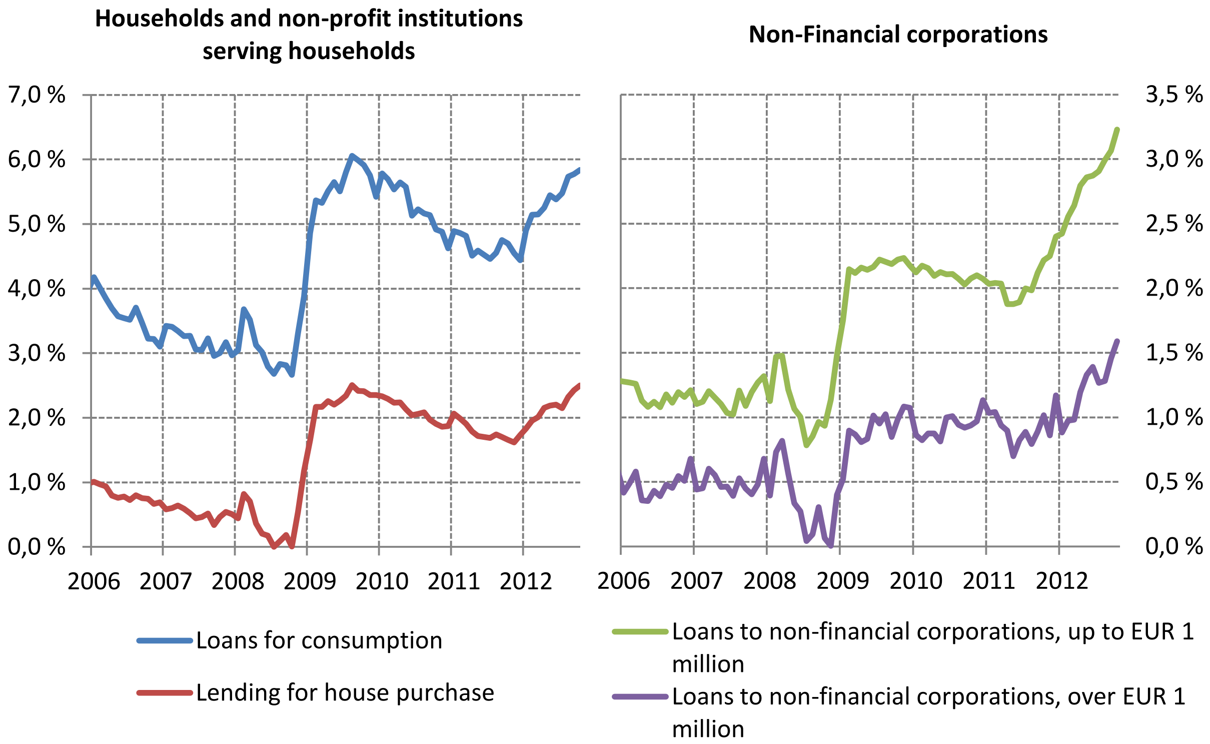

Figure 16. Retail rate spreads against the 12 month EURIBOR. *Data Source: ECB Statistical Data Warehouse.*

According to figure 16, spreads between money market rates and retail rates had been declining in the pre-Lehman period, suggesting strengthening interest rate pass through. However, in late 2008 the spreads rose to significantly higher levels, which suggests a significantly weakened interest rate pass through. After this, pass through improved for households whereas pass through for firms maintained weak.

An interesting feature in both charts is that the interest rate pass through started to weaken again in late 2011 and has kept weakening throughout 2012. This occurs despite the several unconventional measures by the ECB, which raised the outstanding amount of liquidity in the banking system to a record high level (see figure 15). Based on these observations, it seems that interest rate pass through is driven by other factors and not at all affected by liquidity conditions in the banking system. If this was the case, then the unconventional actions of the ECB have not been able to improve interest rate pass through from money market rates to retail rates, which sets future challenges to conducting effective monetary policy through the policy rate.

6. CONCLUSIONS

Traditional monetary policy relies on the interest rate channel of monetary transmission, in which the central bank sets the policy rate and expects that the policy rate passes through to money market rates and bank retail rates, which ultimately affect savings, consumption, investment, aggregate demand and prices. Strong interest rate pass through is particularly important for central banks which have an inflation target, such as the ECB. As a response to the financial crisis and consequent recession, the ECB lowered its policy rate close to the zero lower bound. As this was not enough, the ECB had to rely on several unconventional policies to restore market confidence and to stimulate the economy. Unconventional measures were expected to work through alternative channels, such as the exchange rate-, asset price- and credit channels of monetary policy. If unconventional policies have worked as expected, then the alternative channels could have been valuable in restoring the functioning of the interest rate channel, and thus providing the basis for effective monetary policy in the future.

During the financial crisis, the ECB took over the dysfunctioning interbank market by replacing much of the interbank activity with its FRFA policy and supplementary LTROs. Unconventional operations led to a significant increase in outstanding amounts of liquidity in the banking system. This thesis paid particular interest to the question of whether the liquidity created through unconventional monetary policies was effective in lowering the risk premium in interbank lending, and thus potentially improving interest rate transmission from the ECB policy rate to EURIBOR rates. The empirical part of this thesis added to the very scarce literature providing evidence about the efficiency of unconventional policies.

The empirical results provide support for the effectiveness of the ECB's liquidity provision in affecting interbank spreads. Between October 2008 and December 2011, a 36 % reduction in outstanding amount of liquidity is associated with a 8.5, 6.9 and 12.4 rise in EURIBOR-OIS spreads. Similarly, between December 2011 and September 2012, a 112 % increase in outstanding amount of liquidity is associated with a 36.4, 33.8 and 34.4 decline in EURIBOR-OIS spreads. Keeping in mind the potential problems with the analysis, the results suggest that the Eurosystem's net increase in the outstanding amounts of liquidity has significantly reduced the risk premium in interbank lending, and thus improved the interest rate transmission from the ECB policy rate to EURIBOR rates.

An improved interest rate transmission from the ECB policy rate to EURIBOR rates does not, however, necessarily imply that the transmission from EURIBOR rates to bank retail rates is also improved. Naturally, there are multiple additional factors affecting the determination of bank retail rates in addition to interbank rates. Still, everything else equal, a reduction in interbank rates should result in lower retail rates, which in turn should have expansionary effects on the real economy. In this sense, unconventional measures have not only lowered the risk premium in interbank lending, but also retail rates. However, if the examination is restricted to only account for the second phase of transmission, it seems that interest rate pass through is driven by other factors and not at all affected by liquidity conditions in the banking system. This implies that the functioning of the interest rate channel has improved only through lower interbank rates. Thus, the effectiveness of the ECB's monetary policy during the crisis depends on which viewpoint is taken. Overall, the functioning of the interest rate channel has not been adequately restored so that the effectiveness of future monetary policy through the policy rate would be guaranteed.

As a future prospect, restoring proper functioning of the interest rate channel would require addressing those factors that drive the evolution of retail rates. The bank lending channel is an important factor in this respect, as unconventional policies by the ECB have increased excess reserves in the banking system, which should lead to a higher quantity of bank loans available. However, based on future inflation expectations and current output, it does not seem that the excess liquidity in the banking system has significantly accelerated the velocity of money. Velocity might have increased after July 2012, when the ECB lowered its overnight deposit rate to zero, thereby shifting incentives towards increased lending instead of overnight deposits at the ECB. So far, it is too early to say whether this will stimulate the bank lending channel. However, if the uncertain economic environment in Europe should significantly improve and the ECB adjusts its policy rates slowly, the excess liquidity in the banking system has the potential to cause an unsustainable credit expansion. Although a this would require multiple favorable developments in the economy, the importance of right timing in raising interest rates has grown in preventing future risks from realizing.

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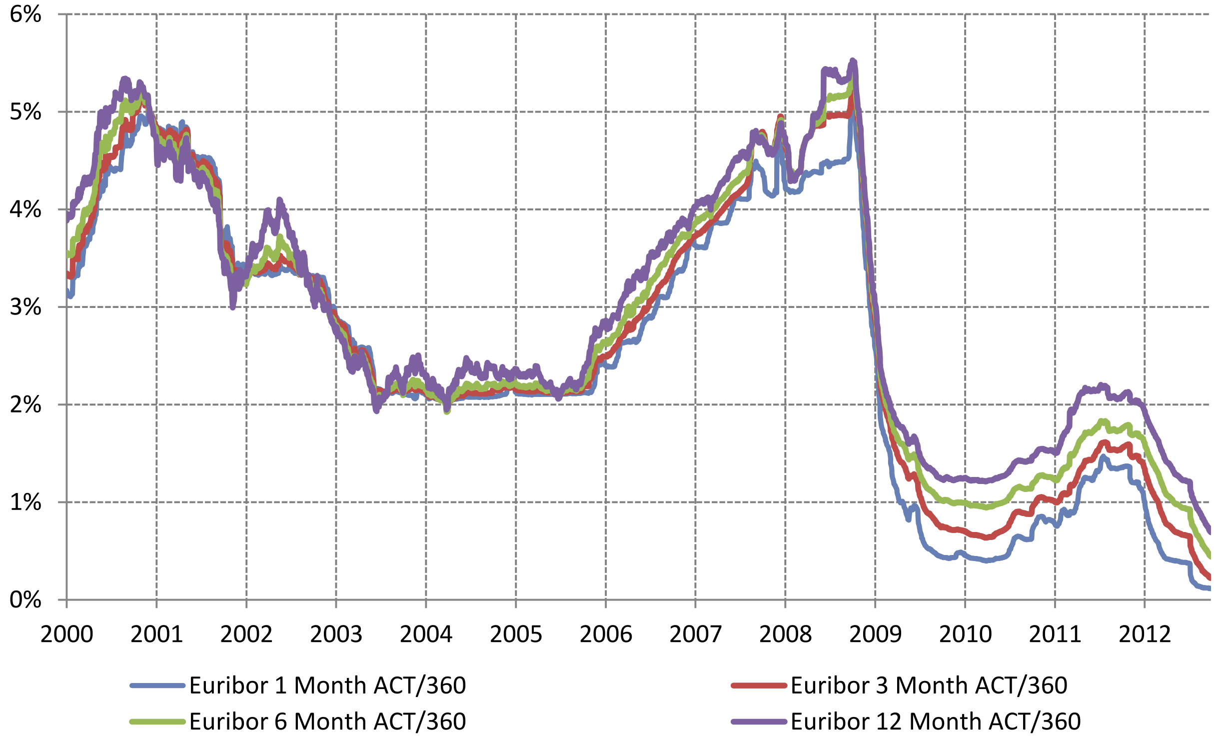
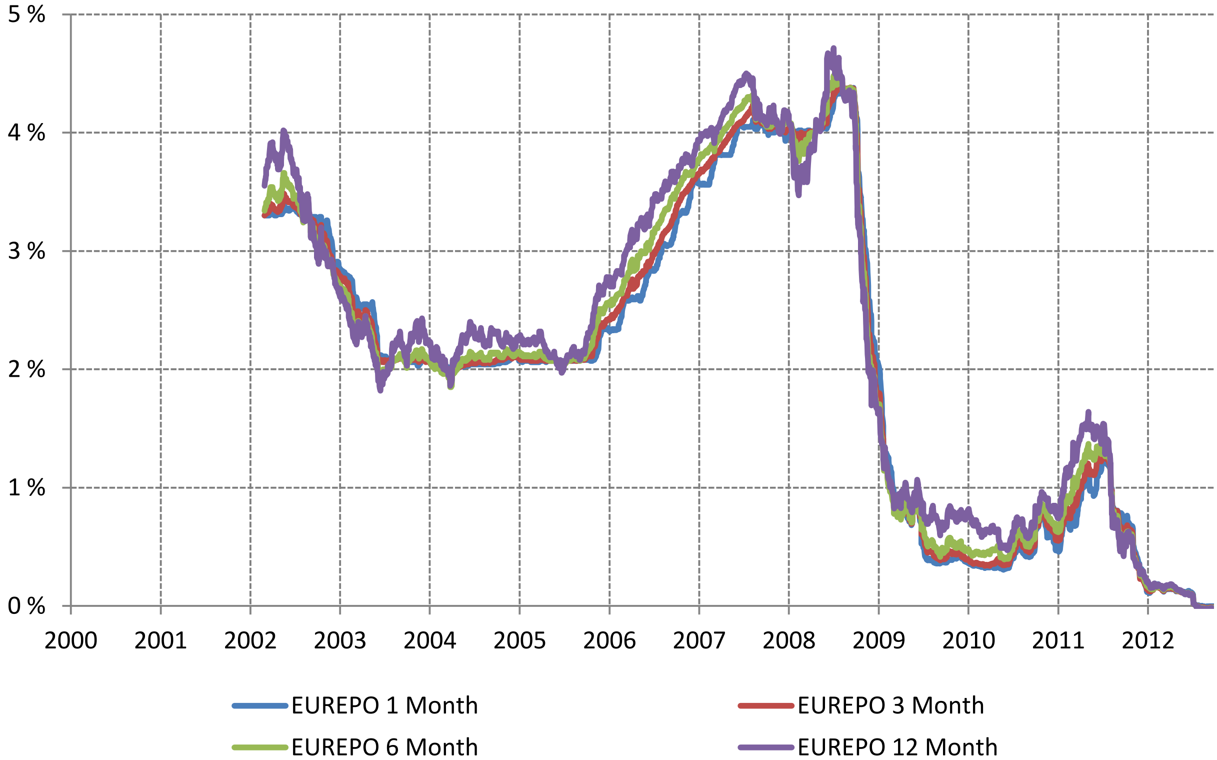
APPENDICES

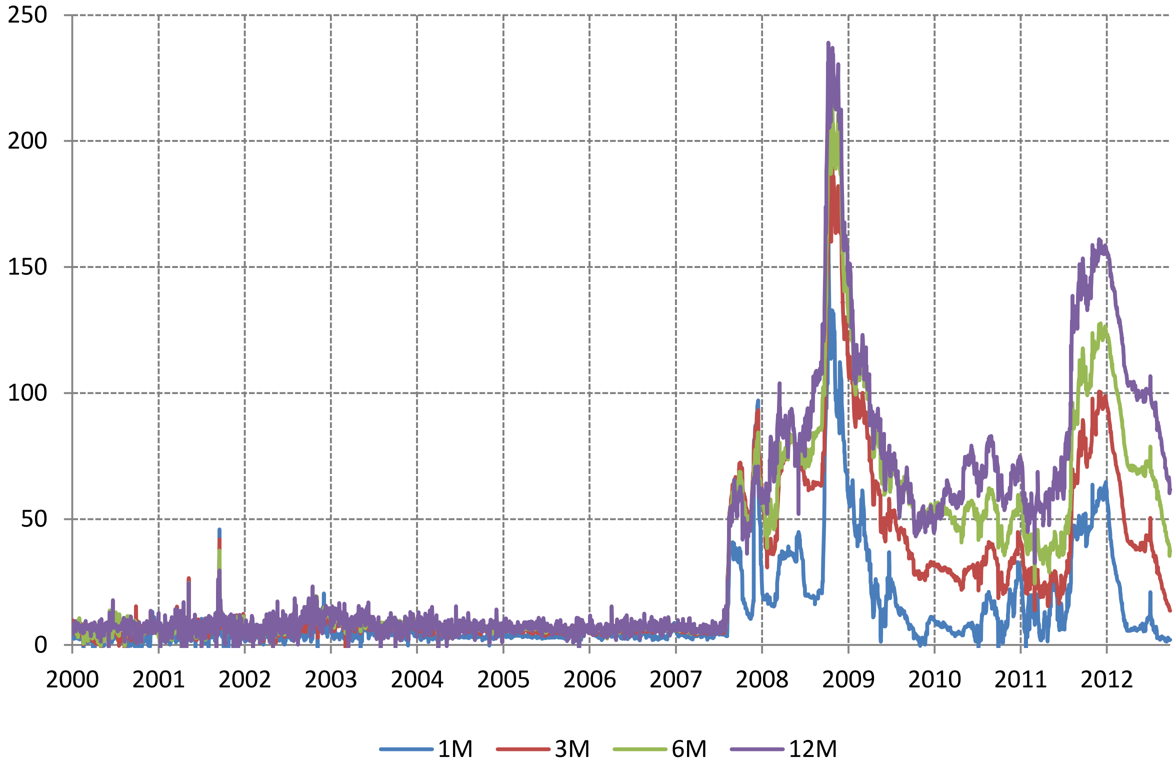
Appendix A. History of EURIBOR and EUREPO rates.





Data source: Bloomberg

Appendix B. History of EURIBOR-OIS spreads



Data source: Bloomberg

Appendix C. Complete structure of ECB's balance sheet

	Assets (EURm)		Liabilities (EURm)
1	Gold and gold receivables	1	Banknotes in circulation
2	Claims on non-euro area residents denominated in foreign currency	2	Liabilities to euro area credit institutions related to monetary policy operations denominated in euro
2.1.	Receivables from the IMF	2.1.	Current accounts (covering the minimum reserve system)
2.2.	Balances with banks and security investments, external loans and other external assets	2.2.	Deposit facility
3	Claims on euro area residents denominated in foreign currency	2.3.	Fixed-term deposits
4	Claims on non-euro area residents denominated in euro	2.4.	Fine-tuning reverse operations
4.1.	Balances with banks, security investments and loans	2.5.	Deposits related to margin calls
4.2.	Claims arising from the credit facility under ERM II	3	Other liabilities to euro area credit institutions denominated in euro
5	Lending to euro area credit institutions related to monetary policy operations denominated in euro	4	Debt certificates issued
5.1.	Main refinancing operations	5	Liabilities to other euro area residents denominated in euro
5.2.	Longer-term refinancing operations	5.1.	General government
5.3.	Fine-tuning reverse operations	5.2.	Other liabilities
5.4.	Structural reverse operations	6	Liabilities to non-euro area residents denominated in euro
5.5.	Marginal lending facility	7	Liabilities to euro area residents denominated in foreign currency
5.6.	Credits related to margin calls	8	Liabilities to non-euro area residents denominated in foreign currency
6	Other claims on euro area credit institutions denominated in euro	8.1.	Deposits, balances and other liabilities
7	Securities of euro area residents denominated in euro	8.2.	Liabilities arising from the credit facility under ERM II
7.1.	Securities held for monetary policy purposes	9	Counterpart of special drawing rights allocated by the IMF
7.2.	Other securities	10	Other liabilities
8	General government debt denominated in euro	11	Revaluation accounts
9	Other assets	12	Capital and reserves

Source: User guide on the consolidated weekly financial statement of the Eurosystem. Includes a detailed explanation of each item. Available at: *http://www.ecb.int/press/pr/wfs/html/wfs-userguide.en.html*

Appendix D. Chow breakpoint tests

Chow breakpoint tests are applied to the following test equation. The test equation is the same as equation (11):

$$R_t(k) = \beta_0 + \beta_1 EUREPO\_OIS_t(k) + \beta_2 CDS_t + \beta_3 VSTOXX_t + \beta_4 XCCY\_SWAP_t + \beta_5 Ln(OMOs)_t + e_t \qquad (11)$$

The chow breakpoint test uses the above equation to obtain the sum of squared residuals for restricted and unrestricted models, which are then compared by the F-statistic. If the sum of squared residuals is different between a sub-sample and the entire sample, the test indicates that there has been a structural change. The null hypothesis states that coefficients from the sub-sample and the entire sample are simultaneously equal (no structural change), or that sums of squared residuals are the same between sub-sample and the entire sample.

The first breakpoint (P1) is set to 15 October 2008 (adoption of FRFA policy) and the second breakpoint (P2) to 8 December 2011 (announcement of 36m LTROs). The table below shows the F-statistic for group of interaction variables:

	k=3M		k=6M		k=12M	
	P1	**P2**	**P1**	**P2**	**P1**	**P2**
F-statistic	337.58	112.22	270.61	129.10	230.88	161.86
[t-prob.]	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**

Results support the existence of breakpoints in 15 October 2008 and 8 December 2011. Thus, the sample period can be divided into three parts.

Appendix E. Descriptive statistics

VARIABLE	UNIT	MIN	MAX	AVERAGE	STDEV
EURIBOR-OIS_3M	basis points	13,6	206,9	54,9	33,3
EURIBOR-OIS_6M	basis points	18,0	222,5	72,9	34,5
EURIBOR-OIS_12M	basis points	22,8	239,0	88,3	39,7
EUREPO-OIS_3M	basis points	-28,1	22,6	-3,5	8,0
EUREPO-OIS_6M	basis points	-22,6	18,4	-2,6	7,5
EUREPO-OIS_12M	basis points	-27,2	27,7	-2,2	7,8
VSTOXX	index points	17,2	87,5	29,6	10,0
CDS	index points	20,4	355,3	142,7	71,2
XCCY_SWAP	basis points	-132,5	1,9	-36,0	21,8
OMOs	bln. euros	180	1119	632	198

The above table provides descriptive statistics about variables from August 2007 to September 2012. Maximum values for EURIBOR-OIS, EUREPO-OIS, and VSTOXX were reached in October 2008. CDS index was at its highest in November 2011, and XCCY_SWAP was at its lowest in October 2008. OMOs peaked after the two rounds of 36m LTROs in June 2012.

Appendix F. Unit root tests

The ADF test applies the following AR(p) process with a constant for each time series in both level and first difference form:

$$\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t$$

where α is constant (drift), p is the lag, β is the coefficient to which the t-statistic is provided, and δ_i is the coefficient for lagged first differences. The null hypothesis states that β = 0, or that the series is non-stationary. The test compares the t-statistic for β with critical values. If the t-statistic for β is smaller (more negative) than critical values, H_0 is rejected and the conclusion is that the series is stationary. By using five lags ($p = 5$), the preferred model was chosen based on the smallest AIC value.

5 % critical value is -2.87 (*)

1 % critical value: -3.45 (**)

August 2007 – October 2008:

LEVELS	T-ADF	p	DIFFERENCES	T-ADF	p
$EURIBOR\_OIS_t(3M)$	-2.211	2	$\Delta EURIBOR\_OIS_t(3M)$	-7.271**	1
$EURIBOR\_OIS_t(6M)$	-0.8871	3	$\Delta EURIBOR\_OIS_t(6M)$	-6.958**	2
$EURIBOR\_OIS_t(12M)$	0.06886	3	$\Delta EURIBOR\_OIS_t(12M)$	-8.455**	2
$EUREPO\_OIS_t(3M)$	-1.695	5	$\Delta EUREPO\_OIS_t(3M)$	-11.53**	5
$EUREPO\_OIS_t(6M)$	-1.625	5	$\Delta EUREPO\_OIS_t(6M)$	-11.86**	5
$EUREPO\_OIS_t(12M)$	-2.812	5	$\Delta EUREPO\_OIS_t(12M)$	-13.10**	4
$VSTOXX_t$	-0.1373	3	$\Delta VSTOXX_t$	-10.61**	2
CDS_t	-2.160	1	ΔCDS_t	-15.21**	0
$XCCY\_SWAP_t$	2.918	5	$\Delta XCCY\_SWAP_t$	-11.80**	4
$Ln(OMOs)_t$	-2.388	5	$\Delta Ln(OMOs)_t$	-13.29**	4

October 2008 – December 2011:

LEVELS	T-ADF	*p*	DIFFERENCES	T-ADF	*p*
$EURIBOR\_OIS_t(3M)$	-3.111*	3	$\Delta EURIBOR\_OIS_t(3M)$	-14.78**	3
$EURIBOR\_OIS_t(6M)$	-2.803	3	$\Delta EURIBOR\_OIS_t(6M)$	-17.91**	2
$EURIBOR\_OIS_t(12M)$	-2.249	3	$\Delta EURIBOR\_OIS_t(12M)$	-18.26**	2
$EUREPO\_OIS_t(3M)$	-0.4688	5	$\Delta EUREPO\_OIS_t(3M)$	-18.32**	5
$EUREPO\_OIS_t(6M)$	-1.478	5	$\Delta EUREPO\_OIS_t(6M)$	-19.25**	5
$EUREPO\_OIS_t(12M)$	-2.345	5	$\Delta EUREPO\_OIS_t(12M)$	-19.32**	5
$VSTOXX_t$	-3.077*	5	$\Delta VSTOXX_t$	-15.95**	4
CDS_t	-0.9642	4	ΔCDS_t	-18.22**	2
$XCCY\_SWAP_t$	-3.127*	5	$\Delta XCCY\_SWAP_t$	-14.91**	5
$Ln(OMOs)_t$	-2.084	5	$\Delta Ln(OMOs)_t$	-17.09**	5

Note: By adding more than 5 lags to the test equation, the ADF test indicates that $EURIBOR\_OIS_t(3M)$, $VSTOXX_t$ and, $XCCY\_SWAP_t$ are all non-stationary. This is because the initial number of 5 lags was not enough to remove autocorrelation from these series. Thus, these series can reliably be treated as non-stationary.

December 2011 – September 2012:

LEVELS	T-ADF	*p*	DIFFERENCES	T-ADF	*p*
$EURIBOR\_OIS_t(3M)$	-1.904	5	$\Delta EURIBOR\_OIS_t(3M)$	-5.131**	4
$EURIBOR\_OIS_t(6M)$	-1.172	5	$\Delta EURIBOR\_OIS_t(6M)$	-4.635**	5
$EURIBOR\_OIS_t(12M)$	-0.5814	2	$\Delta EURIBOR\_OIS_t(12M)$	-8.041**	3
$EUREPO\_OIS_t(3M)$	-0.6605	3	$\Delta EUREPO\_OIS_t(3M)$	-10.25**	3
$EUREPO\_OIS_t(6M)$	-0.5255	4	$\Delta EUREPO\_OIS_t(6M)$	-10.34**	3
$EUREPO\_OIS_t(12M)$	-0.9325	4	$\Delta EUREPO\_OIS_t(12M)$	-10.50**	3
$VSTOXX_t$	-3.266*	0	$\Delta VSTOXX_t$	-9.943**	2
CDS_t	-1.692	0	ΔCDS_t	-14.12**	0
$XCCY\_SWAP_t$	-0.5335	4	$\Delta XCCY\_SWAP_t$	-9.045**	3
$Ln(OMOs)_t$	-2.294	3	$\Delta Ln(OMOs)_t$	-11.47**	2

Note: the ADF test was not able to reject the stationarity of $VSTOXX_t$ at 5 % significance level. However, stationarity is rejected at 1 % significance level. Also, by adding a trend to the test equation the stationarity at 5 % significance level disappears. Thus, the variable can be treated as non-stationary and it should not cause biased estimates.

Appendix G. Cointegration tests

The following tables present unit root test results for e_t in equation (10). Null hypothesis is that $\gamma_1 = 0$.

$$\Delta e_t = \gamma_0 + \gamma_1 e_{t-1} + \sum_{i=1}^{p} \delta_i \Delta e_{t-i} + u_t \tag{10}$$

Lag length was chosen to be three ($p = 3$), from which the appropriate number of lags was chosen based on AIC information criteria.

3 MONTH SPREAD	T-STATISTIC (ADF)	*p*
Aug 2007 – Oct 2008	-3.669**	3
Oct 2008 – Dec 2011	-8.280**	0
Dec 2011 – Sep 2012	-4.378**	2

6 MONTH SPREAD	T-STATISTIC (ADF)	*p*
Aug 2007 – Oct 2008	-4.168**	3
Oct 2008 – Dec 2011	-8.415**	0
Dec 2011 – Sep 2012	-3.847**	2

12 MONTH SPREAD	T-STATISTIC (ADF)	*p*
Aug 2007 – Oct 2008	-3.986**	3
Oct 2008 – Dec 2011	-7.078**	3
Dec 2011 – Sep 2012	-3.568**	2

** and * indicate statistical significance at 1 % and 5 % level, respectively.

The null hypothesis of $\gamma_1 = 0$ is rejected in each case, implying that there is a cointegrating relationship between the variables.

Appendix H. Correlation matrices

9 August 2007 – 14 October 2008:

k=3M	EURIBOR-OIS_3M	EUREPO-OIS_3M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_3M		0.41681	0.48312	0.16636	-0.77164	0.54661
EUREPO-OIS_3M	0.41681		0.45048	0.41659	-0.69800	0.32024
VSTOXX	0.48312	0.45048		0.53485	-0.64883	0.51121
CDS	0.16636	0.41659	0.53485		-0.48704	0.22246
XCCY_SWAP	-0.77164	-0.69800	-0.64883	-0.48704		-0.52872
Ln_OMOs	0.54661	0.32024	0.51121	0.22246	-0.52872	

k=6M	EURIBOR-OIS_6M	EUREPO-OIS_6M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_6M		0.58553	0.62626	0.40459	-0.89939	0.57106
EUREPO-OIS_6M	0.58553		0.42317	0.36475	-0.64731	0.27184
VSTOXX	0.62626	0.42317		0.53485	-0.64883	0.51121
CDS	0.40459	0.36475	0.53485		-0.48704	0.22246
XCCY_SWAP	-0.89939	-0.64731	-0.64883	-0.48704		-0.52872
Ln_OMOs	0.57106	0.27184	0.51121	0.22246	-0.52872	

k=12M	EURIBOR-OIS_12M	EUREPO-OIS_12M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_12M		0.54750	0.69000	0.63174	-0.90817	0.52091
EUREPO-OIS_12M	0.54750		0.31643	0.29172	-0.52296	0.16822
VSTOXX	0.69000	0.31643		0.53485	-0.64883	0.51121
CDS	0.63174	0.29172	0.53485		-0.48704	0.22246
XCCY_SWAP	-0.90817	-0.52296	-0.64883	-0.48704		-0.52872
Ln_OMOs	0.52091	0.16822	0.51121	0.22246	-0.52872	

15 October 2008 – 7 December 2011:

k=3M	EURIBOR-OIS_3M	EUREPO-OIS_3M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_3M		0.18567	0.89814	0.21276	-0.70268	0.27331
EUREPO-OIS_3M	0.18567		0.15594	-0.66061	0.36712	0.51762
VSTOXX	0.89814	0.15594		0.28817	-0.66418	0.30375
CDS	0.21276	-0.66061	0.28817		-0.61721	-0.51746
XCCY_SWAP	-0.70268	0.36712	-0.66418	-0.61721		-0.025641
Ln_OMOs	0.27331	0.51762	0.30375	-0.51746	-0.025641	

k=6M	EURIBOR-OIS_6M	EUREPO-OIS_6M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_6M		0.24679	0.90739	0.23455	-0.73085	0.28806
EUREPO-OIS_6M	0.24679		0.25165	-0.61233	0.27863	0.57306
VSTOXX	0.90739	0.25165		0.28817	-0.66418	0.30375
CDS	0.23455	-0.61233	0.28817		-0.61721	-0.51746
XCCY_SWAP	-0.73085	0.27863	-0.66418	-0.61721		-0.025641
Ln_OMOs	0.28806	0.57306	0.30375	-0.51746	-0.025641	

k=12M	EURIBOR-OIS_12M	EUREPO-OIS_12M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_12M		0.091536	0.88665	0.42556	-0.80151	0.11003
EUREPO-OIS_12M	0.091536		0.26376	-0.58479	0.24131	0.58631
VSTOXX	0.88665	0.26376		0.28817	-0.66418	0.30375
CDS	0.42556	-0.58479	0.28817		-0.61721	-0.51746
XCCY_SWAP	-0.80151	0.24131	-0.66418	-0.61721		-0.025641
Ln_OMOs	0.11003	0.58631	0.30375	-0.51746	-0.025641	

8 December 2011 – 27 September 2012:

k=3M	EURIBOR-OIS_3M	EUREPO-OIS_3M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_3M		-0.78872	0.37098	0.22863	-0.87935	-0.86067
EUREPO-OIS_3M	-0.78872		-0.39209	-0.10394	0.74425	0.66263
VSTOXX	0.37098	-0.39209		0.78097	-0.64816	-0.32092
CDS	0.22863	-0.10394	0.78097		-0.58262	-0.10683
XCCY_SWAP	-0.87935	0.74425	-0.64816	-0.58262		0.70216
Ln_OMOs	-0.86067	0.66263	-0.32092	-0.10683	0.70216	

k=6M	EURIBOR-OIS_6M	EUREPO-OIS_6M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_6M		-0.72730	0.37650	0.23198	-0.87974	-0.84711
EUREPO-OIS_6M	-0.72730		-0.27249	0.021945	0.64579	0.58384
VSTOXX	0.37650	-0.27249		0.78097	-0.64816	-0.32092
CDS	0.23198	0.021945	0.78097		-0.58262	-0.10683
XCCY_SWAP	-0.87974	0.64579	-0.64816	-0.58262		0.70216
Ln_OMOs	-0.84711	0.58384	-0.32092	-0.10683	0.70216	

k=12M	EURIBOR-OIS_12M	EUREPO-OIS_12M	VSTOXX	CDS	XCCY_SWAP	Ln_OMOs
EURIBOR-OIS_12M		-0.66741	0.37741	0.22089	-0.87648	-0.84024
EUREPO-OIS_12M	-0.66741		-0.15237	0.15045	0.52234	0.51907
VSTOXX	0.37741	-0.15237		0.78097	-0.64816	-0.32092
CDS	0.22089	0.15045	0.78097		-0.58262	-0.10683
XCCY_SWAP	-0.87648	0.52234	-0.64816	-0.58262		0.70216
Ln_OMOs	-0.84024	0.51907	-0.32092	-0.10683	0.70216	