LUT School of Business and Management

Strategic Finance and Business Analytics

Master's Thesis

Liquidity risk management in banks
- evidence from the Eurozone during 2006-2014 period

Samuli Mero, 2019

Examiners: Research Fellow Jan Stoklasa

Professor Eero Pätäri

ABSTRACT

Author:	Samuli Mero
Title:	Liquidity risk management in banks
	- evidence from the Eurozone during 2006-2014 period
Faculty:	School of Business and Management
Master's Programme	Strategic Finance and Business Analytics
Year:	2019
Master's Thesis:	Lappeenranta University of Technology
	71 pages, 5 figures, 7 tables and 2 appendices
Examiners:	Research fellow Jan Stoklasa
	Professor Eero Pätäri
Keywords:	liquidity risk, liquidity risk management, liquidity risk exposure, banks

The purpose of this thesis is to examine the liquidity risk in banks of the Monetary Union during the credit- and sovereign debt crisis. The special focus is on the relationship between liquidity risk exposure and liquidity risk management. The selected bank balance sheet variables and quarterly changes in them are used in fixed effects panel regression as proxies for liquidity risk exposure and liquidity risk management following the procedure of Cornett et.al. (2011).

The literature review presents the theory and previous studies about the liquidity risk and liquidity risk management in banks. In the empirical part, the theories and previous studies are tested with the sample that includes listed banks that operated in the Monetary Union during the 2006-2014 period. The sample is divided in to two subperiods (2006-2009 and 2010-2014) to examine possible differences between credit- and sovereign debt crisis, and the banks are divided into three size groups (small, medium and large) to examine effects of the banks size. The results indicate that banks in the Monetary Union manage their liquidity risk by increasing their holdings of liquid assets and by decreasing lending. Strong evidence is found, that illiquid assets portfolio is related to an increased liquidity risk management across the crisis periods and size groups. Some evidence is also found that equity capital plays a different kind of role between large and small banks when liquidity risk management is considered. The results of this thesis are consistent with the previous studies conducted in the U.S market apart from the role of deposits as a proxy for the liquidity risk exposure.

Tiivistelmä

Tekijä:	Samuli Mero
Tutkielman nimi:	Pankkien likviditeettiriski Euroalueella vuosina 2006-2014
Tiedekunta:	Kauppatieteellinen tiedekunta
Pääaine:	Strategic Finance and Business Analytics
Vuosi:	2019
Pro Gradu -tutkielma:	Lappeenrannan teknillinen yliopisto
	71 sivua, 5 kuvaajaa, 7 taulua and 2 liitettä
Tarkastajat:	Tutkijatohtori Jan Stoklasa
	Professori Eero Pätäri
Hakusanat:	likviditeettiriski, likviditeettiriskin hallinta, likviditeettiriskille altistuminen, pankit

Tämän tutkielman tarkoituksena on tutkia Euroalueen pankkien likviditeettiriskiä finanssi- ja velkakriisin aikana. Ensisijaisena tutkimusalueena toimii likviditeettiriskin hallinnoinnin ja likviditeettiriskille altistumisen välinen suhde. Tutkimus suoritetaan kiinteiden vaikutusten mallin paneeliregressiolla, jossa valitut pankkien tasearvot ja niiden kvartaalitason muutokset kuvaavat pankin likviditeettiriskille altistumista ja likviditeettiriskin hallinnointia. Valittu regressiomalli jäljittelee Cornett. et.al. (2011) tutkimuksessa käytettyä mallia.

Pankkien likviditeettiriskiä ja sen hallinnointia käsittelevä teoria sekä aikaisemmat tutkimukset aiheesta esitellään kirjallisuuskatsauksessa. Empiirisessä osuudessa näitä teorioita ja tutkimustuloksia testataan tutkimusaineistolla, joka koostuu Euroalueella vuosien 2006-2014 aikana toimineista listautuneista pankeista. Tutkimuksen aikaperiodi on jaettu kahteen osaperiodiin (2006-2009 ja 2010-2014), jotta voidaan tutkia finanssi- ja velkakriisin mahdollisia eroavaisuuksia. Tutkimusaineiston pankit on myös jaettu kolmeen ryhmään koon perusteella (pienet, keskisuuret ja suure), mikä mahdollistaa pankin koon vaikutusten tutkimisen.

Tulosten mukaan Euroalueen pankit kasvattavat likvidien varojensa määrää ja vähentävät lainanantoa hallinnoidessaan likviditeettiriskiään. Epälikvideillä varoille on vahva suhde likviditeettiriskin kasvaneeseen hallinnointiin kaikissa kokoluokissa sekä molempien kriisien aikana. Oman pääoman ja likviditeettiriskin hallinnoinnin välinen suhde näyttäisi tulosten pohjalta olevan riippuvainen pankin koosta. Tutkimustulokset ovat linjassa Yhdysvalloissa tehtyjen aiempien tutkimusten tulosten kanssa lukuunottamatta talletusten vaikutusta likviditeettiriskille altistumiseen.

Aknowledgements

The writing of this thesis was very demanding and eventually a very long project with lot of setbacks. That said, I feel very rewarded now that the writing has come to an end. The final version is very different from the one I imagined at the onset of this project, but I feel, that if everything had happened the way it was planned, I would have learned much less that I did now. I want to thank research fellow Jan Stoklasa for all the comments and guidance, that I received during the writing process and Lappeenranta University of Technology for providing me with the tools needed to complete my research.

I also want to thank the whole community in Lappeenranta, who were with me in my journey towards graduation. My friends made the life outside of university meaningful and the staff in LUT provided me with the knowledge needed to graduate and to succeed in my future career. I have made some lifelong friends during my time in Lappeenranta, which makes all the long hours in the university worth it. I also want to thank my current employer for the flexibility in the working hours required for me to finish the writing process.

Finally, I want to thank my mother and all my friends in Helsinki for pushing me to apply to the university in the first place and for the support you gave during these 5 years.

In Helsinki, 1.1.2019

Samuli Mero

Contents

1 Introduction and background 8

1.1 Objectives and research questions 10

1.2 Structure of the thesis 12

2 Theoretical background 13

2.1 Liquidity risk 13

2.2 The Spread between secured and unsecured interest rates 18

2.3 Panel regression 20

2.3.1 One-way error component model 20

2.3.2 Two-way error component model 23

3 Generic background of liquidity crises and regulation 25

3.1 Liquidity crises 25

3.2 Regulation 30

3.3 Previous studies of liquidity risk exposure and management 32

4 Data and Methodology 35

4.1 Variables 37

4.2 Decomposition of the Euribor -spread 40

4.3 Model 42

5 Empirical results 44

5.1 Liquidity risk management 44

5.2 Descriptive statistics 45

5.3 The credit crisis (2006-2009 period) 53

5.4 The sovereign debt crisis (2010-2014 period) 56

6 Conclusions 59

List of figures

Figure 1 Linkages between different types of liquidity (risk). (Nikolau 2009)..... 13
Figure 2 Euribor -spread in the 1.1.2006 – 31.12.2014 period..... 26
Figure 3 Decomposition of the Euribor -spread between 1/2006 – 12/2014..... 40
Figure 4 Average liquid assets to assets (percentage) of the whole sample between 2006 and 2014 44
Figure 5 Average loans to assets (percentage) of the whole sample between 2006 and 2014 . 45

List of tables

Table 1. Number of banks in the sample 36
Table 2 Pairwise correlation matrix (2006-2009 period)..... 45
Table 3 Pairwise correlation matrix (2010-2014 period)..... 45
Table 4 Summary statistics of dependent variables..... 49
Table 5 Summary statistics of bank characteristics..... 51
Table 6 Regression results for 2006-2009 period..... 53
Table 7 Regression results for 2010-2014 period..... 56

1 Introduction and background

When the risk exposure of the banks is considered, the researchers and regulators had mainly focused on the banks credit risk and capital requirements instead of liquidity risk prior to the onset of the credit crisis of 2008. During the 2008 crisis and the sovereign debt crisis that followed in the Europe, many financial institutions went bankrupt or had to be bailed out by governments due to the insufficient liquidity to meet their obligations. This global liquidity shortage was caused by the uncertainty about counterparty's risk exposure to the "toxic" assets, which dried up the main liquidity channels for banks, the interbank and the asset market, causing banks to hold on to their liquid assets and decrease lending (De Socio 2013). The failure by the traditional regulations and policies to prevent the crisis spurred the need for new research about the liquidity risk exposure and management in the banking sector.

To avoid misconceptions, the definitions of liquidity risk, liquidity risk exposure and liquidity risk management are in order. Machina and Rotschild (1987) define risk as "the probability of having a realization of a random variable different to the realization preferred by the economic agent". Nikolau (2009) converts this definition into context of liquidity risk, where the economic agent has a preference over liquidity and liquidity risk is defined as probability of not being liquid. Therefore, higher liquidity risk results in higher probability of becoming illiquid and vice versa.

Liquidity risk exposure can be defined in same manner as a set of variables, which influence the liquidity risk. In this thesis the focus is on the relation of liquidity risk and banks' balance sheet and therefore, liquidity risk exposure consists of selected balance sheet variables, which can either increase or decrease the probability of the bank becoming illiquid. In the framework of this thesis the liquidity risk management is defined as set of actions taken to avoid becoming illiquid or in other words to lower the liquidity risk. Similarly to the liquidity risk exposure, the liquidity risk management in this thesis consists of actions affecting the balance sheet variables of the banks.

The concept of the liquidity risk exposure of the banks was introduced already in the 1980s. Bryant (1980) and Diamond and Dybvig (1983) were among the first to explain the importance of banks in creating liquidity for the private sector and to justify the existence of deposit taking institutions. They showed that banks are the providers of insurance to private sector against consumption shocks by keeping the illiquid monetary items of the public in their balance sheet and providing liquidity to depositors and borrowers. On the other hand, this liquidity risk is managed by holdings of cash and liquid items in their balance sheets. Meanwhile banks also transform risk because they issue risk-free deposits and use the money from the deposits to grant risky loans as stated by the risk transformation theory (Diamond 1984).

The sources of liquidity risk started to gather more attention among the researchers after the credit crisis. The post-crisis research about the liquidity risk divides the risk to three parts: funding, market and central bank liquidity (risk). The linkages between the different sources of liquidity ensure the even allocation of liquidity during the normal times but are also the possible sources of global liquidity crises if the flows between them are distorted. The distortions are caused by the uncertainties about the liquidity risk of individual market participants. (Drehmann & Nikolau 2013, Heider, Hoerova, Holthausen 2015, Ferguson et al. 2007)

The view of the regulators in the late-1980s was that banking crises can be avoided with sufficient regulatory capital requirements. During the 1990s the regulation adapted to the changing situation and the regulators understood that some capital is better than other, in other words, some assets provide better risk protection. (Basel Committee on Banking Supervision (BCBS) 1988, BCBS 2004) During the 20th century, the researchers started to question the role of the banks capital as an uncontested provider of risk protection to all banks, despite their differing characteristic like the assets size, especially when liquidity risk is considered (see e.g Diamond and Rajan 2001, Gorton and Winton 2000, Berger and Bouwman 2009)

Other balance sheet items besides capital have also received attention from the researchers as they have attempted to understand, where the risk exposure of banks arises. Studies have shown that government insured deposits can be effective at lowering the liquidity risk exposure of banks during the turbulent times and that the insurances help to avoid the bank runs. The benefit of the hedge offered by deposits is greater when the timing of the liquidity needs is surprising

and not known in advance as would be the case with off-balance sheet items such as loan commitments, which can be realized by the borrowers at any time. Recent crises and especially the bailouts of the struggling large banks have also revealed the relationship between the size and the risk exposure of banks. (see e.g Gorton and Pennacchi 1990, Gatev, E., Schuermann, T., Strahan, P. 2009, O' Hara, M., Shaw, W. 1990)

Studies conducted in the US indicate, that the composition of bank's balance sheet is related to the liquidity risk of the bank. During the times of financial turmoil, the level of liquidity risk has had an impact on the credit production and risk taking of the banks. Banks with lower liquidity risk were able to continue the credit production during the crises whereas, the banks with higher liquidity risk had to cut down on new credit production and focus on hoarding the liquidity. (Cornett, McNutt, Strahan, Tehranian 2011, Khan, Scheule, Wu 2016)

The empirical studies of liquidity risk of banks have focused on the US market even though the last crisis and the following recession lasted longer in Europe. The financial markets in Europe are also more focused around banks than in US, which stresses the importance of understanding liquidity risk in European banks. The member countries of Monetary Union in Europe are not as closely connected as the states in US and there was a lack of unified banking regulation in the Monetary Union during the recent crises. The better understanding of the relation between liquidity risk and different items in banks' balance sheet and how these items affect the liquidity risk management in banks benefits the regulators and policy makers. Due to the limited studies in other markets than US, there is a need for further research on these topics in other geographic areas.

1.1 Objectives and research questions

The purpose of this thesis is to examine the liquidity risk management of banks in the Eurozone during the 2006-2014 period. The research will be done using two fixed effects panel regression models with change in liquid assets and change in loans as dependent variables, following the procedure by Cornett et. al. (2011). First area of interest is the relationship between the hoarding of liquidity and the liquidity risk exposure of banks' balance sheet. This is based on a hypothesis that banks manage their liquidity risk by increasing their holdings of liquid assets (see e.g. Cornett et. al. 2011, Malherbe 2014, Heider, Hoerova, Holthausen 2015). The natural continuum

is that banks cut down on lending since the loans are illiquid in banks perspective (Cornett et. al. 2011). Therefore, the second area of interest is the relationship between lending and liquidity risk exposure of banks' balance sheet. Previous studies (see e.g. Berger and Bouwman 2009, Mishkin 2011, Cornett et. al. 2011) also suggest that the size of bank plays an important role in the liquidity risk management of banks and therefore, the regression will be studied separately for large, medium and small banks in this paper. The division to size groups is done following the procedure of the European Central Bank, which is explained more thoroughly in the chapter 4.

The time period of this paper is divided into two subperiods. First one took place during 2006-2009 period and includes relatively peaceful pre-crisis period (2006 Q1 – 2007 Q2) together with the credit crisis (2007 Q3 – 2009 Q4). The second subperiod (2010-2014) includes the sovereign debt crisis (2010 Q1 – 2012 Q3) and the post-crisis period (2012 Q4 – 2014 Q4). The intensity of the crisis during different quarters is modelled by the spread between Euribor- and EONIA- interest rates (Euribor -spread), which is widely accepted indicator of the financial market distortions. (see e.g. Cornett et al. 2011, De Socio 2013,Taylor and Williams 2009, Beirne et al. 2012) Based on the composition of the Euribor-spread, the former crisis took place in the environment of high liquidity risk, whereas the high credit risk dominated the latter one. These consecutive crisis periods offer an interesting possibility to examine the possible differences in the liquidity risk exposure and management of banks between the two crises. Based on the discussion above, this thesis aims to answer to the following research questions:

1) How did banks in the Eurozone manage their liquidity risk during the Credit- and Sovereign debt -crises?
2) How was the bank's liquidity risk exposure related to the liquidity risk management during the crisis times in the Eurozone?
    a) How did the size of the bank relate to the liquidity risk exposure and liquidity risk management?
3) Were there any indifferences or similarities in the liquidity risk exposure of banks between the credit crisis and the sovereign debt crisis in the Eurozone?
    a) How is the composition of Euribor -spread related to the liquidity risk exposure and management of the Eurozone banks?

1.2 Structure of the thesis

The structure of this thesis is the following: Section 2 with theoretical framework consisting of introduction of liquidity risk, Euribor -spread and panel regression models. Section 3 with generic background, which includes presentation of the international banking regulation, recent liquidity crises and previous studies on the subject. Section 4 presents the data and methodology used in this paper including the regression variables. Section 5 includes the empirical results from the regressions and the descriptive statistics from the data. Finally, the results and conclusion are discussed in the Section 6.

2 Theoretical background

2.1 Liquidity risk

Liquidity in the financial system consist of flows among different agents working in the system. To prevent the financial entity of becoming illiquid these flows have to be realized. The most important forms of liquidity in the banking sector are central bank liquidity (the ability of central bank to supply the required amount of liquidity to the system), market liquidity (ability to sell an asset quickly with low transaction costs and at reasonable price) and funding liquidity (institutions ability to settle its obligations in a timely fashion). During normal times flows

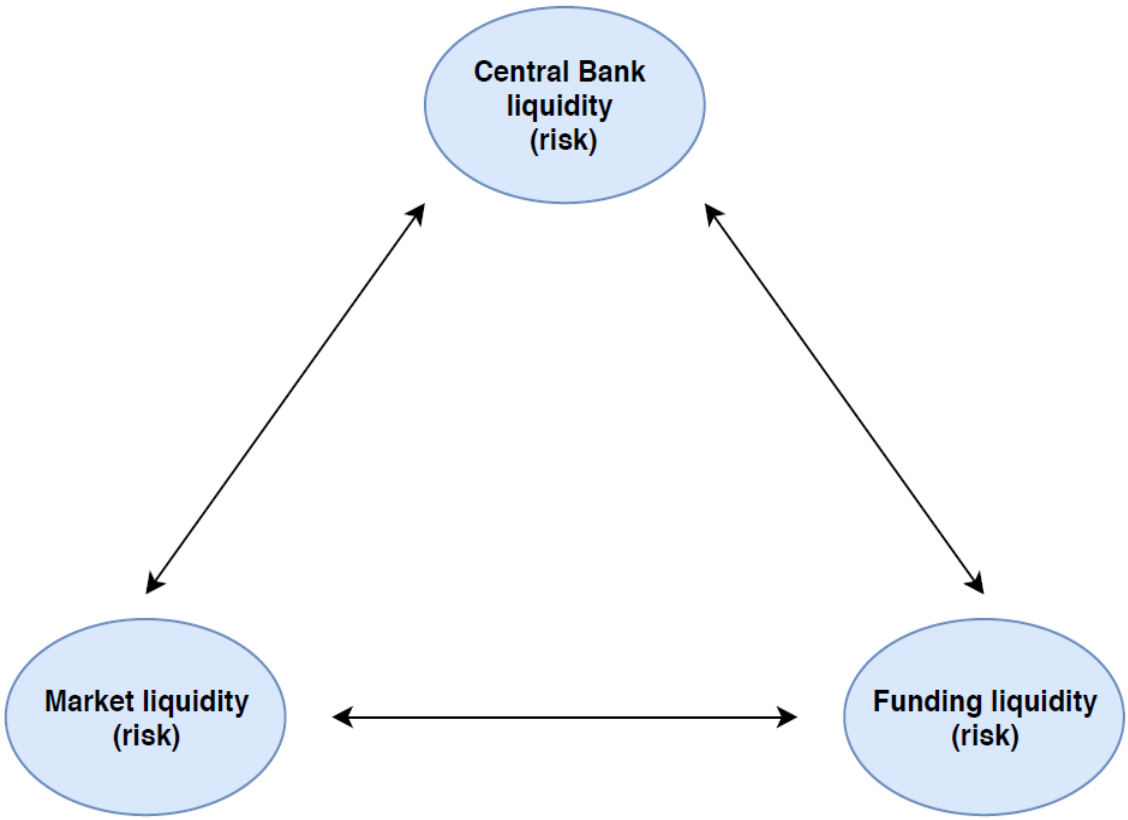

Figure 1 Linkages between different types of liquidity (risk). (Nikolau 2009)

among these sources of liquidity ensure the stability of the financial system but each source is also associated with the risk. (Nikolau 2009)

Funding liquidity risk has many definitions, but the consensus is that it measures the banks inabilities to settle their liabilities in time (IMF 2008). Definitions differ usually by the time horizon, which is used to measure the probability of the bank to become insolvent (Drehman and Nikolau 2013). To stay solvent, banks relay on four main sources of liquidity: deposits from depositors, sales of assets to the markets, interbank market for short term loans and direct funding from the central bank (Nikolau 2009). Drehmann (2007) states that funding liquidity risk implies to distortions of these flows in the banks budget restriction equilibrium, which also reveals the linkage between the marker liquidity and funding liquidity risks:

$$Cash\ Outflows\ \leq Cash\ inflows:$$

$$\text{Expenses } + Liabilities_{due} + Assets_{new,rolled\ over} + Off - Balance\ Sheet_{met-liquidity\ demand}$$

$$\leq$$

$$Income + Liabilities_{new,rolled\ over} + Assets_{due} + Value\ of\ Assets\ Sold$$

The role of the banks as intermediaries between depositors and investors exposes them to funding liquidity risk as they grant loans to the investors and fund them with deposits from depositors. By doing so banks face the structural risk associated with the maturities of these transactions because loans usually have long maturities whereas deposits can be withdrawn anytime by the depositors. (Bryant 1980, Diamond and Dybvig 1983, Strahan 2008). Banks also transform risk as the investors may default on their loan payments, but the deposits are considered to be risk-free for the depositor (Diamond 1984). Incomplete markets and asymmetric information can incite the depositors to withdraw their deposits from the bank, which combined with the banks structural risk can cause a failure of the bank (Nikolau 2009).

Market liquidity risk is the systematic part of the liquidity risk and relates to the inability to sell assets or acquire financing at fair price and without delays. It is usually low and stable during the normal market times but can have serious consequences for the financial system. (Nikolau 2009) Individual institution’s funding liquidity risk can lead to the failure of that financial

institution but could be beneficial for the system as a whole (Diamond and Dybvig 1983). The market wide systematic liquidity risk on the other hand has more severe consequences and it can be a starting point of financial crisis (Ferguson et al. 2007).

Nikolau (2009) explains that the linkages between the different types of liquidity (Picture 1) are crucial at understanding, how the system is able to provide liquidity during the normal times and why liquidity can dry up during the financial turmoil. During the normal times the European Central Bank (in Europe) provides the system with the amounts of liquidity, which balance demand and supply of liquidity. Market liquidity distributes and recycles that liquidity via functioning assets markets and the funding liquidity (banks) allocates the liquidity resources efficiently. This circle ensures that funding liquidity risk remains stable and banks are able to acquire the required liquidity. (Nikolau 2009)

Due to these linkages, funding liquidity risk of individual banks can transform into a system wide market liquidity risk. According to Nikolau (2009) there are two main channels from which the funding liquidity risk can transform into market liquidity risk: the interbank channel and the asset channel. During the crisis period both of these channels, that are commonly thought to be highly liquid, can be distorted by the problems considering asymmetric information and incomplete markets.

Asymmetric information about the counterparty's credit worthiness increases the incentive for safer, liquidity rich bank to leave the interbank market and hold on to their liquid assets rather than supplying liquidity to potentially illiquid banks. The loss of liquid banks from the interbank market sets upward pressure on the interest rates. Eventually the level of interest rate is too high for even the most illiquid banks causing them to leave the interbank market. (Heider, Hoerova, Holthausen 2015) Asymmetric information also distorts the allocation of liquidity and creates moral hazard, where insolvent banks might acquire liquidity instead of the solvent illiquid banks (Nikolau 2009). The hoarding of liquidity in face of future market illiquidity further distorts the allocation of liquidity in the system and reduces the liquidity creation of banks (Malherbe 2014, Cornett et al. 2011). Uneven liquidity flows and liquidity hoarding generate flight-to-quality phenomenon, where healthier banks acquire monopolistic position as liquidity providers in the interbank market and moral hazard, where two parties entering the transaction do not have the

same level of information regarding the transaction, can lead to exploitations of this position, which places further upward pressure to the price of liquidity. (Acharya, Gromb and Yorulmazer, 2007)

The above described problems in the interbank market can spread to the assets markets as banks have to liquidate their assets to prevent insolvency. This can lead to fire sales, where banks have to liquidate their assets below their fair values in a short time period. (Nikolau 2009, Diamond and Rajan 2009) In the short time period, the assets markets are inelastic to changes in supply and demand caused by the increased assets sales of banks, which can lead to increased volatility of the asset prices (Allen and Gale 2005). Asymmetric information about the quality of the assets at sale further distorts the functioning of the markets and the efforts of illiquid banks to acquire needed liquidity (De Socio 2013).

The second-round effects of the linkage between funding liquidity risk and market liquidity risk start the loop between them. Reasons for this vicious circle lie in mark-to-market accounting of balance sheet items and the regulatory framework considering capital adequacy. The increased asset sales and price volatility affect the balance sheet values of banks due to mark-to-market accounting, where assets are valued by their market prices. Deterioration of the balance sheet forces financial institutions into further asset sales to meet the capital adequacy regulations set upon them and increases the funding liquidity risk of the institutions, which again distorts the interbank markets. (Cifuentes, Ferrucci and Shin 2004)

The central bank liquidity risk is practically inexistent due to the fact that central bank holds monopoly as a provider of liquidity, but the costs associated with its actions affect the liquidity risk in the system (Nikolau 2009). Therefore, the focus is on the tools that central banks can utilize to prevent system wide liquidity shortages. In the Eurozone, the open market operations, standing facilities and reserve requirements are tools for managing money market liquidity and steering interest rates, and together these tools comprise the operational framework of the European Central bank. (Delivorias 2015)

The open market operations, which are the most commonly used for liquidity management, include maintenance refinancing operations (MROs), longer-term refinancing operations (LTROs), fine-tuning operations (FTOs) and structural operations. These operations are usually

conducted by entering into a reverse transactions, which include asset sales under the repurchase agreements or undertaking collateralized credit operations. Operations can also be conducted by performing outright transactions, issuing ECB debt certificates, engaging in foreign exchange swaps or collecting fixed term deposits. (Delivorias 2015)

The two available standing facilities are the marginal lending facility and the deposit facility, which allow banks to borrow or deposits funds overnight at their national central banks against eligible collateral. The interest rates offered in these transactions are usually worse than in the money market, which means that these facilities are used mainly in the absence of alternatives. (Delivorias 2015)

All banks in the Eurozone are required to keep a specific amount of minimum reserve funds on current account with the national central bank. The two key functions of the minimum reserve requirements are the stabilization of money market interest rates via the averaging provisions and the enlargement of the structural liquidity shortages in the banking system. The latter is also related to the effectiveness of the ECBs liquidity providing operations used to steer interest rates. (ECB 2011)

The central banks acts as a lender of last resort and aims to break down the loops between funding and market liquidity risks during the financial turmoil. The central bank liquidity risk differs from the other two components of the liquidity risk as central bank cannot become insolvent, but its actions might have an undesirable effect due to asymmetric information and moral hazard problems. Central bank might end up providing liquidity to the insolvent institutions instead of solvent but illiquid banks due to asymmetric information. This may result in increasing funding liquidity risk in these healthy banks. This breeds the moral hazard among the insolvent banks to participate into riskier investments with the available liquidity from the central bank. The actions of the central bank are targeted at minimizing the negative externalities of shocks to the financial system, but the prevention of the liquidity shortages relies on regulation and supervision. (Nikolau 2009)

2.2 The Spread between secured and unsecured interest rates

The spread between the unsecured and secured interest rate, for example Euribor – and EONIA -rates, is widely accepted indicator of distortions in the interbank market and the liquidity constraints in the financial system (Cornett et al. 2011, De Socio 2013,Taylor and Williams 2009, Beirne et al. 2012). This spread is small and stable during the normal times but increases during the financial crises because of liquidity and credit risk components. (De Socio 2013). Observations of this spread during the crisis times reveal the magnitude of financial sector distress during different phases of the crises (Cornett et al. 2011). Composition of risks included in the spread at different time periods can shed light to the effects of government and central bank interventions during the crisis times (Beirne et al. 2012).

The following four main components form the level of an interest rate in a term loan such as LIBOR –rate (McAndrews, Sarkar and Wang 2017):

1. The geometric average of overnight risk-free interest rates
2. The interest rate risk
3. The credit risk
4. The liquidity risk

On the other hand, the studies of the OIS –rate show that it reflects mainly the expectations of future risk-free rates and premium of the interest rate risk containing a little or none premium of the credit or liquidity risk (Sundaresan, Wang and Yang 2016). Therefore, after subtracting the OIS –rate from the LIBOR – rate, the resulting spread is mainly composed of the credit and liquidity risk premium and this composition of the spread is widely accepted by the researchers (e.g. Hui et al. 2013, McAndrews et al. 2017, Michaud and Upper 2008). The credit risk component affects the level of the spread because of the uncertainty that the counterparty is able to pay back the loan whereas liquidity risk affects the level of the spread in case the bank is afraid of becoming illiquid before the loan is paid back. (De Socio 2013)

Many researchers have used the Credit Default Swap (CDS) –spreads as a proxy for the credit risk component in the LIBOR-OIS –spread. CDS –contracts offer insurance for the lender as the

seller of the CDS agrees to cover the losses of lender in case of a default by the borrower. Higher CDS –spreads are related to the loans of more risky borrowers reflecting the risk of default. (McAndrews et al. 2017) The credit risk component can be derived from the CDS –spreads of individual banks using the following methodology (Hull 2006):

$$PD \approx 1 + e^{(\frac{-CDS}{1-R})}$$

where PD is the probability of default and CDS is the CDS spread of the individual bank.

First the implicit probability of default (PD) is calculated using the average default intensity of the banks by dividing the CDS –spread with 1-R, where R stands for the recovery rate. The credit spread included in an unsecured loan is equal to the expected loss:

$$Credit\ spread = PD * (1 - R)$$

The credit risk component of the LIBOR -spread is the average of the credit spreads of the banks in the dataset.

An important feature of the good proxy for the credit risk is that it should not be related to the liquidity risk component. Michaud and Upper (2008) found out that the CDS –premium of the banks was not related to liquidity operations of central bank even though these operations did affect the LIBOR –spread. CDS –spreads of the banks in the Euribor –panel were found to be not related to the measures of market liquidity during the subprime crisis (De Socio 2013).

Only the liquidity risk component should remain in the LIBOR –spread after subtracting the credit risk component from it based on the composition of term loan interest rate resulting in the following formula for the composition of LIBOR –spread (Bank of England 2007):

$$LIBOR - OIS = CDS + Liquidity\ risk$$

This methodology was first proposed by the Bank of England (2007) and has been used in many papers for the purpose of studying the composition of LIBOR –spread during the crisis times. Researchers also notice that the unexplained part of the spread probably includes some other factors besides the liquidity premium but in the absence of reliable proxies for the liquidity risk, the unexplained part of the spread is often assumed to be the liquidity risk premium component. (De Socio 2013, McAndrews et al. 2017)

2.3 Panel regression

This section covers the theoretical background of panel data regression used in this thesis. Only theory about fixed effects regression with one- and two-way error component models are described because the random effects model is not used in this thesis.

2.3.1 One-way error component model

Panel data contains more data and therefore more information than simple cross-sectional or time-series data. It also reduces the problems with multi-collinearity and gives more degrees of freedom, which lead to better results. With panel data we can also identify heterogeneity of individual cross-sections. Panel data regression takes a following form:

$$y_{it} = \alpha + \beta X_{it} + u_{it} \quad (1)$$

where i denotes the cross-sectional dimension (i = 1,…,N) and t denotes the time dimension (t = 1,…,T), α is an intercept term, β is a K x 1 vector and the X_{it} is the itth observation on K independent variables (1 x K vector). (Baltagi 2005 pp.11)

Equation 1 can be written in matrix form:

$$y = \alpha \iota_{NT} + \mathrm{X}\beta + \mathrm{u} = \mathrm{Z}\delta + \mathrm{u} \quad (2)$$

where y is NT x 1, X is NT x K, Z = $[\iota_{NT}, X], \delta' = (\alpha', \beta')$ and ι_{NT} is a vector of ones of dimension NT.

Based on the research dataset we can choose different kind of model specifications. The most suitable model can be found with Hausman test. The results of this test indicate if it is possible to use the fixed effects model or random effects model. Further testing with F-test and Breusch-Pagan test will reveal if pooled OLS model is most suitable. (Brooks 2008)

The error term in one-way error component model can be written as:

$$u_{it} = \mu_i + v_{it} \quad (3)$$

where μ_i stands for unobserved individual-specific effect and v_{it} denotes the disturbance that remains after individual effects. μ_i is time invariant and it captures individual-specific effects that are accounted for in the regression. v_{it} can be thought of as a usual error term in a regression as it varies with individuals and time.

The equation 3 for the error term can be written in the matrix form:

$$\mathrm{u} = Z_\mu \mu + v \tag{4}$$

where $\mathrm{u}' = (\mathrm{u}_{11}, \ldots, \mathrm{u}_{1T}, \mathrm{u}_{21}, \ \ldots, \mathrm{u}_{2T}, \ldots, \mathrm{u}_{N1}, \ldots, \mathrm{u}_{NT})$ and Z_μ is a selector matrix of individual dummies that can be included into the regression if μ_i's are assumed to be fixed: $\mu' = (\mu_1, \ldots, \mu_N)$ and $v' = (v_{11}, \ldots, v_{1T}, \ldots, v_{N1}, \ \ldots, v_{NT})$. (Baltagi 2005 pp. 11)

In fixed effects model we assume that μ_i are fixed parameters and v_{it} are independent and identically distributed. The explanatory variables are assumed to be independent of the v_{it} for all time periods and individuals. This model is useful when we are studying a specific set of N individual firms, countries or states as our inference is conditional on the set of N individuals that are observed. (Baltagi 2005 pp. 11)

The equation 1 becomes

$$y_{it} = \alpha + \beta X_{it} + \sum_{i=1}^{N} \mu_i D_i + v_{it} \tag{5}$$

Where D is a dummy variable representing an individual firm, country or state. To avoid a problem of perfect multicollinearity between the intercept and the dummy variables, the so called dummy variable trap, there is a restriction on μ's given by $\sum_{i=1}^{N} \mu_i = 0$. The OLS estimator for this equation is the best linear unbiased estimator (BLUE) but two problems arise. The loss of degrees of freedom results because we need to estimate N+K+1 parameters and there is a risk of multicollinearity problems due to the large number of dummy variables. We can average the equation 1 over time and get:

$$\bar{y}_{i.} = \alpha + \beta \bar{x}_{i.} + \bar{v}_{i.} \tag{6}$$

where we have average variable values for each individual through all of the time periods.

We can now subtract the average values over time (equation (6)) from equation (1) to get the demeaned values of variables:

$$y_{it} - \bar{y}_i = \beta(x_{it} - \bar{x}_i) + (v_{it} - \bar{v}_i) \tag{7}$$

which can also be written as:

$$\ddot{y}_{it} = \beta\ddot{x}_{it} + \ddot{v}_{it} \tag{8}$$

which utilizes the restriction $\sum_{i=1}^{N} \mu_i = 0$. Equation 8 can now be estimated by running OLS without the earlier mentioned problems and the resulting estimator β is called a least squares dummy variable estimator (LSDV). If the assumption that v_{it} has a zero mean and variance covariance matrix of $\sigma_v^2 I_{NT}$ the LSDV estimator is BLUE. (Baltagi 2005 pp. 13, Brooks 2008 pp. 529)

In a matrix form we can create a fixed effects model by substituting the disturbances from the equation 2 to equation 4 resulting in:

$$y = \alpha\iota_{NT} + \mathrm{X}\beta + Z_\mu\mu + v = \mathrm{Z}\delta + Z_\mu\mu + v \tag{9}$$

We can multiply the model by Q, which is the orthogonal projection of Z_μ and perform OLS to obtain the least squares dummy variables (LSDV) estimator:

$$Q_y = QX\beta + Q_v \tag{10}$$

The Q matrix wipes out the individual effects because $QZ_\mu = Q\iota_{NT} = 0$, since $PZ_\mu = Z_\mu$. Due to the fact that the individual effects are wiped out, the fixed effects estimator is unable to estimate any time-invariant variables. (Baltagi 2005 pp. 12)

Arellano (1987) pointed out that even though v_{it} are assumed to be independently distributed across individuals, heteroskedasticity and serial correlation are allowed into the model because the lack of restrictions for the form of autocovariances for a given individual. He suggested a method for obtaining a robust standard errors for the within estimator to allow for a general variance-covariance matrix on the v_{it} similar to White (1980). This method includes stacking a panel as an equation for each individual:

$$y_i = \mathrm{Z}_i\delta + \mu_i\iota_T + v_i \tag{11}$$

where y_i = T x 1, $Z_i = [\iota_T, X_i]$, X_i = T x K, μ_i is a scalar, $\delta' = (\alpha, \beta')$, ι_{NT} is a vector of ones of dimension T and v_i is T x 1. The zero-mean assumption for the v_i still holds. The following formula results from performing the within estimator for the equation 11:

$$\tilde{y}_i = \beta \tilde{x}_i + \tilde{v}_i \tag{12}$$

The robust least squares can be calculated from the equation 12 following White's (1980) procedure by placing a restriction for each equation to have a same β one gets the within estimator of β. (Arellano 1987)

2.3.2 Two-way error component model

Wallace and Hussain (1969) among others presented a two-way error component model, which is similar to the one-way error component model equation 3 but with two-way error components disturbances:

$$u_{it} = \mu_i + \lambda_t + v_{it} \tag{13}$$

where λ_t denotes the unobservable time-specific effect not captured by the model and other components are like in the equation (3). λ_t is individual invariant and can account for extraordinary time period effects like for example strike year.

Equation 13 can be written in vector form:

$$\mathrm{u} = Z_\mu \mu + Z_\lambda \lambda + v \tag{14}$$

where Z_λ is the matrix of time dummies, which can be used in regression to estimate λ_t in case they are fixed parameters and $\lambda' = (\lambda_1, \ldots, \lambda_T)$. Other parts of the equation are as in equation 4. (Wallace and Hussain 1969)

The traditional assumptions about the error term v_{it} are as in the one-way error component model and the two-way model suffers from similar estimation problems as one-way model regarding the large number of dummy variables in the regression [(N-1) + (T-1)]. The within transformation that sweeps out the individual and time specific effects is needed to estimate the model. (Wallace and Hussain 1969)

Averaging the equation (1) over individuals, time and all observations by utilizing the restrictions $\sum_i \mu_i = 0$ and $\sum_t \lambda_t = 0$ results in:

$$(y_{it} - \bar{y}_{i.} - \bar{y}_{.t} - \bar{y}_{..}) = \beta(x_{it} - \bar{x}_{i.} - \bar{x}_{.t} - \bar{x}_{..}) + (v_{it} - \bar{v}_{i.} - \bar{v}_{.t} - \bar{v}_{..}) \quad (15)$$

and we can get the within estimator $\tilde{\beta}$ by running OLS on the equation above. Time or individual invariant variables will be wiped out and cannot be estimated unlike in the one-way model where only time invariant variables were wiped out. The one-way model suffers from omission bias in case the time dummies are found to be statistically significant. (Baltagi 2005)

3 Generic background of liquidity crises and regulation

3.1 Liquidity crises

The recent financial crises provide a real-world example of how the shocks to the financial system distorted the flows of liquidity within the liquidity circle described in the previous chapter. This resulted in liquidity shortages in the financial system, failure of some major financial institutions and finally downturn in the economies around the world.

The credit crisis started from the housing markets of United States in the summer of 2007. The drop in the housing prices revealed the low credit worthiness of borrowers as it led to large number of defaults in mortgages. These events materialized the risks included in the mortgage backed securities (MBS) and made the valuation of these instruments difficult. Financial institutions that held these MBS's in their balance sheets found it difficult to borrow against them, which lead to liquidity problems and fire sales of these assets. (Diamond and Rajan 2009)

The reinforcing feedback loop between market and funding liquidity risk together with increased credit risk was in the center of the development of crisis as the problems in the asset markets spread into interbank market (Borio 2010). Asymmetric information between banks about the proportions of their holdings in these "toxic" assets distorted the interbank market and the liquidity in the markets dried up (De Socio 2013). European banks were highly exposed to the problems in the asset-backed security markets of United States and the crisis quickly spread to Europe as well (Lane 2012). The effects of the first phase of credit crisis can be observed from the first peak of the Euribor -spread at the end of 2007. (Figure 2).

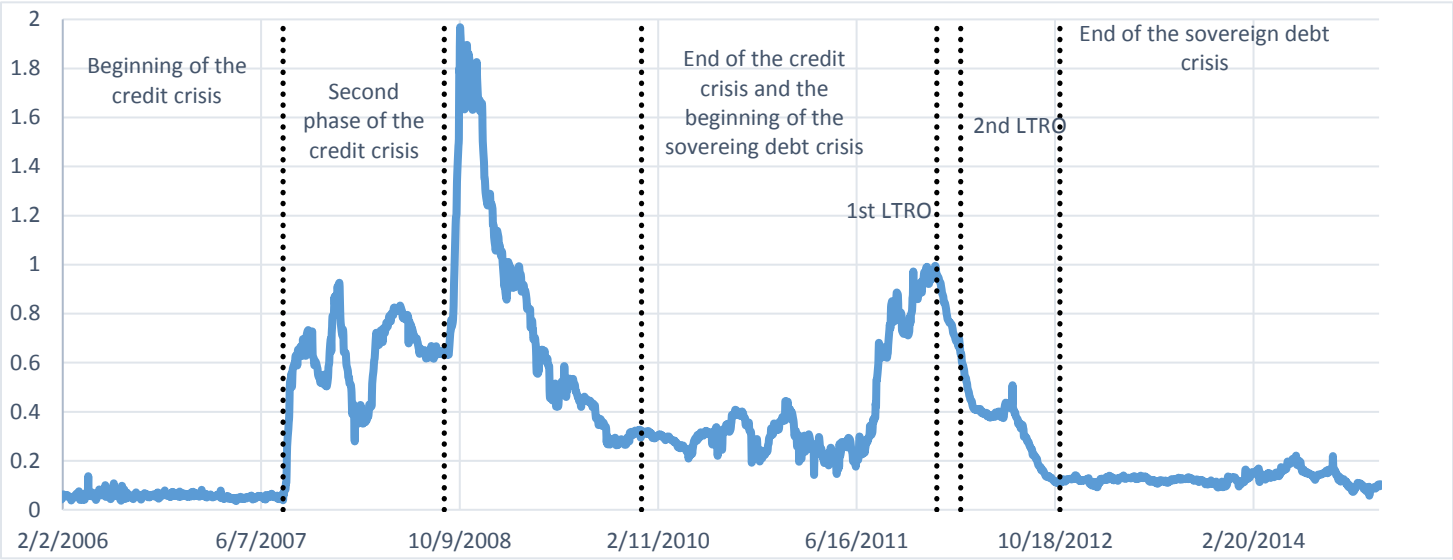

Figure 2 Euribor -spread in the 1.1.2006 – 31.12.2014 period

The central banks of EU and US took action to increase the available liquidity in the markets. On the onset of the crisis in the summer of 2007, the European central bank (ECB) reacted to the liquidity shortages immediately with open market operations by providing unlimited overnight funds to the banks against eligible collateral between the 9th and 14th of August. During the following months, supplementary LTROs were also initiated with the maturities of three and six months. (ECB 2010)

On December 12, 2007, The Federal Reserve announced about the initiation of a temporary Term Auction Facility (TAF), which allows banks to borrow funds against permissible collateral. TAF was linked to the ECB through foreign exchange swap operations, which focused on reducing the dollar shortages of banks in the Eurozone caused by the reduced cross-border lending. (Frank and Hesse 2009) These actions succeeded at decreasing the Euribor -spread temporarily before the second phase of the crisis began (Figure 2).

The second phase of the crisis started in the last quarter of 2008 when the investment bank Lehman Brothers went bankrupt. Three equally important events quickly followed when during a single day, the investment company AIG collapsed and Reserve Primary Fund (RPF) exhibited a run, and not long after that Federal Reserve confronted difficulties at passing the Troubled Asset Relief Plan (TARP). The fall of Lehman together with the troubles of AIG and RPF made

market aware that the risk taking in the asset markets had been significantly higher than first proposed, which lead to an increased market liquidity risk. Also, the struggle with TARP made markets unaware about the competence of the government to deal with the crisis. (Mishkin 2011)

The major central banks around the world reacted to the second phase by lowering their policy interest rates (Delivorias 2015). On the 8th of October 2008, ECB announced the reduction of their policy interest rates and about the adoption of non-standard measures, which included transformation to the fixed rate allotment in all refinancing operations and extensions in the list of assets accepted as eligible collateral (ECB 2010).

In May 7 of 2009, ECB announced the release of three supplementary LRTOs with one-year maturity with settlement dates in June, October and December of 2009 (ECB 2009). During the same year in efforts to save the deteriorating covered bond market, ECB launched the covered bond purchase program in the June of 2009, which involved purchases of covered bonds from the primary and secondary markets with the amount of 60 billion euros between the June 2009 and June 2010 (Beirne et al. 2011)

However, the effectiveness of central bank liquidity injections around the world suffered as banks decided to hold on to acquired liquidity instead of lending it forward. Eventually, the liquidity injections revived the interbank market together with the stress tests designed to measure the vulnerability of the major banks. (Mishkin 2011) The huge drop in the Euribor - spread reflects the ending of the crisis in the US but the spread remains above the pre-crisis levels indicating that the turbulences did not disappear totally in the EU (Figure 2).

The creation of single currency union meant that single European nations could all borrow at same currency. This created concerns about the possibility that some countries would exploit this opportunity and take extensive amounts of debt compared to their GDP. To cope with this problem, the current account deficits and the amount of public debt compared to the nations GDP were restricted together with the creation of “no-bailout” clause, which stated in the presence of the failure of government to meet its obligations the sovereign default would occur. However, the lower interest rates and the availability to raise cross border liquidity in domestic currency increased the credit activities of Eurozone banks and led to greater imbalances in the

current account deficits among the countries in the Eurozone. This credit boom intensified especially in the pre-crisis period of 2003-2007. (Lane 2012)

The cross-border bank lending increased dramatically in the pre- credit crisis periods, especially between the developed countries, creating capital flows between these countries. Banks in the Eurozone had a great presence in the United States and vice versa, which lead to increases in market liquidity risk in the Eurozone as well, when the problems in the US began. Banks decreased cross-border lending, which decreased the available liquidity in the Eurozone. During the crisis periods investors also started to pull out their foreign investments, which decreased the capital flows between Europe and United States and alongside the falling assets prices deepening the liquidity shortages. (Milesi-Ferretti and Tille 2011) The size of the banking system related to financial system is much larger in the Eurozone than in United States and borrowers rely more heavily on the bank liquidity, which emphasizes the effects of bank crisis to the economy (Shambaugh, Reis, Rey 2012).

The large sovereign debt and imbalances in the current account deficits in the Eurozone started to draw attention after the peak of the banking crisis had passed in 2009 and the economic recovery had started in many countries. The government spreads between government bond yields in the Eurozone, which in most part only reflect the differences between country risk of nations, started to increase in 2010. Greece, Ireland and Portugal were cut down from the bond markets and required bailouts during 2010-2011. During the 2011 the yields of Italy and Spain were also elevated causing concerns about the credit worthiness of the countries. (Lane 2012)

The credit crisis and the sovereign debt crisis in the Eurozone had a strong connection. The holdings of European banks in troubled assets in the asset-backed securities in US was primary concern during the credit crisis. European banks also hold large portions of the government debt in their balance sheets, which started raising concerns after the spreads between the government bond yields began to increase. (Shambaugh et al. 2012) The holding of government debt in largest Greek banks were over 100 % of their Tier 1 equity capital (IMF 2011). Similar proportions of government debt were also found from the balance sheets of Italian, Belgian and Spanish banks (OECD 2011). Because of the magnitude of these holdings, the loss in the value

of government debt, would have resulted in a complete loss of capital in these banks (Shambaugh et al. 2012).

ECB reacted to these problems and introduced the Securities Market Programme in May 10 2010. Under the programme, ECB purchased sovereign bonds from the Euro banks in the secondary markets and its volume at the peak totaled at 210 billion euros. This was followed by the increases in the Core Tier 1 Capital requirements, which further increased the market turbulence and showed the need for additional interventions from the ECB. (Delivorias 2015)

ECB addressed the problems considering bank liquidity by proving troubled banks with long-term refinancing operations (LTRO) that took place in December 2011 and in February 2012. LTROs included low interest rate loans with three-year maturities and purchases of government debt securities from the balance sheets of the banks. On top of that, the governments started providing the troubled banks with funds and guarantees because the solvency issues of banks were not under the ECBs jurisdiction but were treated as national concerns. (Shambaugh et al. 2012) The evolution of the Euribor -spread reveals that these actions were effective as the spread dropped very close to its pre-crisis level at the end of 2012, marking an end of the long-lasting turbulent times in the interbank market (Figure 2).

3.2 Regulation

The international banking regulation started in 1974 when the Committee on Banking Regulations and Supervisory Practices (The Basel Committee) was established. The first goal of the Committee was to unify the banking supervision across the countries so that every bank in the world would be under the adequate and consistent supervision. (BIS 2018) After the principles of unified banking regulation were set, the focus of banking regulation has been heavily on the capital requirements of banks since the publication of the Basel 1 (Arnold et. al. 2012).

In 1988 the Basel 1: Basel Capital Accord was published to unify the differing national capital requirements for banks around the world. The minimum ratio of capital to risk-weighted assets was set to 8 % in the original Accord. During the following decade, new amendments were included into the Accord. The most notable amendment in 1996 allowed banks to address market risk alongside credit risk and to use internal value-at-risk models when measuring their capital requirements. (BIS 2018) During the 20th century, the original ideology of accord, in which more capital was perceived as good and capital requirements were based solely on the credit risk of banks, started to feel too restrictive and narrow leading up to the publication of the Basel 2 (Arnold et. al. 2012).

Basel 2 was released in 2004 and its framework was built on three pillars:

1. Minimum capital requirements
2. Supervisory review process
3. Market discipline

The committee aimed at improving risk-sensitivity of capital requirements by expanding and developing the rules set out at 1988 and to address the new innovations in the financial markets. In 2006 the committee released a revised version of Basel 2, which focused also into the treatment of banks trading book under the new framework. (BIS 2018) The most important revisions compared to the Basel 1 were the understanding that also other risk than credit risk should affect the regulatory capital requirements, moving the focus of credit risk weights to the

obligors creditworthiness rather than obligors category type and the allowance for the banks to use their own models for assessing risk under independent supervisory evaluation (Arnold et. al. 2012).

The framework of Basel II was not strong enough to prevent the banks at entering the financial crisis of 2008 with too high leverage and too weak liquidity buffers. Basel III was created as a response to the financial crisis of 2008 but the need for change was acknowledged even before the crisis. The Committee published "Principes of sound liquidity risk management" in 2008 as a response to the problems considering high leverage and low liquidity buffers in the banking sector. (BIS 2018) The publication included 17 principles, which aimed at helping banks with problems at estimating the required liquidity to satisfy their contingent obligations, applying the correct liquidity risk management and assessing the liquidity risk of individual products and business lines (BCBS 2008).

The strengthening of Basel II capital framework began in 2009 and lead to the issuance of Basel III in 2010. The higher global minimum capital standards were announced increasing the minimum common equity from 2 percent to 4,5 percent and total common equity requirements to 7 percent with addition of new layer of common equity called conservation buffer. Basel III also introduced a measure of minimum loss-absorbing capital relative to the banks assets and off-balance sheet exposures called the leverage ratio, and the countercyclical capital buffer to reduce the losses of banks in case of system-wide credit booms. (BCBS 2010a) The minimum liquidity requirements were introduced in the new accord alongside the capital requirements in the form of Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR) (BCBS 2010b).

3.3 Previous studies of liquidity risk exposure and management

The theoretical foundation for the liquidity risk exposure stemming from the banks holdings of illiquid assets was created through the model from Diamond and Dybvig (1984) and extended by Diamond (2007). They presented the risk transformation process in which the banks participate while creating liquidity to their customers involves banks providing the public with deposits, which are more liquid than banks own assets such as loans. However, during the times of increased demand for liquidity, the depositors can run the bank resulting in the failure of the bank with highly illiquid assets portfolio. (Diamond and Dybvig 1984, Diamond 2007) Empirical support for this theory is supported by the studies in US market, where illiquid assets were found to have a positive relation to the liquidity risk of banks (Cornett et. al. 2011, Khan, Scheule and Wu 2016).

Another balance sheet item, which has been widely modelled as a proxy for the liquidity risk exposure of the banks is deposits. Deposits are viewed as stable source of financing for the banks because they provide banks with liquid funds needed during the liquidity shortfall and therefore, protect banks from the bank runs. However, the protection from the bank runs is only available through the insured deposits and core deposits, which are viewed as safe from the depositors' point of view. The lowered funding liquidity risk in banks with high deposit ratios has been linked to an increased lending. (Diamond and Dybvig 1983, Gorton and Pennachi 1990, Acharya and Naqvi 2012, Wagner 2007) On top of these theoretical models, empirical studies in US market have shown that deposits to assets ratio has positive relationship with growth in lending of the bank (Khan, Scheule and Wu 2016, Ivashina and Scharfstein 2010, Cornett et. al. 2011).

Diamond and Rajan (2000, 2001) present the "Financial Fragility" -hypothesis considering the relationship between bank equity capital and liquidity creation. They build a model, where banks acquire financing from investors and then provide it to the entrepreneurs. Both the entrepreneur and bank can hold back from further investing the acquired liquidity. If the financing happens through deposits, the depositors can run the bank in case bank withholds effort, which maximizes the liquidity creation. Providers of capital financing do not have the same ability as

depositors, which decreases their willingness to provide capital and therefore decreases the liquidity creation. Gorton and Winton (2000) also argue that higher capital ratios decrease the liquidity creation by crowding out the deposits, due to the fact that deposits are liquid and equity capital is illiquid, resulting in decrease of overall liquidity for investors. These two theories are referred to as "Financial fragility – Crowding out" -hypothesis in the literature (Berger and Bouwman, 2009).

An opposite view to the relation of capital and liquidity creation also exists. Repullo (2004) models the behavior of banks in a world, where the banks acquire financing through deposits of equity and then invest into high or low risk assets. They show that increased capital requirements ensure that banks do not follow the risky strategy as it is not in the best interest of shareholders. Bhattacharya and Thakor (1993) also point out that the capital decreases the riskiness of banks as it guides them towards less riskier investments. In addition, there exists a strand of literature, which argues that higher liquidity creation increases the risk of banks as it exposes them to greater losses in possible assets disposals required to meet the liquidity demands of depositors (Allen and Gale, 2004). The hypothesis, that combines these views, where higher capital supports liquidity creation by helping to absorb risk, which is caused by increased liquidity creation, is referred as "Risk absorption" -hypothesis in the literature (Berger and Bouwman, 2009)

Empirical evidence about the relationship between equity capital and bank lending supports the "Risk absorption" hypothesis, where higher capital ratios result in increased lending. Positive relationship between the two in the US market were found by Cornett et. al. (2011) and Khan, Scheule and Wu (2016). Karmakar and Mok (2015) also found evidence that supports "Risk absorption" -hypothesis but their results differed based on the size of the banks total assets as the relationship was stronger in larger banks.

Berger and Bouwman (2009) argued that the two opposite hypotheses about the relationship between bank capital and liquidity creation both apply to banks depending of the size of banks total assets. They propose, that "financial fragility – crowding out" -hypothesis applies to smaller banks and "risk absorption" -hypothesis to larger banks. The borrower monitoring, which is the key rationale behind the "financial fragility" -hypothesis, is more common to the

smaller banks due to the popularity of relation-specific lending. They also argue, that capital crowds out more deposits in smaller banks based on two arguments. First one is related to the size of the market, where banks operate. The small banks usually operate in smaller markets, where the investors usually invest in both equity and deposits and therefore, increased investments in equity usually result in decreased investments in deposits. In large markets the investors are usually more segmented, and they do not invest in both equities and deposits of same bank. Large banks usually operate in these markets, which implies that equity capital crowds out less deposits in larger banks. (Berger and Bouwman, 2009)

The "risk absorption" -hypothesis applies to larger banks due to three reasons. The regulatory demands and monitoring increases as the size of the bank increases, which forces banks to increase their capital buffers to reduce their riskiness. Second reason considers the uninsured providers of finance, who expose larger banks to greater market discipline. Due to the market discipline, higher equity capital ratio lowers the cost and increases the availability of uninsured financing and the effects are greater in larger banks. Third one relates to the better ability of some larger banks to find off-balance sheet investment opportunities, which involve higher risk and reward. These large banks may increase their equity buffers due to the risk involved in the off-balance sheet investment opportunities. (Berger and Bouwman, 2009)

Kishan and Opiella (2000) argued that the bank's assets size affected the loan growth responsiveness of banks to the changes in monetary policy. Their finding supported this hypothesis and revealed that loan creation of smaller banks is more responsive to the monetary policy changes than in larger banks and find it hard to provide liquidity to the private sector during contradiction policy. Their findings also supported the research of Kashyap and Stein (1997), which presented evidence that monetary policies of European Central Bank could face distributional difficulties because of the differences in the balance sheet strength of banks in different EU countries.

4 Data and Methodology

The dataset for the panel regression consists of the selected balance sheet items of the commercial banks, which were based in the Eurozone during the time period of 2006-2014 (Appendix 2). The data is collected from the Thomson Reuters Datastream and the initial sample includes 136 banks. The data is filtered in Datastream to show equities from the countries belonging to the Monetary Union in each of the time periods and to show only equities belonging to the sector of banks. Only the banks, which have their headquarters located in a country belonging to the Monetary Union, are included into the dataset. The now dead or delisted banks are also included to the sample in case they were still active during the time period of the study to avoid the survivorship bias.

The Worldscope bank balance sheet data is collected quarterly from Datastream starting from the first quarter of 2006 and ending in the last quarter of 2014. Therefore, the number of time periods included into the sample is 36. The dataset is divided into two subsamples in order to study the differences between the credit crisis and the sovereign debt crisis. Pre- and post-crisis quarters are also included into the subperiods in order to study the liquidity risk management, which should mostly take place in the crisis quarters. The 2006-2010 period includes a relatively normal phase in the economy prior to the crisis and the credit crisis that started during the third quarter of 2007. The 2010 – 2014 period includes the European sovereign debt crisis and the post-crisis period. The worst phase of the crisis was over in the end of 2009 in the global scale but the Euribor-OIS -spread did not return to its pre-crisis level until the fourth quarter of 2012 even though it fell notably during the last quarter of 2009. The movement of the spread combined with the events that took place in Europe during the 2010 indicate that 2010 is a correct year to split the dataset.

The banks in the sample are also divided into three size groups based on the value of their total assets following the same procedure used by the European Central Bank (ECB 2018):

1. Small sized banks: Total assets less than 0,005 percent of the total banking sector assets in the European union

2. Medium sized banks: Total assets over 0,005 percent and less than 0,5 percent of the total banking sector assets in the European union
3. Large sized banks: Total assets over 0,5 percent of the total banking sector assets in the European union

For some of the banks in the sample, there was only semiannual data available instead of quarterly. In those cases, the missing quarterly values were estimated with linear interpolation to avoid heavily unbalanced panels. The banks with more than 2 missing values from one or more variables in either of the subperiods were dropped out from the sample for the same reason described above. Overall, this resulted in 20 banks to be dropped of the whole sample. The most significant banks had better records available in Datastream, which indicates that the significant banks remained in the sample after these 20 banks were eliminated. Table 1 presents the number of banks included into sample for each quarter in the study. The dataset consists of listed banks, which causes the sample to be biased towards larger companies. As a result, a majority of banks in the sample belong into either medium or large group. This is taken into consideration when the results are discussed in the final chapter.

Table 1. Number of banks in the sample

Credit Crisis						Sovereign Debt Crisis					
Year	Quarter	Small	Medium	Large	Total	Year	Quarter	Small	Medium	Large	Total
2006	1	6	72	14	92	2010	1	9	61	12	82
	2	6	72	14	92		2	9	61	12	82
	3	4	73	15	92		3	9	61	12	82
	4	4	73	15	92		4	9	61	12	82
2007	1	5	73	14	92	2011	1	9	61	12	82
	2	5	73	14	92		2	9	61	12	82
	3	6	67	12	85		3	9	61	12	82
	4	4	69	12	85		4	8	62	12	82
2008	1	7	66	12	85	2012	1	8	63	11	82
	2	7	66	12	85		2	9	62	11	82
	3	5	68	12	85		3	9	62	11	82
	4	6	67	12	85		4	9	62	11	82
2009	1	7	66	12	85	2013	1	7	47	12	66
	2	7	66	12	85		2	7	47	12	66
	3	6	67	12	85		3	7	47	12	66
	4	6	67	12	85		4	7	47	12	66
						2014	1	7	47	12	66
							2	7	47	12	66
							3	7	47	12	66
							4	7	47	12	66

4.1 Variables

The purpose of this study is to examine the liquidity risk management of the banks during the crisis quarters. The dependent variables in two models measure the changes in liquid assets and in loans. Both of these variables are normalized by dividing them with the total assets of a bank. For the remainder of this paper the change in liquid assets to assets ratio will be referred as LIQA and change in loans ratio will be referred as LOAN.

$$1. \quad LIQA_{i,t} = \frac{\Delta liquid\ assets_{i,t}}{Assets_{i,t-1}}$$

First variable measures the changes in liquid assets of the banks. The use of this variable is based on premise, that banks with high liquidity risk exposure started managing their liquidity risk by hoarding liquidity in an effort to prevent them becoming illiquid.

The variable liquid assets was created by calculating the sum of the following Worldscope balance sheet items: Cash & Due from Banks and Investments minus the asset- and mortgage backed securities. The market for asset- and mortgage-backed securities dried up during the crisis periods and therefore, these assets are considered illiquid in this study similarly to Cornett et.al. (2011).

$$2. \quad LOAN_{i,t} = \frac{\Delta loans_{i,t}}{Assets_{i,t-1}}$$

The second variable measures the changes in proportion of loans in banks assets. The reasoning for using the change in loans is based on the hypothesis, that as banks start hoarding liquidity they are also expected to decrease lending since loans are highly illiquid assets. The variable loans was created by summing up the Worldscope balance sheet item Net of Loans.

These variables act as good proxies for the liquidity risk management of banks but the loans in the balance sheet do not account for the whole liquidity creation of banks. This study is missing one important variable, off-balance sheet loan commitments, which has been shown to account for almost 50 percent of the liquidity creation in commercial banks (Berger & Bouwman, 2009). This data limitation is due to the fact that Worldscope only has data about the balance sheet values of banks and therefore, the off-balance sheet activities are not included in the sample.

Based on the earlier studies, the following four variables are chosen as proxies of liquidity risk exposure of the banks. First variable is a proxy for the liquidity risk linked to the asset portfolio of the banks. Next two proxies are from the liabilities side of the balance sheet and represent the ways banks finance their assets. All of the independent variables are also interacted with the Euribor -spread in the regression to emphasize the relation between dependent variables and the proxies of liquidity risk exposure during the most turbulent periods of the crises :

$$3.\quad ILIQA_{i,t-1} = \frac{Illiquid\ Assets_{i,t-1}}{Assets_{i,t-1}}$$

The risk transformation that banks participate in by holding illiquid risky loans in their balance sheet and by supplying deposits to the public on demand makes them fragile during the liquidity shortages. Banks tend to cut down on new loans, if the future liquidity needs are anticipated to be high. (Diamond and Rajan 2001) Banks with high proportion of liquid assets in their balance sheet can cope with the future liquidity needs better and have less pressure to hoard liquidity or decrease lending.

This variable (illiquid assets) was created as a sum of the following Worldscope balance sheet items: asset – and mortgage backed securities, net of loans, investments in associated companies, customer liabilities on acceptances, real estate assets, net of property , plant and equipment, other assets. For the remainder of this paper the illiquid assets to assets ratio will be referred as ILIQA.

$$4.\quad DEPA_{i,t-1} = \frac{Deposits_{i,t-1}}{Assets_{i,t-1}}$$

Deposits are considered as a stable source of financing for the bank, if they are insured by the government. Higher portion of deposits to assets are traditionally viewed as a way to prevent or mitigate the bank runs during the liquidity shortages. Higher deposits to assets ratio is also linked in more aggressive lending due to lowered funding liquidity risk of the bank. (see e.g. Diamond and Dybvig 1983, Gorton and Pennachi 1990, Khan, Scheule and Wu 2016, Acharya and Naqvi 2012) In this paper, variable deposits is constructed from the Worldscope balance sheet item total deposits. For the remainder of this paper the deposits to assets will be referred as DEPA.

5. $CAPA_{i,t-1} = \frac{Equity\ Capital_{i,t-1}}{Assets_{i,t-1}}$

Equity capital is also considered as a stable source of financing for the banks and therefore, the higher portion of equity to assets should reduce the liquidity risk exposure of a bank (Diamond and Dybvig 1983, Gorton and Pennachi 1990). Legislators require banks to keep a certain level of equity to assets in case of liquidity shortages to protect depositors, but previous studies have shown that higher portion of equity capital might have a different kind of relation to liquidity risk exposure for large and small banks through "financial fragility – crowding out" and "risk absorption" hypotheses (Berger and Bouwman 2009). The variable equity capital consists of Worldscope balance sheet items: common equity and preferred stock. For the remainder of this paper the equity to assets ratio will be referred as CAPA.

6. $LOGA_{i,t-1} = Log\ of\ assets_{i,t-1}$

The size of the bank is expected to have an impact on the risk exposure management also. Some financial institutes are called to be Too-Big-To-Fail (TBTF) meaning that they would be bailed out in case of bankruptcy to prevent large scale negative impacts on the financial system. This lowers the actual riskiness of the bank. (Mishkin 2011) Cornett. et al. (2011) also noted that there probably is a relation between the liquidity management and size of the assets but assets size proxies for other sources of heterogeneity. Following their procedure, the assets size is included into the regression, but its results will not be interpreted in this paper and LOGA will act solely as a control variable. This variable was created by taking a natural logarithm of the Worldscope balance sheet item total assets.

4.2 Decomposition of the Euribor -spread

Figure 3 presents the movement and composition of the Euribor-spread during the 2006-2014 period. The spread remained close to zero before the credit crisis started at 2007 and then it jumped to over 0,5, where it stayed until the end of credit crisis in 2009. In 2011 the spread peaked again as the sovereign debt crisis started to unravel in the banking market in Europe.

The liquidity and credit risk components of the spread are calculated by following the method proposed by the Bank of England (2007). 5 -year credit default swaps (CDS) were used to calculate the credit risk of the banks belonging to the Euribor-panel (Appendix 1) and the recovery rate is assumed to be 0,4. (Hull 2006) The CDS data could not be found from Datastream for every bank in the Euribor -panel since Datastream only has data about the listed companies.

The decomposition of the spread demonstrates, how the dominant component of spread changes as time passes. In the beginning of the crisis, the liquidity risk component dominated, but after 2009 the credit risk component took over. The liquidity injections of the ECB, presented in chapter 3.1, started to increase liquidity in the system, which should have lowered the spread back to zero, but the

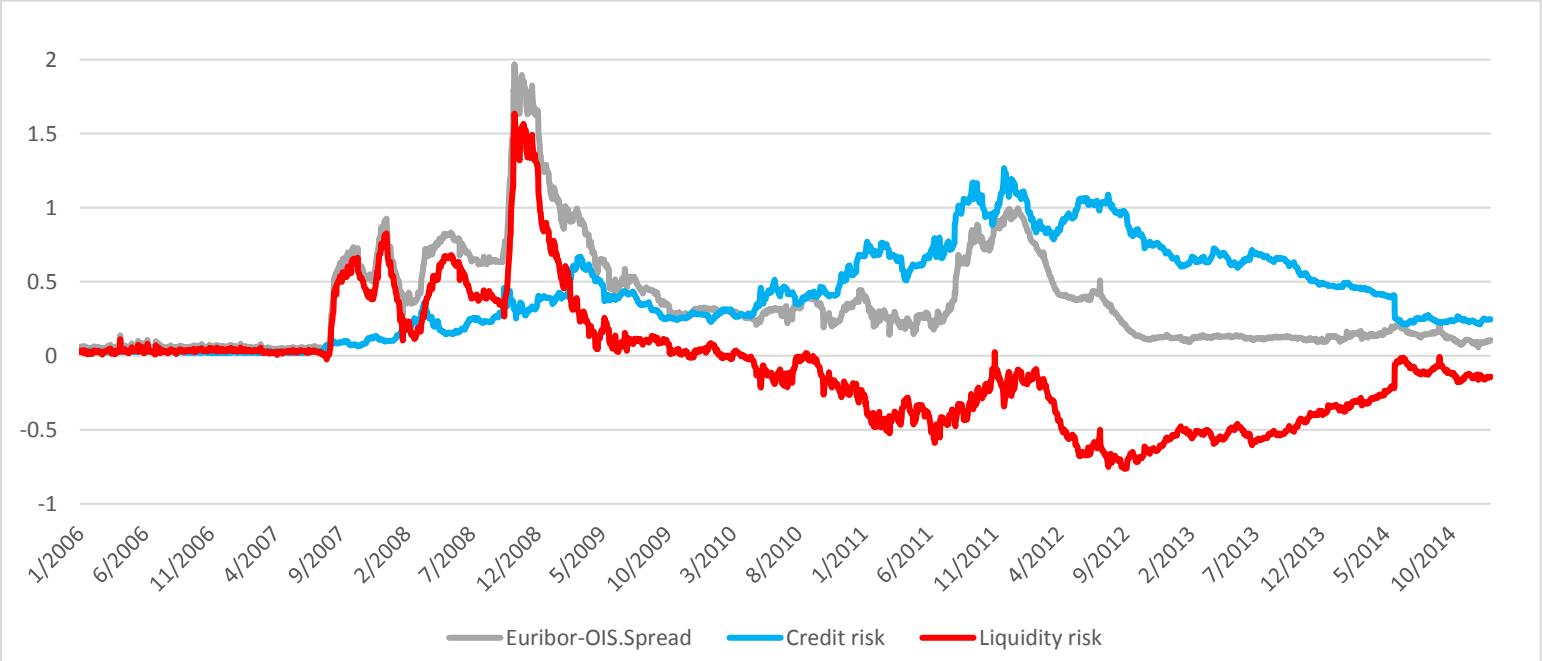

Figure 3 Decomposition of the Euribor -spread between 1/2006 – 12/2014

credit risk remained at high level in the Eurozone increasing the level of the spread. Banks did not distribute the available liquidity throughout the system and the distortions did not disappear from the interbank market before 2013.

Cornet et al. (2011) used TED –spread to model the severity of the credit crisis of 2007-2009 in the United States. Their method involved a regression of the liquidity risk management of banks, where different proxies of liquidity risk exposure acted as independent variables. The TED-spread was used to interact with the independent variables in the regression to emphasize the most turbulent quarters of the crisis.

In this thesis, the interaction between the Euribor -spread and the independent variables in the regressions is used to emphasize the most turbulent periods in our time frame. As we can see from the Figure 3, the last quarter of 2008 will have a multiplier of almost 2, whereas the peaceful period in 2006 has a multiplier close to zero. Also differing composition means that during peak of the 2008, the interaction emphasizes the relation of independent and dependent variables under high liquidity risk, whereas the peak of the 2011 does the same under high credit risk.

During the sovereign debt crisis the liquidity risk component turned negative, which indicates that the banks were not afraid of becoming illiquid before the pay-back of the loan but rather concerned about the counterparty's credit worthiness. However, in this case the liquidity risk component should have remained at zero and the level of the spread should have equaled to the average CDS-spreads of the Euribor-panel banks. The fact that the credit risk component rose above the spread after the credit crisis raises questions about the accuracy of this method at determining the level of credit risk. All-in-all, the increased average CDS-spread of the Euribor-panel banks indicates that the credit risk was higher during the sovereign debt crisis than the credit crisis and therefore the liquidity risk was lower since the Euribor-spread was lower during the Sovereign debt crisis.

4.3 Model

There are two models in this paper, one for the study of liquidity hoarding and other for the study of changes in lending. Fixed effects panel regression is used in order to analyze the relation between the independent variables and the proxies for liquidity risk exposure. All of the independent variables are also interacted with the Euribor -spread. The models are similar to Cornett et. al. (2011) paper, which studied the liquidity risk exposure and liquidity risk management of the banks in the United States during the credit crisis. My model differs from that model by the use of Euribor -spread as an interaction term instead of the TED -spread, which is the difference between the three-month LIBOR -rate and the three-month Treasury rate

The two-way error component model, where the time and individual specific effects are fixed, is employed in both regressions:

$$u_{it} = \mu_i + \lambda_t + v_{it} \tag{13}$$

The time effects are fixed to remove the effects of market shocks, which occurred during the different phases of the crises and the individual effects are fixed to absorb the unobserved heterogeneity at the bank level. The robust standard errors are obtained using method of Arellano (1987) to avoid the problems with serial correlation and heteroskedasticity.

First regression uses liquid assets ratio as independent variable and models the relationship between liquidity hoarding and liquidity risk exposure:

$LIQA_{i,t}$=$\mu_i^1 + \lambda_t^1 + \beta^1 \mathrm{ILIQA}_{i,t-1} + \beta^2 \mathrm{ILIQA}_{i,t-1} * EBOR_t + \beta^3 \mathrm{DEPA}_{i,t-1} + \beta^4 \mathrm{DEPA}_{i,t-1} * EBOR_t + \beta^5 \mathrm{CAPA}_{\mathrm{i,t-1}} + \beta^6 \mathrm{CAPA}_{i,t-1} * EBOR_t + \beta^9 \mathrm{LOGA}_{i,t-1} + \beta^{10} LOGA_{i,t-1} * EBOR_t + \epsilon_{i,t}$,

where

μ_i denotes the individual specific effects, i=1,…,N

λ_t denotes the time specific effects, t=1,…,T

$LIQA_{i,t}$ is the dependent variable $\frac{\Delta Liquid\ assets_{i,t}}{Assets_{i,t-1}}$,

$\mathrm{ILIQA}_{i,t-1}$ is the independent variable illiquid assets ratio in the beginning of the period,

$\mathrm{DEPA}_{i,t-1}$ is the independent variable deposits ratio in the beginning of the period,
$\mathrm{CAPA}_{\mathrm{i,t-1}}$ is the independent variable equity ratio in the beginning of the period,
$\mathrm{LOGA}_{i,t-1}$ is the control variable log of total assets in the beginning of the period,
$EBOR_t$ is the Euribor -spread in the end of the period.

Second regression uses loans ratio as independent variable and models the relationship between lending and liquidity risk exposure:

$$LOAN_{i,t}=\mu_i^1+\lambda_t^1+\beta^1\mathrm{ILIQA}_{i,t-1}+\beta^2\mathrm{ILIQA}_{i,t-1}*EBOR_t+\beta^3\mathrm{DEPA}_{i,t-1}+\beta^4\mathrm{DEPA}_{i,t-1}*EBOR_t+\beta^5\mathrm{CAPA}_{\mathrm{i,t-1}}+\beta^6\mathrm{CAPA}_{i,t-1}*EBOR_t+\beta^9\mathrm{LOGA}_{i,t-1}+\beta^{10}LOGA_{i,t-1}*EBOR_t+\epsilon_{i,t},$$

where
μ_i denotes the individual specific effects, i=1,…,N
λ_t denotes the time specific effects, t=1,…,T
$LOAN_{i,t}$ is the dependent variable $\frac{\Delta Loans_{i,t}}{Assets_{i,t-1}}$,
$\mathrm{ILIQA}_{i,t-1}$ is the independent variable illiquid assets ratio in the beginning of the period,
$\mathrm{DEPA}_{i,t-1}$ is the independent variable deposits ratio in the beginning of the period,
$\mathrm{CAPA}_{\mathrm{i,t-1}}$ is the independent variable equity ratio in the beginning of the period,
$\mathrm{LOGA}_{i,t-1}$ is the control variable log of total assets in the beginning of the period,
$EBOR_t$ is the Euribor -spread in the end of the period.

5 Empirical results

The evolution of the proxies for liquidity risk management are presented in the start of this chapter. The following part of the chapter includes descriptive statistics of the dependent and independent variables together with pairwise correlation matrices. In the end of the chapter, the regression results from both of the subperiods are presented.

5.1 Liquidity risk management

Figures 4 and 5 present the liquid assets and loans to assets ratios on a yearly level. Both ratios experience similar trend when considering the turning point that occurred in 2008 and the jump that occurred in 2011. These years were also the most turbulent periods in the crises based on the Euribor -spread (Figure 2). The development of these ratios also supports the theory of liquidity hoarding and the reduction of lending in banks during the liquidity shortages.

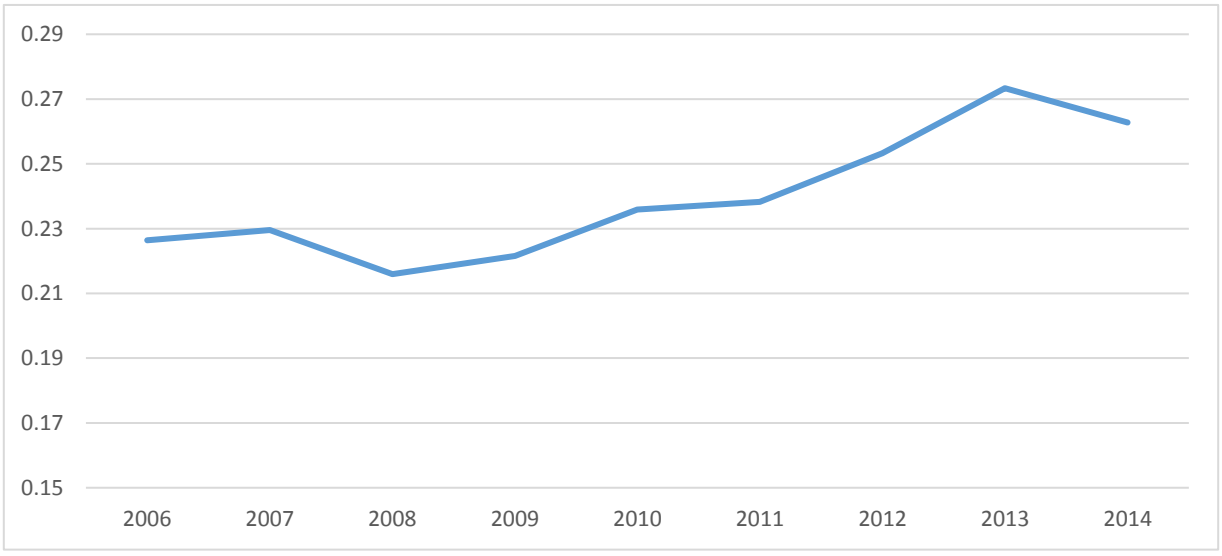

Figure 4 Average liquid assets to assets (percentage) of the whole sample between 2006 and 2014

The increase in liquid assets ratio after 2008 reflects the actions of the ECB. The increased central bank liquidity allowed banks to increase their liquidity buffers and this trend continued until 2013. The second peak that occurred in 2011 reflects the LTRO's, which again increased the available liquidity. Figure also indicates that banks were not distributing the central bank liquidity into the system but rather holding on to it in the anticipation of future liquidity needs. The opposite trend is visible in development of the loans to assets ratio further supporting the theory about the liquidity risk management (Figure 5).

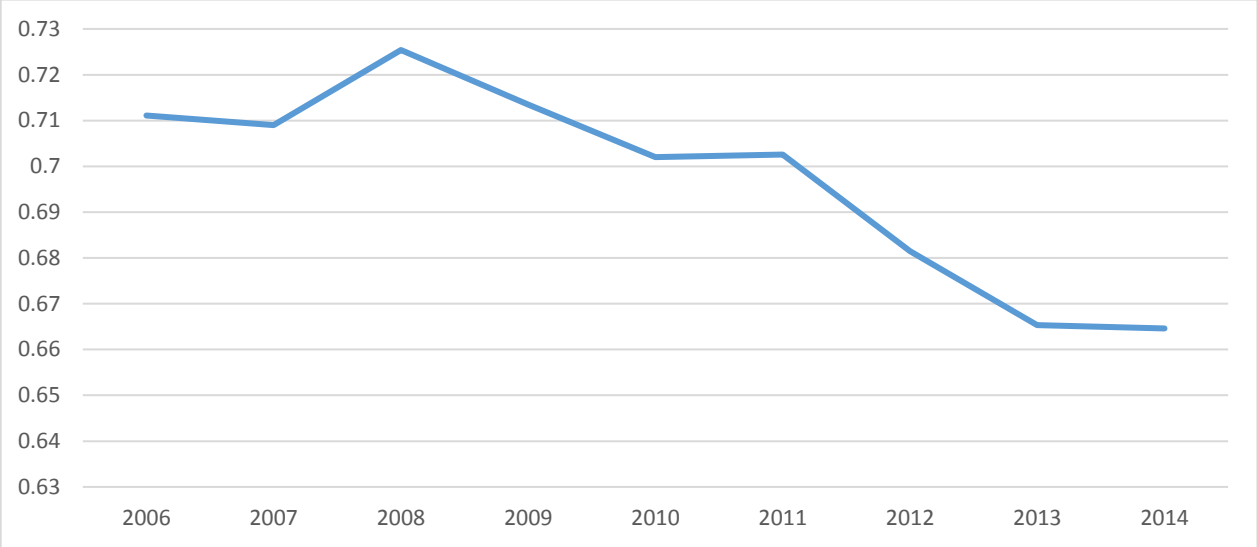

Figure 5 Average loans to assets (percentage) of the whole sample between 2006 and 2014

5.2 Descriptive statistics

Tables 2 and 3 present the pairwise correlation matrices of the variables used in the regressions. The Spearman correlation coefficients are calculated for dependent and independent variables in both of the subperiods used in regressions. The correlation coefficient of the independent variables, which have been interacted with Euribor -spread are also presented in the tables.

There is a significant negative correlation between dependent variables LIQA and LOAN in both subsamples as expected. DEPA and CAPA exhibit a significant negative correlation with LIQA during the first subperiod. Sign of the correlation with LOAN turns positive as expected but DEPA loses its significance. ILIQA does not exhibit significant correlation with either of the dependent variables in the first subperiod. During the second subperiod, CAPA exhibits significant negative correlation with LIQA and positive correlation with LOAN similarly to the previous subperiod. DEPA and ILIQA also have significant positive correlations with LOAN, but similar correlations are not found with LIQA during the second subperiod.

After the interaction with Euribor -spread, all of the independent variables exhibit a significant negative correlation with LOAN in the first subperiod but no significant correlations are found with the LIQA. In the second subperiod CAPA has a significant positive correlation with LOAN and CAPA is the only independent variable that exhibits a significant correlation with either of the dependent variables. Some of the independent variables exhibit significant correlations with each other but the coefficients stay below 0,4 with all of the other explanatory variables except control variable LOGA and the interaction terms. High correlation with the control variable does not pose a problem since it will not be interpreted in the final regression results. The correlation between interaction terms is expected to be high but it will not automatically lead to biased estimates but might increase the standard errors in regression. Serial correlation and heteroskedasticity were also present in the data but these problems were addressed in the regression with the use of robust standard errors.

Table 2 Pairwise correlation matrix (2006-2009 period)

The *, **, *** are marked behind the coefficient value denote whether the correlation coefficients are statistically significantly different from zero at 10 percent, 5 percent and 1 percent level respectively.

	LIQA	LOAN	ILIQA	DEPA	CAPA	LOGA	ILIQA*EBOR	DEPA*EBOR	CAPA*EBOR	LOGA*EBOR
LIQA	1	-0,1077*	-0,0453	-0,0557**	-0,1449***	0,0633**	-0,0367	-0,0118	-0,0329	-0,0210
LOAN	-0,1077*	1	0,0433	0,0310	0,1177***	-0,0221	-0,0960***	-0,1193***	-0,0888***	-0,0906***
ILIQA	-0,0453	0,0433	1	-0,003	0,2551***	-0,4297***	0,0336	-0,0725***	-0,0033	0,3727***
DEPA	-0,0557**	0,0310	-0,003	1	0,3422***	-0,4609***	0,0265	-0,1094***	0,3924***	-0,0338
CAPA	-0,1449***	0,1177***	0,2551***	0,3422***	1	-0,3070***	0,2214***	-0,0396	0,1794***	0,1083***
LOGA	0,0633**	-0,0221	-0,4297***	-0,4609***	-0,3070***	1	-0,0332	0,1497***	-0,1847***	-0,1315***
ILIQA*EBOR	-0,0367	-0,0960***	0,0336	0,0265	0,2214***	-0,0332	1	0,9255***	0,8240***	0,8445***
DEPA*EBOR	-0,0118	-0,1193***	-0,0725***	-0,1094***	-0,0396	0,1497***	0,9255***	1	0,7282***	0,7897***
CAPA*EBOR	-0,0329	-0,0888***	-0,0033	0,3924***	0,1794***	-0,1847***	0,8240***	0,7282***	1	0,6764***
LOGA*EBOR	-0,0210	-0,0906***	0,3727***	-0,0338	0,1083***	-0,1315***	0,8445***	0,7897***	0,6764***	1

Table 3 Pairwise correlation matrix (2010-2014 period)

The *, **, *** are marked behind the coefficient value denote whether the correlation coefficients are statistically significantly different from zero at 10 percent, 5 percent and 1 percent level respectively.

	LIQA	LOAN	ILIQA	DEPA	CAPA	LOGA	ILIQA*EBOR	DEPA*EBOR	CAPA*EBOR	LOGA*EBOR
LIQA	1	-0,1625***	-0,0170	0,0273	-0,0980***	-0,0028	-0,0262	0,0073	0,0410	-0,008
LOAN	-0,1625***	1	0,0772***	0,1007***	0,0753***	-0,0729***	0,0205	-0,0078	0,0948***	0,0442*
ILIQA	-0,0170	0,0772***	1	0,0786***	0,2521***	-0,4894***	0,0198	-0,1447***	-0,0039	0,4436***
DEPA	0,0273	0,1007***	0,0786***	1	0,2885***	-0,3985***	-0,0326	-0,1819***	0,4944***	-0,0583**
CAPA	-0,0980***	0,0753***	0,2521***	0,2885***	1	-0,3686***	0,3460***	0,0029	0,2055***	0,1881***
LOGA	-0,0028	-0,0729***	-0,4894***	-0,3985***	-0,3686***	1	-0,1328***	0,1313***	-0,2423***	-0,2741***
ILIQA*EBOR	-0,0262	0,0205	0,0198	-0,0326	0,3460***	-0,1328***	1	0,8955***	0,7245***	0,8109***
DEPA*EBOR	0,0073	-0,0078	-0,1447***	-0,1819***	0,0029	0,1313***	0,8955***	1	0,6393***	0,7240***
CAPA*EBOR	0,0410	0,0948***	-0,0039	0,4944***	0,2055***	-0,2423***	0,7245***	0,6393***	1	0,5999***
LOGA*EBOR	-0,008	0,0442*	0,4436***	-0,0583**	0,1881***	-0,2741***	0,8109***	0,7240***	0,5999***	1

Descriptive statistics of the dependent variables of the panel regression (LIQA and LOAN) are presented in the Table 4. The sample has been divided into subsamples based on the time periods and the size of the banks to capture the differences between non-crisis and crisis periods and the between the size groups. The use of 4 subperiods instead on 2 is based on an effort to study, if the liquidity risk management increased during the crisis quarters. The first time period from 2006 to the second quarter of 2007 represents non-crisis period before the credit crisis. The following period includes the crisis quarters, which took place during the credit crisis. Third time period represents the second crisis quarter in our sample, which started in 2010 and ended in the third quarter of 2012 whereas, the last time period consists of the relatively peaceful quarters, which took place after the height of the sovereign debt crisis had passed.

The observations from our first dependent variable (LIQA) indicates that the banks in our sample did not increase their holdings of liquid assets on average during the credit crisis in any of the size groups but rather decreased their holdings during the crisis quarters compared to non-crisis quarters. On average LIQA ratio fell from -0.275 to -0.278 percent in small banks, from 0.779 to 0.33 percent in medium banks and from 3.65 to 0.2 percent in large banks.

The second dependent variable LOAN did on average decrease during the turbulent quarters of the credit crisis in the medium banks from 2.93 percent to 1.4 percent and in large banks 1.94 percent to 0.39 percent. Small banks experienced increase in LOAN on average from -1.52 percent to 1.79 percent between non-crisis and crisis quarters.

During the latter two time periods, LIQA kept decreasing on average throughout the sovereign debt crisis and the post crisis period in medium banks and especially in large banks, which experienced on average a decrease from 0.164 to -0.923 percent between the crisis and non-crisis quarters. In the small bank group, LIQA jumped from -0.278 to 0.593 percent between the credit and sovereign debt crisis and then decreased again in the post crisis quarters. LOAN also decreased throughout the sovereign debt crisis and the post crisis quarters in all size groups.

Table 4 Summary statistics of dependent variables

Table 2 reports average, lower quartile, median, upper quartile and standard deviation of dependent variables for small (Total assets < 0,005 percent of total consolidated assets of EU banks), medium (Total assets between 0,005 and 0,5 percent of total consolidated assets of EU banks) and large (Total assets > 0,5 percent of total consolidated assets of EU banks) banks.

	Average	25th Percentile	Median	75th percentile	Standard deviation
Small Banks during 2006 - 2007 Q2					
LIQA (percent)	-0.275	-0.986	0	3.930	6.950
LOAN (percent)	-1.520	-1.490	0	1.650	6.990
Medium Banks during 2006 - 2007 Q2					
LIQA (percent)	0.779	-0.414	0.370	1.660	4.030
LOAN (percent)	2.930	0.317	2.520	4.740	5.420
Large Banks during 2006 - 2007 Q2					
LIQA (percent)	3.650	-0.192	0.552	4.170	11.00
LOAN (percent)	1.910	-0.332	0.889	2.340	8.980
Small Banks during 2007 Q3 - 2009					
LIQA (percent)	-0.278	-2.640	0.033	2.100	6.310
LOAN (percent)	1.790	-2.200	0.576	2.370	9.170
Medium Banks during 2007 Q3 - 2009					
LIQA (percent)	0.330	-1.130	0.172	1.480	3.800
LOAN (percent)	1.400	-0.391	1.060	3.080	5.480
Large Banks during 2007 Q3 - 2009					
LIQA (percent)	0.200	-2.890	-0.121	2.710	6.370
LOAN (percent)	0.378	-1.670	0.448	2.480	5.520
Small Banks during 2010 - 2012 Q3					
LIQA (percent)	0.593	-1.130	0.118	1.980	5.130
LOAN (percent)	0.388	-1.300	0.634	2.300	4.260
Medium Banks during 2010 - 2012 Q3					
LIQA (percent)	0.212	-1.010	0.058	1.090	2.970
LOAN (percent)	0.276	-1.330	0.302	1.660	3.810
Large Banks during 2010 - 2012 Q3					
LIQA (percent)	0.164	-2.490	0.130	2.370	5.310
LOAN (percent)	0.222	-2.020	0.285	3.060	5.070
Small Banks during 2012 Q4 - 2014 Q1					
LIQA (percent)	0.136	-2.490	-0.167	1.950	4.530
LOAN (percent)	0.140	-0.967	0.108	1.740	3.210
Medium Banks during 2012 Q4 - 2014 Q1					
LIQA (percent)	0.193	-1.090	0.162	1.210	3.270
LOAN (percent)	-0.413	-1.950	-0.551	1.160	5.380
Large Banks during 2012 Q4 - 2014 Q1					
LIQA (percent)	-0.923	-3.660	-0.829	1.810	5.010
LOAN (percent)	-0.848	-2.780	-0.712	2.090	4.470

It ended up negative in large and medium size banks during the post crisis period reflecting to the increased counterparty credit risk as indicated by the composition of Euribor-spread (Figure 3).

In general, these observations indicate that banks started preparing for the turbulent periods in advance by increasing their holding of liquid assets during the peaceful pre-crisis period. Other notable observation is that during the crisis quarters, the banks on average increased their holdings of liquid assets and the average growth speed in loans decreased from period to period as the crisis went on. These observations together show further evidence that the liquidity injections of the ECB did not provide expected results due to the fact that banks managed their liquidity risk by holding on to the provided liquidity.

The fact that the average quarterly lending kept on decreasing in the post-crisis period suggests that the turbulences did not disappear from the markets in the end of 2012 as indicated by the Euribor-spread (Figure 2). Similar effect can be observed from the Figure 5, where the total loans to assets does not grow during the post crisis period. The credit risk component of the spread was still at high level even though the actual spread was at the pre-crisis level, which raises questions about the efficiency of the spread as an indicator of the market turbulences in post-crisis era.

Table 5 presents the characteristics of banks belonging in different size groups. The sample is divided in two time periods representing the pre-crisis together with credit crisis and sovereign debt crisis together with post crisis period. The rationale behind this is to observe the possible differences in the liquidity exposure of banks between the two crises.

Smaller banks seem to rely more on deposits to finance their assets as DEPA is close to 70 percent on average in small banks sample during both of the time periods. Same ratio for medium banks stayed below 50 percent and for large banks below 40 percent. Similar trend is evident with CAPA as large banks have circa 4 percentage points lower CAPA than small and medium sized banks. Therefore, it seems that larger banks relied on more unstable sources of finance than smaller banks during the 2006-2014 periods.

Table 5 Summary statistics of bank characteristics

Table 2 reports average, lower quartile, median, upper quartile and standard deviation of independent variables for small (Total assets < 0,005 percent of total consolidated assets of EU banks), medium (Total assets between 0,005 and 0,5 percent of total consolidated assets of EU banks) and large (Total assets > 0,5 percent of total consolidated assets of EU banks) banks.

	Average	25th Percentile	Median	75th percentile	Standard deviation
Small Banks during 2006 - 2009					
Total Assets (billions)	1267.00	455.62	547.57	2209.00	888.65
DEPA (percent)	68.3	56.5	79.1	87.1	25.8
CAPA (percent)	8.85	6.08	7.63	11	4.46
ILIQA (percent)	63.9	58.2	68.5	76.6	26.7
Medium Banks during 2006 - 2009					
Total assets (billions)	44520.00	8396.00	21760.00	63300.00	52260.00
DEPA (percent)	46.7	32.8	46.3	57.9	19.6
CAPA (percent)	7.18	5.08	6.39	8.79	3.48
ILIQA (percent)	82	77.2	84.6	89.3	11.3
Large Banks during 2006 - 2009					
Total assets (billions)	863900.00	505500.00	635400.00	1072000.00	508600.00
DEPA (percent)	33.1	22.7	32.7	41.5	13.2
CAPA (percent)	3.78	2.53	3.12	5.02	1.79
ILIQA (percent)	57.8	44.4	62.8	71.3	17
Small Banks during 2010 - 2014					
Total assets (billions)	1268.00	665.71	871.46	1968.00	734.62
DEPA (percent)	72	67.3	78.2	83	18.9
CAPA (percent)	8.01	5.8	7.3	10.2	3.2
ILIQA (percent)	71.9	65.1	75.4	94.5	26.2
Medium Banks during 2010 - 2014					
Total assets (billions)	54840.00	9627.00	29390.00	81920.00	60630.00
DEPA (percent)	48.9	35.6	50.8	59	17.9
CAPA (percent)	7.03	5.28	6.9	9.13	3.14
ILIQA (percent)	79.4	73.4	79.9	87.7	9.78
Large Banks during 2010 - 2014					
Total assets (billions)	1043000.00	590200.00	912500.00	1506000.00	547600.00
DEPA (percent)	36.1	28.9	36.8	44.9	12.4
CAPA (percent)	4.68	3.23	4.3	6.37	1.94
ILIQA (percent)	57.6	44	60.3	69.6	14.6

This comparison suggest that larger banks were more exposed to the liquidity risk than smaller banks based on the exposure of the funding sources of assets. On the other hand, small banks had a higher ILIQA than the large banks, which indicates that small banks had a higher liquidity risk exposure in the assets side of the balance sheet. Similar study in the US market found that larger banks were more exposed to the liquidity risk in all three dimensions (ILIQA, CAPA and DEPA) than their smaller counterparts (Cornett et al, 2011).

Some notable differences can be found also between the two time periods. DEPA increased in all size groups during the sovereign debt crisis compared to the credit crisis. This indicates that banks tried to decrease their liquidity risk exposure as the crisis deepened. CAPA also increased in the large bank -panel further indicating the pressure to reduce liquidity risk among this group of banks. Another notable reason for the increase in CAPA is found from the changing legislation. The minimum Tier 1 Capital ratio was raised in 2010, which placed pressure for the large banks to lower their liquidity risk exposure further.

5.3 The credit crisis (2006-2009 period)

Table 6 introduces the regression results for the 2006-2009 period with includes the global credit crisis and the peaceful pre-crisis period. The first regression that models the liquidity hoarding of the banks with LIQA as dependent variable has an R-squared of 0,432 in panel of small banks, 0,409 in panel of medium size bank and 0,508 in panel of large banks. The results from the second regression that models the credit creation of the banks with LOAN as dependent variable also have a R-squared over 0,4 in the small and large bank panels but the panel for medium sized banks suffers from a low R-squared of 0,145. Overall, the values of R-squared were expected to be lower than in the previous studies since one important variable, the unused loan commitments, had to be omitted from the study due to the data limitations.

DEPA does not have a significant relationship to LIQA in the first regression of the panel A consisting of the small banks (total assets less than 0,005 percent of the total banking sectors assets in the European Union). However, the other proxy for the liquidity risk exposure stemming from the liabilities side of the balance sheet, CAPA, has a significant (10 %) large negative relation to LIQA. The significant relation (5 %) remains after CAPA is interacted with the Euribor -spread but turns positive and smaller suggesting that during the more turbulent periods, lower liquidity risk exposure in the form of higher equity ratio increased the liquidity hoarding in small banks. The liquidity risk exposure proxy from the asset side of the balance sheet, ILIQA, has a significant (10 %) fairly weak negative relation to the dependent variable but there is no significant relation anymore after the variable is interacted with the Euribor -spread.

In the second regression for panel A, DEPA has significant (1 %) negative relation to the dependent variable and significant (5 %) positive relationship after it has been interacted with the Euribor -spread. CAPA also has a significant (10 %) negative relation to the loan creation without the interaction. Together these results indicate that lower liquidity exposure from the liabilities side of the balance sheet reduced the lending during the less turbulent periods but at least higher DEPA was beneficial during the most turbulent periods. ILIQA has significant (10

%) relation to the LOAN both with and without the interaction but the sign of the relation turns from positive to negative after the variable is interacted with the EURIBOR -spread.

In the panel B consisting of the medium sized banks (total assets greater than 0,005 percent and lower than 0,05 percent of the total banking sector assets in the European Union) only the DEPA after the interaction with Euribor-spread has a significant (5%) weak positive relation to the dependent variable in the first regression when the liabilities side proxies are considered. On the assets side, ILIQA has a significant (1 %) negative relationship to the LIQA and a significant (1 %) positive relation after interaction with the Euribor -spread. In the second regression of panel B, only ILIQA with and without the interaction have a significant relation to LOAN but the sign of the relation turns from positive to negative similarly to the panel A.

In the panel C consisting of large banks (total assets over 0,05 percent of the total banking sector assets in the European Union), none of the independent variables from the liabilities side have a significant relation with LIQA in the first regression. On the other hand, ILIQA has a significant (1 %) fairly strong negative relation with LIQA without interaction and a significant (1 %) positive relation after interaction with the Euribor -spread. These results suggest that only the liquidity risk exposure in the assets side of the balance sheet contributed to the liquidity hoarding in the large banks.

The results of second regression show that, both DEPA (1 %) and CAPA (10 %) have a significant positive relation to LOAN. However, both variables lose their significance after they are interacted with the Euribor -spread. ILIQA has a significant relation to LOAN, and similarly to the other panels, the sign of the coefficient turns to opposite after ILIQA is interacted with the spread.

Table 6 Regression results for 2006-2009 period

Panel A reports fixed effects regression results for small (Total assets < 0,005 percent of total consolidated assets of EU banks) banks, panel B for medium (Total assets between 0,005 and 0,5 percent of total consolidated assets of EU banks) banks and panel C for large (Total assets > 0,5 percent of total consolidated assets of EU banks) banks. The robust standard errors are presented in parenthesis and *, **, *** marked behind the coefficient value denote whether the coefficients are statistically significantly different from zero at 10 percent, 5 percent and 1 percent level respectively. Time and entity fixed effects were controlled for in each regression.

	Panel A: Small Banks		*Panel B: Medium Banks*		*Panel C: Large Banks*	
	$LIQA_t$	$LOAN_t$	$LIQA_t$	$LOAN_t$	$LIQA_t$	$LOAN_t$
DEPA_{t-1}	-0.028	-0.304***	-0.006	-0.025	0.104	0.368***
	(0.084)	(0.082)	(0.015)	(0.023)	(0.082)	(0.085)
$\mathrm{DEPA}_{t-1} * EBOR_t$	-0.120	0.185**	0.032**	-0.020	0.125	0.105
	(0.081)	(0.089)	(0.013)	(0.024)	(0.112)	(0.117)
$CAPA_{t-1}$	-1.890*	-1.263*	-0.154	-0.005	-0.746	1.685*
	(0.895)	(0.675)	(0.109)	(0.193)	(0.926)	(0.964)
$CAPA_{t-1} * EBOR_t$	0.692**	-0.031	-0.003	-0.011	-0.826	-0.744
	(0.234)	(0.453)	(0.092)	(0.109)	(0.889)	(0.926)
$ILIQA_{t-1}$	-0.324*	0.285*	-0.519***	0.287**	-0.743***	0.245**
	(0.148)	(0.170)	(0.029)	(0.116)	(0.091)	(0.095)
$ILIQA_{t-1} * EBOR_t$	0.059	-0.156*	0.236***	-0.155***	0.379***	-0.272***
	(0.075)	(0.085)	(0.024)	(0.046)	(0.089)	(0.092)
$LOGA_{t-1}$	-0.141	-0.214**	-0.081***	-0.107***	-0.206***	-0.162***
	(0.124)	(0.089)	(0.013)	(0.030)	(0.040)	(0.042)
$LOGA_{t-1} * EBOR_t$	-0.030	0.035	0.011***	-0.006	0.074***	-0.011
	(0.036)	(0.032)	(0.002)	(0.004)	(0.023)	(0.024)
Individual effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.432	0.561	0.409	0.145	0.508	0.438
Adjusted R-squared	0.221	0.316	0.342	0.126	0.388	0.302

The relationship between the dependent variables and liquidity risk exposure from the asset side of the balance sheet is consistent across the panels in both of the models. However, in the second model, there is a difference between panels A and C when it comes to the liabilities side risk exposure. Both CAPA and DEPA have a significant relation to LOAN in both panels but the sign of the relation is opposite between these two panels. After CAPA and DEPA are interacted with the Euribor -spread the signs of the coefficients are similar between panels indicating that in the height of the crisis, the relation between liquidity risk exposure and the loan growth is similar in all size groups.

5.4 The sovereign debt crisis (2010-2014 period)

Table 7 introduces the regression results for the 2010-2014 period with includes the sovereign debt crisis of European Union and the peaceful post-crisis period. The first regression that models the liquidity hoarding of the banks with LIQA as dependent variable has an R-squared of 0,399 in the panel of small banks, 0,294 in the panel of medium size banks and 0,583 in the panel of large banks. The results from the second regression that models the credit creation of the banks with LOAN as dependent variable also have a R-squared over 0,4 in the small and large bank panels but the panel for medium sized banks suffers from a low R-squared of 0,086 similarly to the previous time period.

The results of first regression from panel A shows that DEPA without the interaction with Euribor -spread, has a significant (5 %) positive relation to LIQA. Other liquidity risk exposure proxies from the liabilities side do not have a significant relations. ILIQA has a significant (1 %) negative relationship but after the interaction with Euribor -spread, the relation is no longer statistically significant.

Variables from the liabilities side of balance sheet have negative relation to LOAN in second regression similarly to the results of panel A in previous time period. DEPA has a significant (10 %) but weak negative relation and CAPA has significant (1 %) strong negative relation to LOAN. Neither of these variables has a significant relation after they are interacted with the

Euribor -spread. ILIQA also has significant (1 %) but positive relation to LOAN only without the interaction in panel A.

In the panel B, CAPA has a significant (10 %) and negative relation to LOAN but there is no significant relation anymore after the interaction with Euribor -spread. ILIQA shows a significant (1 %) relation to LIQA in the first regression. The sign of the coefficient turns from negative to positive after the variable is interacted with the Euribor -spread similarly to the results from the previous time period.

DEPA has a significant (10 %) weak positive relation to LOAN for medium size banks but only when it is interacted with the spread. On the other hand, CAPA has a significant (1 %) strong positive relation to LOAN but only after it is interacted with the Euribor- spread. In the assets side of balance sheet, ILIQA has a significant (1 %) relation to LOAN and the sign of relation turns opposite after the interaction with Euribor -spread in panel B similar to the previous time period.

LIQA has a statistically significant (1 %) relation only with ILIQA in panel C. The sign of the coefficient is again negative before and turns positive after the interaction with Euribor -spread. In the second model, relationship with ILIQA and LOAN behaves similarly to the previous time period and is significant at 1 percent risk level. CAPA also has a significant (5 %) strong positive relation to LOAN after it is interacted with the spread in panel C.

The relationship between the dependent variable and liquidity risk exposure from the asset side of the balance sheet is consistent across the panels in both of the models similarly to the previous period. The relation between the proxies of liquidity risk exposure from liabilities side and dependent variable suffer from low statistical significance overall in both models but results still indicate that there are some differences in the relationship between credit creation and liquidity risk exposure based on the size of the bank.

Table 7 Regression results for 2010-2014 period

Panel A reports fixed effects regression results for small (Total assets < 0,005 percent of total consolidated assets of EU banks) banks, panel B for medium (Total assets between 0,005 and 0,5 percent of total consolidated assets of EU banks) banks and panel C for large (Total assets > 0,5 percent of total consolidated assets of EU banks) banks. The robust standard errors are presented in parenthesis and *, **, *** marked behind the coefficient value denote whether the coefficients are statistically significantly different from zero at 10 percent, 5 percent and 1 percent level respectively. Time and entity fixed effects were controlled for in each regression.

	Panel A: Small Banks		*Panel B: Medium Banks*		*Panel C: Large Banks*	
	$LIQA_t$	$LOAN_t$	$LIQA_t$	$LOAN_t$	$LIQA_t$	$LOAN_t$
DEPA_{t-1}	0.118**	-0.090*	0.001	0.040*	-0.071	-0.028
	(0.051)	(0.049)	(0.014)	(0.021)	(0.057)	(0.066)
$\mathrm{DEPA}_{t-1} * EBOR_t$	-0.288	-0.176	0.025	-0.029	-0.152	0.213
	(0.184)	(0.123)	(0.022)	(0.035)	(0.148)	(0.162)
$CAPA_{t-1}$	0.078	-0.839***	0.069	-0.089	0.988	-1.021
	(0.424)	(0.306)	(0.066)	(0.105)	(0.604)	(0.763)
$CAPA_{t-1} * EBOR_t$	-0.103	-0.187	-0.253*	0.607***	-1.057	2.045**
	(0.551)	(0.461)	(0.132)	(0.208)	(0.883)	(0.684)
$ILIQA_{t-1}$	-0.649***	0.262***	-0.473***	0.184***	-0.809***	0.393***
	(0.085)	(0.080)	(0.030)	(0.047)	(0.077)	(0.107)
$ILIQA_{t-1} * EBOR_t$	0.269	0.031	0.415***	-0.218***	0.420***	-0.492***
	(0.175)	(0.077)	(0.045)	(0.071)	(0.127)	(0.127)
$LOGA_{t-1}$	-0.056	-0.182***	-0.035***	-0.063***	-0.118***	-0.039
	(0.104)	(0.041)	(0.009)	(0.014)	(0.042)	(0.026)
$LOGA_{t-1} * EBOR_t$	-0.054	-0.171***	0.017***	-0.006	0.035	0.006
	(0.056)	(0.046)	(0.004)	(0.006)	(0.034)	(0.035)
Individual effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.399	0.448	0.294	0.086	0.583	0.512
Adjusted R-squared	0.268	0.253	0.220	-0.009	0.486	0.445

6 Conclusions

This paper studied the liquidity risk management of the banks located in the Eurozone during a financially turbulent period of 2006-2014. The liquidity risk management was modelled by the growth in liquid assets ratio (LIQA) and decrease in the lending (LOAN). The fixed effects panel regression was used to examine the relationship between different proxies of liquidity risk exposure and the liquidity risk management. The widely accepted indicator of financial market distress, the Euribor -spread, was also included into the regressions to model the intensity of the crises during different quarters.

The sample was divided into two subsets in order to examine the differences between the two crises, the credit crisis and the sovereign debt crisis, which took place in the Eurozone. The credit crisis period from 2006-2009 includes the peaceful pre-crisis period and then one of the most turbulent periods in the history of financial markets. The second sub-sample covers the period from 2010 to 2014 including the peaceful post crisis period together with the sovereign debt crisis of European Union. In addition, the banks in the sample were divided into three panels based on the size of their total assets. The Euribor -spread was divided into the liquidity and credit risk components to better understand the changing composition of the spread.

The analysis of the bank characteristics in chapters 5.1 and 5.2 revealed that the larger banks had a higher liquidity risk exposure measured by the equity (CAPA) and deposits (DEPA) ratios during the 2006 to 2014 period. The results also indicate that banks were less exposed to the liquidity risk during the European sovereign debt crisis compared to the credit crisis suggesting that banks started to relay more on the stable sources of financing as the crisis went on. The size of the bank did not play as crucial role in the liquidity risk exposure of banks measured by the illiquid assets ratio (ILIQA) during the credit crisis but during the following crisis, the large banks were less exposed to the liquidity risk than their smaller counterparts. Overall, the results indicate that larger banks were more exposed to the liquidity risk than their smaller counterparts during both crises and that the exposure decreased during the second crisis. The results considering the size of the bank are also in line with previous study (Cornett. et. al. 2011) from

the US market with the exception that in that paper, the larger banks were also more exposed to the liquidity risk stemming from the holdings of illiquid assets.

The peak of the credit crisis in 2008 was the turning point in the liquidity risk management of the banks in general since after that, LIQA increased, and LOAN decreased on yearly basis until the year 2013. The liquidity risk management also intensified during 2011, which was the peak of the sovereign debt crisis based on the Euribor -spread. The average quarterly changes in the holdings of liquid assets indicate that larger banks started hoarding liquidity already in the pre-crisis period and that the average growth in liquid assets slowed down during the both crises. On the other hand, the small banks did on average decrease their holdings of liquid assets during the credit crisis but experienced the liquidity hoarding during the following crisis. One notable observation was that the quarterly average growth in the liquid assets ratio remained positive throughout the crisis in all size groups except for the small banks during the credit crisis. The average quarterly loan growth decreased from the credit crisis onwards regardless of the size of the bank. These findings provide support for the theory that banks manage their liquidity risk by increasing their holdings of liquid assets and by decreasing lending.

The regression results from the credit crisis period (chapter 5.3) in general suggest, that the proportion of illiquid assets in the bank's balance sheet had the most consistent relation to the liquidity risk management of banks. After ILIQA was interacted with the Euribor-spread to emphasize the crisis periods, the higher ILIQA in the beginning of the quarter resulted in higher growth in LIQA and decrease in LOAN during that quarter regardless of the size of the bank. The results also suggest that the equity capital plays a different role in small and large banks when it comes to the new credit creation. Higher CAPA increased the growth in LOAN in larger banks and decreased the growth of LOAN in smaller banks. In the medium sized banks, the relationship between CAPA and growth of LOAN became non-existent, further indicating that the relationship is dependent of the size of the bank. DEPA behaved similarly to the equity ratio but the strength of the relationship with the loan growth was smaller.

The results from the sovereign debt crisis (chapter 5.4) indicate that ILIQA was again the most consistent proxy for the liquidity risk exposure across the different size groups. The other proxies suffered from low statistical significance with some exceptions. CAPA had a very strong

positive relation to LOAN in the large and medium size banks after it was interacted with the Euribor -spread. On the other hand, CAPA played an opposite role in the loan growth ratio of the smallest banks even though only when the Euribor-spread was not included into the variable.

In general, the differences between the two time periods were marginal. ILIQA had the most consistent relationship to the liquidity risk management during both time periods. When it was not interacted with the Euribor-spread, the higher proportion of illiquid assets increased the liquidity hoarding and decreased the loan growth but after the Euribor-spread was included into the variable, the relationship turned into the opposite direction. Since the interaction with the Euribor-spread emphasizes the results from the crisis quarters, these results indicate that there was no need for banks to manage their liquidity risk during the peaceful quarters regardless of their risk exposure. All in all, it seems evident that banks with lower illiquid assets ratio exhibited less liquidity hoarding and were better able to continue lending during the crisis quarters. These results are consistent with previous studies conducted in the US market from Cornet et. al (2011) and Diamond and Rajan (2001).

The liquidity risk exposure stemming from the liabilities side of the balance seemed to be less straightforward and more dependent on the size of the bank than the time period in question. DEPA did not seem to relate to the liquidity hoarding of banks during either of the two crises and CAPA only during the credit crisis in the small banks. The second regression showed more meaningful results but the inconsistency of the results among the size groups makes it difficult to make generalized conclusions. DEPA has been shown to have a decreasing effect on the liquidity risk by the previous studies (Cornett et al 2011, Khan, Scheule and Wu 2016, Ivashina and Scharfstein 2010).

There is some evidence in the results of relationship between the capital and loan growth indicating, that the smaller banks follow the “financial fragility – crowding out” -hypothesis and the larger banks follow the “risk absorption” -hypothesis. The higher CAPA increased the loan growth in large banks and behaved in an opposite manner in small banks regardless of the subperiod in question. These results are in line with the discussion about the relationship between bank capital and liquidity creation and the role that the size of the bank plays in it. (e.g. Berger and Bowman 2009, Gorton and Winton 2001, Diamond and Rajan 2001, Allen and Gale

2004) However, the robustness of these results suffers from the fact that differences between the size groups were only evident without the interaction with the Euribor-spread in the results for credit crisis and with the interaction in the results for the sovereign debt crisis. The dataset also consisted solely of listed banks, which eliminates the majority of the small banks from the sample. On the other hand, the results of the latter crisis indicate that equity played a larger role in the growth in loans. One reason for this could be fact that during the sovereign debt crisis, the credit risk portion of the Euribor -spread was the dominant one, effecting the lending between banks.

The results of this thesis indicate that banks in the Eurozone manage increased liquidity risk during the crisis by increasing their holdings of liquid assets and in the same time decrease their lending. It seems that banks which hold sufficiently liquid asset portfolios at the beginning of the crisis can continue lending better than their counterparts suggesting that liquidity of the asset portfolio is related to the liquidity risk. Results also suggest that relaying on equity capital to finance banks operations provides large banks with similar benefits as liquid asset portfolio. On the other hand, equity capital has an opposite effect on the credit creation in small banks. These results were evident in the Eurozone during the credit crisis and the sovereign debt crisis but the relationship between capital and lending was more profound during the latter crisis. The results of this thesis also indicate that the liquidity risk management of the Eurozone banks is not highly dependent on the composition of the Euribor- spread as the results under high liquidity (credit crisis) and credit (sovereign debt crisis) risk were almost identical. However, there is some evidence that the role of the equity capital becomes more profound under high credit risk.

Unfortunately, the results of this thesis suffer from the insufficient dataset that was used in this paper. The data limitations forced me to remove one potentially important variable, the unused off-balance sheet loan commitments, from the regressions and this is expected to have a notable effect in the final results. Data limitations also forced me to use data only from the listed companies, which in turn removes a large portion of the smallest banks from the sample used in this study. Finally, the same limitations made it impossible for me to create core deposits to assets variable as accurately as I would have wanted and instead I had to work with broader deposits to assets variable. Nevertheless, the goodness of fit in the regressions of this thesis was

at sufficient level and results seem reasonable considering the previous literature and theory about the subject.

The results of this thesis could be helpful for the legislators to gain a better understanding for the role played by the liquid assets and equity capital in the banks risk management. The understanding of the liquidity risk management of banks and the changing composition of the Euribor -spread during crises provides the policy makers and central banks better understanding about the effects of the actions they took during the turbulent times. This thesis added a European view to the literature about the liquidity risk management, which has been strongly focused towards the US market.

Previous studies (Szaijt et. al. 2015, Kashyap et. al- 1997) indicate, that there are some differences between banks in the Eurozone based on the country in which they operate. Also, this thesis further indicates, that the relationship between capital and liquidity creation is dependent on the size of the bank. A better understanding about the differences in the determinants of bank liquidity creation and risk exposure based on the size and location of the bank is crucial for the legislators and policy makers of the EU. The unified banking regulation only works if all of the participating banks are taken into account. Therefore, for the future study, it would be interesting to examine the relation between bank size and location to liquidity creation in the Eurozone with broader dataset.

References

Acharya V., Gromb D. & Yorulmazer, T. 2007. Imperfect competition in the interbank market for liquidity. Working Paper, London Business School.

Acharya, V. & Naqvi, H. 2012. The seeds of a crisis: a theory of bank liquidity and risk taking over the business cycle. *Journal of Financial Economics*, vol. 106, pp. 349-366.

Allen, F. & Gale, D. 2004. Financial Intermediaries and Markets**.** *Econometrica*, Vol. 72, No. 4, pp. 1023-1061

Allen, F. & Gale, D. 2005. From Cash-in-the-Market Pricing to Financial Fragility. *Journal of the European Economic Association*, vol. 3 (2-3), pp. 535-546.

Arellano, M. 1987. Practitioners' Corner: Computing Robust Standard Errors for Within-groups Estimators *. *Oxford Bulletin of Economics and Statistics*, vol. 49(4), pp. 431-434.

Arnold, B., Borio, C., Ellis, L. & Moshirian, F. 2012. Systemic risk, macroprudential policy frameworks, monitoring financial systems and the evolution of capital adequacy. *Journal of Banking & Finance*, vol. 36, issue 12, pp. 3125-3132.

Baltagi, B., H., 2005. Econometric analysis of panel data. 3rd ed. Chichester: John Wiley & Sons Ltd

Bank of England 2007. An indicative decomposition of Libor spreads. *Quarterly Bulletin*, 4th quarter, pp. 498-499.

Basel Committee on Banking Supervision 1988. International convergence of capital measurement and capital standards

Basel Committee on Banking Supervision 2004. Basel II: International Convergence of Capital Measurement and Capital Standards: a Revised Framework

Basel Committee on Banking Supervision. 2008. Principles of Sound Liquidity Risk Management and Supervision. September 2008

Basel Committee on Banking Supervision 2010a. Basel III: A global regulatory framework for more resilient banks and banking systems

Basel Committee on Banking Supervision 2010b. Basel III: International framework for liquidity risk measurement, standards and monitoring

Beirne, J., Caporale, G. & Spagnolo, N. 2012. Liquidity risk, credit risk and the overnight interest rate spread: A stochastic volatility modelling approach. *Manchester School*, vol. 81(6).

Beirne J., Dalitz L., Ejsing J., Grothe M., Manganelli S., Monar F., Sahel B., Sušec M., Tapking J. & Vong T. 2011. The impact of the eurosystem's covered bond purchase Programme on the primary and secondary Markets. *European Central Bank Occasional Paper Series*, No. 122.

Berger, A. N. & Bouwman, C. 2009. Bank Liquidity Creation. *The Review of Financial Studies*, vol. 22(9), pp. 3779-3837.

Bhattacharya, S. & Thakor, A. 1993. Contemporary Banking Theory, *Journal of Financial Intermediation*, vol. 3, pp. 2–50.

Bank for International Settlements 2018. History of the Basel Committee. [online document]. [Accessed 10.6.2018]. Available at https://www.bis.org/bcbs/history.htm

Borio, C. 2010. Ten propositions about liquidity crises, *CESifo Economic Studies,*vol. *56*(1), pp. 70-95.

Brooks, C. 2008. Introductory econometrics for finance, 2nd edition, Cambridge: Cambridge University Press.

Bryant, J. 1980. A model of reserves, bank runs and deposit insurance, *Journal of Banking and Finance*, vol. 4(1), pp. 335-344.

Cifuentes, R., Ferrucci, G. & Shin, H. 2005. Liquidity Risk and Contagion, *Journal of the European Economic Association*, vol. 3(2-3), pp. 556-566.

Cornett, M.M., McNutt, J.J., Strahan, P.E. & Tehranian, H. 2011. Liquidity risk management and credit supply in the financial crisis, *Journal of Financial Economics,* vol. 101, no. 2, pp. 297-312.

De Socio, A. 2013. The interbank market after the financial turmoil: Squeezing liquidity in a "lemons market" or asking liquidity "on tap". *Journal of Banking & Finance*, vol. 37, no. 5, pp. 1340-1358.

Delivorias, A. 2015. Monetary Policy of the European Central Bank: Strategy, Conducts and Trends. *European Parliamentary Research Service*, February 2015.

Diamond, D. 2007. Banks and Liquidity Creation: A Simple Exposition of the Diamond-Dybvig Model, *Economic Quarterly - Federal Reserve Bank of Richmond,* vol. 93(2), pp. 189-200.

Diamond, D. & Dybvig, P. 1983. Bank Runs, Deposit Insurance, and Liquidity. *The Journal of Political Economy*, vol. 91(3), pp. 401-419.

Diamond, D.W. & Dybvig, P. 1984. Financial Intermediation and Delegated Monitoring. *The Review of Economic Studies*, vol. 51, no. 3, pp. 393-414.

Diamond, D. & Rajan, R. 2000. A Theory of Bank Capital. *Journal of Finance,* vol. 55, issue 24, pp. 31–65.

Diamond, D. & Rajan, R. 2001. Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking, *Journal of Political Economy*, vol. 109, pp. 287–327.

Diamond, D. & Rajan, R. 2009. The credit crisis: Conjectures about causes and remedies. *American Economic Review*, vol. 99(2), pp. 606-610.

Drehmann, M. 2007. Discussion, The Structure and Resilience of the Financial System, Reserve Bank of Australia.

Drehmann, M. & Nikolaou, K. 2013, Funding liquidity risk: Definition and measurement. *Journal of Banking & Finance*, vol. 37, no. 7, pp. 2173-2182.

ECB (2009) Longer-term refinancing operations, Press Release, 7 May 2009

ECB (2010), The ECB's Response to the Financial Crisis, Monthly Bulletin, October 2010

ECB 2011. The Monetary Policy of the ECB, 3rd ed, May 2011.

ECB 2018. Consolidated Banking Data. [online document]. [Accessed 10.6.2018]. Available at https://www.ecb.europa.eu/stats/supervisory_prudential_statistics/consolidated_banking_data/html/index.en.html

Frank, N. & Hesse, H. 2009. Financial Spillovers to Emerging Markets during the Global Financial Crisis. *Finance a Uver, vol. 59*(6), pp. 507.

Ferguson, R.W., Hartmann, P., Panetta, F. & Portes, R. 2007. International Financial Stability. *Geneva Reports on the World Economy*, ICBM (International Center for Monetary and Banking studies), CEPR, 9.

Gatev, E., Schuermann, T. & Strahan, P. 2009. Managing Bank Liquidity Risk: How Deposit-Loan Synergies Vary with Market Conditions. *The Review of Financial Studies*, vol. 22(3), pp. 995-1020.

Gorton, G. & Pennacchi, G. 1990. Financial Intermediaries and Liquidity Creation. *Journal of Finance*, vol. 45(1), pp. 49-71.

Gorton, G. & Winton, A. 2017. Liquidity Provision, Bank Capital, and the Macroeconomy. *Journal of Money, Credit and Banking*, vol. 49(1), pp. 5-37.

Hui, C.H., Chung, T.K. & Lo, C.F. 2013. Using Interest Rate Derivative Prices to Estimate LIBOR-OIS Spread Dynamics and Systemic Funding Liquidity Shock Probabilities, *Asia-Pacific Financial Markets*, vol. 20, issue 2, pp. 131-146.

Hull, J. C. 2006. Option, Futures, and Other Derivatives, 6th edition, New York: Prentice Hall.

International Monetary Fund. Monetary and Capital Markets Department 2008. *Global Financial Stability Report*, April.

International Monetary Fund 2011. Greece: Fifth Review under the Stand-By Arrangement, Rephasing and Request for Waivers of Nonobservance of Performance Criteria; Press Release on the Executive Board Discussion; and Statement by the Executive Director for Greece. *IMF Country Report*, no. 11/351, Washington, December.

Ivashina, V. & Scharfstein, D. 2010. Bank lending during the financial crisis of 2008, *Journal of Financial Economics*, vol. 97(3), pp. 319-338.

Heider, F., Hoerova, M. & Holthausen, C. 2015. Liquidity hoarding and interbank market rates: The role of counterparty risk. *Journal of Financial Economics*, vol. 118(2), pp. 336.

Karmakar, S. & Mok, J. 2015. Bank capital and lending: An analysis of commercial banks in the United States, *Economics Letters*, vol. 128(C), pp. 21-24.

Kashyap, A. & Stein, J. 1997. The role of banks in monetary policy: A survey with implications for the European monetary union, *Economic Perspectives,* vol. 21(5), pp. 2-18.

Khan, M., Scheule, H. & Wu, E. 2017. Funding liquidity and bank risk taking. *Journal of Banking and Finance*, vol. 82, pp. 203-216.

Kishan, R. & Opiela, T. 2000. Bank Size, Bank Capital, and the Bank Lending Channel. *Journal of Money, Credit and Banking*, vol. 32, no. 1, pp. 121-141.

Lane, P. 2012. The European Sovereign Debt Crisis. *Journal of Economic Perspectives*, vol. 26, pp. 49-68.

Nikolau, K. 2009. Liquidity (Risk) Concepts Definitions and Interactions. *European Central Bank Working Paper Series*, no. 1008, February 2009.

Malherbe, F. 2014. Self-Fulfilling Liquidity Dry-Ups. *The Journal of Finance,* vol. 69(2), pp. 947-970.

Machina, M. & Rothschild, M. 1987. "Risk", The New Palgrave Dictionary of Economics, London: MacMillan, pp.203-5.

Mcandrews, J., Sarkar, A. & Wang, Z. 2017. The effect of the term auction facility on the London interbank offered rate. *Journal of Banking and Finance*, vol. 83, pp. 135-152.

Michaud, F. & Upper, C. 2008. What drives interbank rates? Evidence from the Libor -panel, *BIS Quarterly Review,* March 2008.

Milesi-Ferretti, G., Tille, C., Ottaviano, G. & Ravn, M. 2011. The great retrenchment: International capital flows during the global financial crisis, *Economic Policy*, vol. 26(66), pp. 285-342.

Mishkin, F. 2011. Over the cliff: From the subprime to the global financial crisis, *Journal of Economic Perspectives*, vol. 25(1), pp. 49-70.

The Organization for Economic Co-operation and Development 2011. OECD Economic Outlook, vol. 2011, issue 1

O' Hara, M. & Shaw, W. 1990. Deposit Insurance and Wealth Effects: The Value of Being "Too Big to Fail". *Journal of Finance*, vol. 45(5), pp. 1587-1600.

Repullo, R. 2004. Capital requirements, market power, and risk-taking in banking. *Journal of Financial Intermediation*, vol. 13(2), pp. 156-182.

Shambaugh, J., Reis, R. & Rey, H. 2012. The Euro's three crises, *Brookings Papers on Economic Activity*, vol. 1, pp. 157-211.

Strahan, P. 2008. Liquidity Production in the 21st Century. *NBER Working Paper*, no. 13798.

Sundaresan, S., Wang, N. & Yang, J. 2015. Dynamic Investment, Capital Structure, and Debt Overhang, *The Review of Corporate Finance Studies*, vol. 4, issue 1, pp. 1–42

Szaijt, M. & Wojcik-Mazur, A. 2015. Determinants of liquidity risk in commercial banks in the European Union, *Argumenta Oeconomica*, vol. 2(35), pp. 25-47.

Taylor, J. & Williams, J. 2009. A Black Swan in the Money Market. *American Economic Journal: Macroeconomics*, vol. 1(1), pp. 58-83.

Wallace, T. & Hussain, A. 1969. The Use of Error Components Models in Combining Cross Section with Time Series Data**,** *Econometrica*, vol. 37, no. 1, pp. 55-72

W. Wagner 2007. The liquidity of bank assets and banking stability, *Journal of Banking Finance*, vol. 31, pp. 121-139

White, H. 1980. A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. *Econometrica*, vol. 48(4), p. 817.

Appendices

Appendix 1 Euribor -panel banks during 2006-2014 period (The European Money Markets Institute (EMMI) 2018)

Bank	**Country**
Erste Group Bank AG	Austria
Dexia Group	Belgium
KBC Group	Belgium
Nordea	Sweden
BNP Paribas	Spain
Société Générale S.A.	France
Natixis	France
Crédit Agricole SA	France
Deutsche Bank	Germany
Commerzbank AG	Germany
Landesbank Baden-Württemberg	Germany
Banca Monte dei Paschi di Siena	Italy
UniCredit S.p.A	Italy
Bank of Ireland	Ireland
Allied Irish Banks	Ireland
Banco Bilbao Vizcaya Argentaria	Spain
Barclays	United Kingdom
Danske Bank	Denmark
Svenska Handelsbanken	Sweden

Appendix 2 Member countries of the Eurozone during 2006-2014 period (European Commission 2018)

State	Member of the Eurozone since
Austria	1999
Belgium	1999
Cyprus	2008
Estonia	2011
Finland	1999
France	1999
Germany	1999
Greece	2001
Ireland	1999
Italy	1999
Luxembourg	1999
Malta	2008
Netherlands	1999
Portugal	1999
Slovakia	2009
Slovenia	2007
Spain	1999