Leena Naski

EARLY WARNING INDICATORS OF THE GLOBAL FINANCIAL CRISIS

Focus on bank profitability and funding in the United States 2004-2008

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TIIVISTELMÄ:
Globaali finanssikriisi sai alkunsa Yhdysvalloissa 2007 asuntomarkkinoiden hintojen romahtaessa. Rahoituslaitokset huomasivat taseissaan oleviensa asuntolainavakuudellisten arvopapereiden arvojen olevan nopeasti huomattavasti oletettua alhaisempia. Pankkien kannattavuus kääntyi jyrkkään laskuun. Lyhytaikainen likviditeetti ehtyi riskien kasvaessa ja luottamus arvopaperien vakuuksiin heikkeni. Rahoituslaitokset joutuivat turvautumaan monimuotoisempiin rahoitusratkaisuihin. Rahoitusinstrumenttien monimutkaiset rakenteet ja liiallinen arvopaperistaminen levittivät kriisin nopeasti koko pankkijärjestelmään. Tämä aiheutti paniikin, joka lamautti rahoitusmarkkinoiden tehokkaan toiminnan.

Yksityiset ja julkiset instituutiot pyrkivät aktiivisesti ennustamaan ja ennakoimaan tulevia kriisejä ja markkinoiden muutoksille herkkiä ennakoivia indikaattoreita käyttämällä ekonometrisia mallinnuk-sia. Ennen finanssikriisiä Yhdysvalloissa ennakoivat indikaattorit ja mallinnukset kuitenkin epäonnistuivat ennustamaan kriisin alun. Tämän tutkimuksen tarkoituksena on analysoida, mikäli finanssikriisin alku olisi voitu ennakoida pankkijärjestelmän arvopaperistettujen ja lyhytaikaisen rahoituksen avulla. Päämääränä on selvittää, oliko asuntolainavakuudellisilla arvopapereilla, takaisinostosopimuksilla sekä yhdysvaltain keskuspankin liikkeellelaskemien pankkien välisten markkinoiden arvopapereilla merkittävä vaikutus pankkien kannattavuuteen ja pääoman tuottoasteeseen. Tärkeänä kysymyksenä on, toimivatko kyseiset muuttujat kriisejä ennakoivina indikaattoreina. Tutkimuksen aineisto sisältää Worldscope -tietokannan yhdysvaltalaisia pankkeja vuosilta 2004-2008. Tutkimusmenetelminä ovat lineaarinen sekä kiinteiden menetelmien -regressiomalli.

Yleisesti kyseisillä muuttujilla on akateemisessa kirjallisuudessa nähty olevan suora vaikutus finanssikriisin alkuun. Tämän tutkimuksen tulokset ovat kuitenkin poikkeavia. Lineaarinen regressiomalli löytää ainoastaan merkittävän positiivisen korrelaation takaisinostosopimusten ja pankkien pääoman tuottoasteen väliltä. Tämä viittaa siihen, että takasisinostosopimusten käyttö ennakoivina indikaattoreina on soveltuvaa vain, jos sopimukset kärsivät nopeasta määrän laskusta tai romahduksesta. Kiinteiden menetelmien -malli puolestaan ei löydä minkäänlaisia merkittäviä korrelaatioita. Tässä tulkintana on, että pankkikohtaiset ajassa muuttumattomat taustalla olevat ominaisuudet olivat todelliset perusteelliset syyt kriisin vakavuudelle. Vastaavasti myös arvopapereiden taustalla olevat riskit vaikuttivat merkittävästi kriisin syntyyn ja pankkien kannattavuuden romahdukseen. Tulosten perusteella tutkitut muuttujat eivät itsessään toimi hyvinä ennakoivina indikaattoreina, ja käytetyissä ekonometrisissa malleissa tulisi vahvasti huomioida taustalla olevat muuttumattomat ominaisuudet ja riskit. Tällöin kriisien ennakoiminen pankkien arvopapereiden pohjalta tuottaisi tehokkaampia ja käyttökelpoisisempia ennusteita.

AVAINSANAT: financial crises, banks (monetary institutions), economic indicators, securitisation, regression analysis, profitability, monetary policy, lending

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1 Introduction

Laeven & Valencia (2020) define a financial crisis as an event, that causes distress and significant losses in the banking system. As a respond to the losses, significant banking policy intervention measures are executed in the financial markets. If the policy interventions and distress and losses in the banking system appear at the same time, the financial crisis is defined as a systemic crisis. Systemic crises are systemic events, that described by Lo Duca & Peltonen (2013) are periods of extreme financial instability. The extreme financial stress in the financial markets can lead up to negative real economic consequences with severe potential real costs (Lo Duca & Peltonen, 2013). As consequence to the systemic crises a sustained decline in economic activities and in financial intermediation can ensue (Laeven & Valencia, 2020). Ultimately the economic welfare can be fundamentally declined and disrupted.

The global financial crisis of 2007-2011 was a systemic financial crisis. In the U.S., the Federal Reserve initiated a series of aggressive policy actions and unconventional open market programs to alleviate the extreme financial stress (Brave & Genay, 2011; Laeven & Valencia, 2020). During the crisis, the U.S. economy suffered 30% GDP output loss (Laeven & Valencia, 2020). The severe distress in the financial markets affected the credit lending of every firm and institution. Merely during 2008, the U.S. stock market lost about 8 trillion USD (Brunnermeier, 2009). The U.S. household wealth fell in less than a year more than 17%, and every month nearly 800 000 were lost (U.S. Department of the Treasury, 2019).

The first indicators and signals of the 2008 global financial crisis began to surface on February 2007, when the U.S. housing prices started to fall, and large subprime mortgage lenders and institutions began to report losses (Reinhart & Rogoff, 2008; Cecchetti, 2009). The falling house prices and the followed higher default levels led into the subprime crisis in the early autumn 2007 (Reinhart & Rogoff, 2008). In late August 2007, the global

financial crisis was set, and the symptoms of the crisis began to spread globally on the financial markets. The U.S. financial system started to fall apart (Cecchetti, 2009).

The financial institutions found themselves in a situation, where the assumed value of the mortgage-backed securities they were holding was much less than expected. Accurate valuation of the assets was getting increasingly more difficult, which was affected by the innovation of complex bundling of obligations. The innovation made the newly constructed instruments extremely nontransparent and caused them to become illiquid in the markets struggling with the falling house prices. The effect was a severe magnification of the losses and distress in the financial sector (Reinhart & Rogoff, 2008; Cecchetti, 2009). The banks and institutions became more reluctant to lend, because the uncertainties of their asset values and the banks' solvencies had sprung up. This affected the ability of the financial intermediaries to find much needed short-term funding, that they needed to continue their daily operations (Cecchetti, 2009).

The lack of funding and financial turmoil caused the markets for short-term debt to become extremely vulnerable, which affected especially hard the repo markets. The short-term funding through repo markets dried up due to increased risks and decreased collateral values. Banks were driven to a situation, where their market liquidity had become increasingly scarce and inaccessible (Gorton & Metrick, 2012). The absence of overnight liquidity increased the demand for overnight federal funds and the heightened liquidity risks, funding distress and increased payment shock drove the banks to rely on holding excessive interbank funds on their balance sheets (Ashcraft, McAndrews & Skeie, 2011). The federal funds markets became distressed, and the interbank markets shifted into a general state of freeze. The panic led to asset write downs and to a downward spiral of the prices of structured products (Gorton, 2010, p. 146; Ashcraft et al., 2011).

During the crisis, the U.S. banks suffered from extreme decreases of value and from severe strains on their profitability. These were shown in the banks' return on equity (ROE). The excessive risk-taking and higher targeting of profitability exposed the banks to

systemic risks (Moussu & Petit-Romec, 2017). During the crisis, the ROE for U.S. commercial banks crashed down from its precrisis all-time high to its all-time low below zero (Federal Reserve Bank of St. Louis and Federal Financial Institutions Examination Council, 2020; World Bank, 2020).

The early warning indicators and systems are meant to predict and identify vulnerable states in the financial markets, that could lead to financial crises (Peltonen, Rancan & Sarlin, 2018). The assessment is done through various empirical econometric models based on explanatory variables. Historical data and theoretical models are used to construct the early warning systems. The variables are expected to have an impact or correlation to the financial development, and their effect to a possible onset of a crisis is analyzed. However, predicting early warning indicators is challenging. Especially during the precrisis years, the indicators and systems used in the U.S. financial markets failed to efficiently predict the onset of the global financial crisis (Berg, Borensztein & Pattillo, 2004; Rose & Spiegel, 2009).

The global financial crisis became the first crisis, that thoroughly affected globally the modern high-income economies. In the preceding years since the 1970s the banking crises had mainly affected the low- and middle- income countries, and only locally by short periods of high-income countries. In 2008 it became clear, that despite the income level, financial crises posed an equal threat to all economies (Laeven & Valencia, 2020). Moussu & Petit-Romec (2017) find strong evidence, that pre-crisis ROE as a bank performance and profitability measure was a significant key predicative indicator for bank losses during the crisis. This raises a further question: If the bank losses during the financial crisis and ROE were strongly correlated, could ROE, and thus bank profitability, have been estimated through correlation with other bank metrics? And even further, could these variables have been effective on predicting the crisis, and overall be used as early warning indicators. Could the global financial crisis have been avoided?

This study uses return on equity as a measure of bank profitability during the global financial crisis and analyzes the correlation and effects of the bank specific volumes of mortgage-backed securities, repurchase agreements and federal funds to the U.S. bank profitability. The research problem focuses on assessing and answering, whether these variables have a significant correlation with the banks' ROE values, and if the variables can be used as early warning indicators. The analysis is done by using multiple linear regression -model and fixed effects -model as the empirical econometric methods. Historical and theoretical data is crucial for the future prediction, prevention and resolving of financial crises (Laeven & Valencia, 2020). Similarly, the goal of this paper is to bring insights to the causes and predictability of financial crises. The results will hopefully bring more information and perspective about the early warning system, that can be used in the future.

The structure of this study is following: Chapter two discusses the framework and the two main topics of this study -the global financial crisis and early warning indicators- from the perspective of theoretical and academical concepts and literature. Chapter three presents the four examined factors and variables: return on equity, mortgage-backed securities, repurchase agreements and federal fund loans. It also includes a comprehensive academic review and theoretical analysis of the four banking sector variables during the financial crisis. Chapter four follows by presenting the data and empirical methods as well as performing the empirical analysis. Chapter five presents and analyzes the empirical results. Finally, chapter six concludes.

2 Global financial crisis and early warning indicators

The following chapters includes the theoretical discussion of the two main topics and framework of this study: the global financial crisis and early warning indicators. The chapter reviews and discusses the causes and developments of the global financial crisis and its policy responses and gives an overview of the academic literature and theory of the early warning indicators.

2.1 Global financial crisis

A banking crisis is an event, that fulfills two conditions:

I. There are significant signs of banking distress in the banking system, such as bank runs and losses in bank liquidations and the whole banking system. The losses are considered significant if NPL-ratio exceeds 20%, bank closures exceed 20% of banking system assets or if fiscal restructuring costs are exceeding 3% of GDP. At least one of these three conditions must be fulfilled.

II. There are significant banking policy intervention measures meant to respond to the significant losses. These policy interventions include deposit freezes, government takeovers, government guarantees on liabilities, Treasury liquidity support, recapitalization and asset purchase by the treasury or a government entity. At least three of these six conditions must be fulfilled.

When both of two criteria are fulfilled, the banking crisis is defined as systemic, and the year is set as the starting year of the systemic crisis. Systemic banking crises are events, that bring out high levels of disruption, which can lead to sustained declines in economic

activities and in financial intermediation. As consequence, ultimately the welfare can be fundamentally declined and disrupted. The definition derives from the comprehensive global database on systemic banking crises by Laeven & Valencia (see Laeven & Valencia, 2013). This database is being used worldwide as the standard reference for banking crises information and definition of the crises episodes. In this study, the updated version is used. (Laeven & Valencia, 2013; Laeven & Valencia, 2020.)

There have been recorded globally throughout history various previous banking and financial crises. The most recent crises include Latin America in the early 1980s, savings and loan crisis in the U.S. in the late 1980s, Nordic crisis in the early 1990s, Tequila crisis in 1994 and Asian crisis as well as Japan in the late 1990s. The beginning of the new millennium was unusual due to low incidence of crises (Laeven & Valencia, 2020). That became quickly to its end, when 2007 was faced with subprime crisis in the U.S., and the banking crisis started in the autumn of 2007. When December 2007 rolled in, the banking crisis had transformed into systemic crisis. This quickly evolved to **the global financial crisis of 2008** (Cecchetti, 2009; Laeven & Valencia, 2020).

Gorton & Metrick (2012) depicts the traditional banking to be business, where banks and other financial institutions make, own, hold and issue loans, bonds, and securities. Differing from traditional banking, **"securitized banking"** is reallocation of the loans and securities to the banking system by packing them into new various financial instruments and reselling these securitized loans and bonds in the financial market (Gorton & Metrick, 2012). Brunnermeier (2009) sees, that this kind of new banking model focusing on securitization gained popularity in the precrisis banking sector and supplanted old traditional banking models. Like Gorton & Metrick (2012) call this kind of banking "securitized banking", Brunnermeier (2009) calls it "originate and distribute" banking model. Instead of banks holding loans until they are repaid, the loans are pooled, allotted into tranches and sold through the process of securitization. The banking sector had managed to distribute the risk to those, who were the most able to bear them by default of the financial markets. This led to decline in the standards, by which the banks were abiding by in their

lending activities (Brunnermeier, 2009). However, problems in bank and market efficiencies and ineffective fund allocation in the banking system can lead to misallocation of funds and capital. In addition, the risks might not be effectively distributed amongst banks. At worst, the effects can lead up to a bank run (Afonso, Kovner & Schoar, 2011).

What this new banking model had not taken account, was the unprecedented credit expansion and interconnectedness (Brunnermeier, 2009). A characteristic of the era preceding the financial crisis was indeed the increase of the new technologically innovated financial instruments in the financial markets, that were only lightly or completely unregulated. The positive affect of these instruments was, that they undeniably increased the overall stability against shocks and reduced the transaction costs while increasing liquidity of the markets. They also distributed the risks globally and allowed a broad mix of new financial tools to be introduced. But as a downturn, the vulnerabilities against each other increased and the transparency of the instruments dropped, giving them a sort of hazed opaqueness (Reinhart & Rogoff, 2008; Gorton, 2010, p. 146). Baglioni (2012) finds similar results emphasizing, that the opacity of the OTC markets and to the lack of information put on to the quality of the complex bank assets prevented market participants to clearly see the distribution of the potential risks. Especially large banks had more opaque funding structures and assets in their balance sheets, which were only uncovered when the crisis began (Moussu & Petit-Romec, 2014). Due to these concerns, a more effective regulations and market and bank supervision would have been needed (Baglioni, 2012).

Another special feature of the financial markets to be considered important is a **maturity mismatch**. In the financial markets, the lenders are usually also borrowers. Many commercial banks finance their long-term loans, like investments or mortgages with short-term funding and deposits. The short-term assets are usually collateralized with other assets, e.g. loans and mortgages, that have been pooled to be used as a collateral. Using these kind of off-balance-sheet vehicles as funding strategy, meaning investing in

long-term assets and borrowing and funding the investments with short-term assets, which are usually securitized, will expose the banks to funding liquidity risk: on the times of financial turmoil and doubts the investors might stop buying the collateralized short-term assets, thus preventing the banks from rolling over their short-term debt, which is fundamental for ensuring the ongoing funding and liquidity for the banks. In other words, banks and financial institutions grow their risk of not being able to borrow against assets, especially short-term assets, that the banks and institutions are dependable on rolling over. This creates a maturity mismatch in the financial markets, that was highlighted before the start of the financial crisis. (Brunnermeier, 2009.)

From 2002 until August 2007 the financial markets were experiencing a relatively calm period (Bech, Klee & Stebunovs, 2012). Somewhat on the contrary to firm-level shocks, banks' balance sheets can transmit shocks in the financial markets rapidly and unpredictably due to banks' exposure to multiple sources of risk as being direct and intermediary holders of financial instruments (Peltonen et al., 2018). During the precrisis years, low lending standards and cheap credit incited the booming housing frenzy and created more fundaments for a crisis (Brunnermeier, 2009). The credit boom peaked in summer 2007. That was seen e.g. in the total commercial paper outstanding in the U.S. banking system, which had reached more than 2.2 trillion USD (Figure 1) (Ivashina & Scharfstein, 2010). Banks were actively increasing their capital to enhance their value. In banking theory, the limited liability of shares forms a lower limit for the potential losses of bank equity holders. Because the gains grow with more risk taking, the banks had an incentive to take excessive risks at the expense of other stakeholders (de Bandt, Camara, Pessarossi & Rose, 2014). The credit boom was setting the fundaments for the financial crisis (Ivashina & Scharfstein, 2010).

When the housing bubble popped in July 2007, the funding liquidity for banks dried up, and the effects were quick to spread (see Chapter 3.2.1) (Brunnermeier, 2009). In the summer, the wealth had started increasingly contract and the functioning of the credit market had started to impair (Reinhart & Rogoff, 2008). The depositary institutions

experienced major downgrading of many of their assets, including several pooled tranches consisting of mortgage-related products (see Chapter 3.3.1). Onwards from July 2007 house prices and sales continued to increasingly drop. The worst case hit the financial markets, when in August 2007 the short-term market for asset-backed commercial papers dried up completely. The losses of the subprime mortgages had started to realize (Brunnermeier, 2009).

What had not been seen before in the previous banking crises, was the amount of **securitization**. It caused the financial markets to become an interconnected network of obligations and agreements without transparency and transform them to an opaque web of information (Brunnermeier, 2009). In the financial markets when it becomes increasingly harder for banks and financial institutions to roll-over their short-term debt and issue other financial instruments against a cash flow to raise funding, the overall liquidity in the financial markets suffers. The same goes vice versa. When the markets' overall liquidity is in distress and it becomes more difficult to transfer assets with their entire cash flow, the same time the use of assets as a funding strategy, like rolling over debt or deploying the cash flows of other assets into more securitized and layered financial securities, becomes increasingly more difficult and less conventional. Due to these interactions between different kinds of liquidities and securitized assets in the financial markets, even the relatively small shocks in 2007 influenced and actuated the gravity of the financial crisis (Brunnermeier, 2009). For instance, the problem of securitization and interconnectedness in 2007 was able to be seen with the volume of outstanding derivatives in the financial markets. The amount of credit default swaps in the markets was on its highest approximately more than 12-times higher than the amount of the underlying corporate bonds in the market (Brunnermeier, 2009).

The distress in the financial markets causes **bank runs**. However, during the financial crisis they differentiated from the traditional bank runs. The traditional bank runs are caused by uninsured depositors in the need of deposit insurance, as well as sudden withdrawals of deposits (Ivashina & Scharfstein, 2010; Gorton & Metrick, 2012). Instead, the

bank runs during the crisis were caused by creditors, borrowers, and other counterparties in the short-term debt market, who were concerned about the rising risks of insolvency and illiquidity in the banking system (Ivashina & Scharfstein, 2010). Ivashina & Scharfstein, (2010) and Chari, Christiano & Kehoe (2008) find, that even though, for example the U.S. banking sectors' total corporate and industrial loans in the aggregate balance sheet increased around 6.70 percent unit from September 2008 to October 2008, and the consumer loans steadily stayed above 800 billion USD, the overall liquidity in the banking sector started to decrease dramatically even months before that. The outstanding financial commercial paper in the markets plummeted more than third of its value in August 2008 (Figure 2) (Chari et al., 2008; Ivashina & Scharfstein, 2010).

Figures 1 and 2 demonstrate the developments and dry ups of **total and financial commercial paper** in the U.S. markets before and during the financial crisis. Both values had generally regular movements from the beginning of 2002 until the spring of 2005. Outstanding total commercial paper fluctuated between 1.3 and 1.5 trillion USD, while financial commercial paper moved between 500 and 600 billion USD. During the spring and summer of 2005 volumes started to heavily increase until the autumn of August 2007, when total commercial paper reached more than 2.2 trillion USD. On August 5th, total commercial paper crashed sharply, falling to 1.85 trillion USD in less than two months, and was not able to revive after. Financial commercial paper experienced a smaller crash from 800 billion USD to approximately 730 billion USD, and differing from total commercial paper, was still able to revive and increase after the fall to almost 830 billion USD. But in the autumn of 2008 a second sharp crash was to arrive, when on August 31st both values crashed once again, total commercial paper declining to 1.4 trillion USD and financial commercial paper falling to less than 560 billion USD. This time there was no way back, and by the beginning of 2011, both the values had experienced a severe decline. By January 16th, outstanding financial commercial paper had decreased to 450 billion USD. The overall liquidity of total outstanding commercial paper had experienced even more drastic fall, with a value on January 16th being less than a trillion in 916 billion USD. (Board of Governors of the Federal Reserve System, 2020a.)

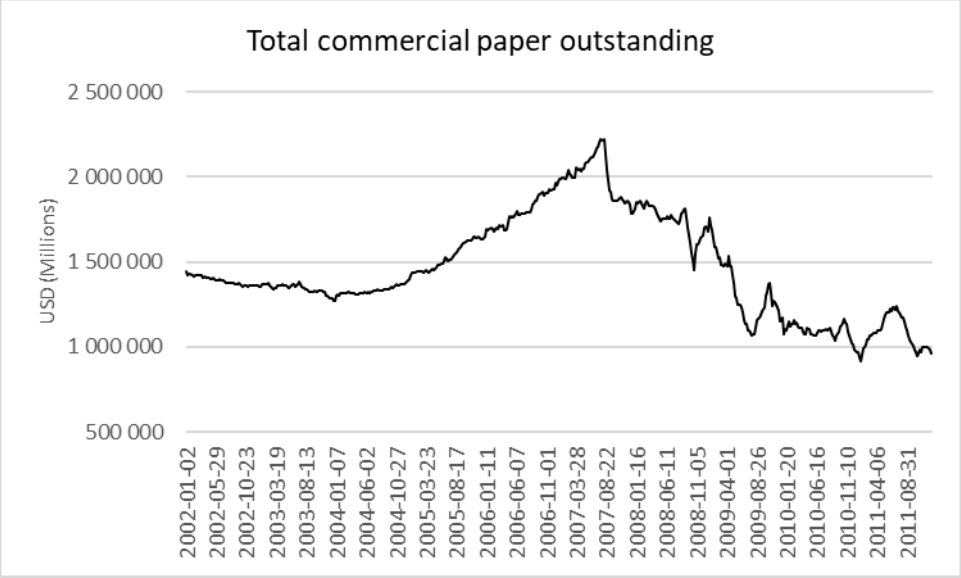


Figure 1. Volume of total commercial paper outstanding in the U.S. financial markets. Weekly values, seasonally adjusted. Includes financial, nonfinancial, asset- backed and other commercial papers outstanding. Adapted from Board of Governors of the Federal Reserve System (2020a).

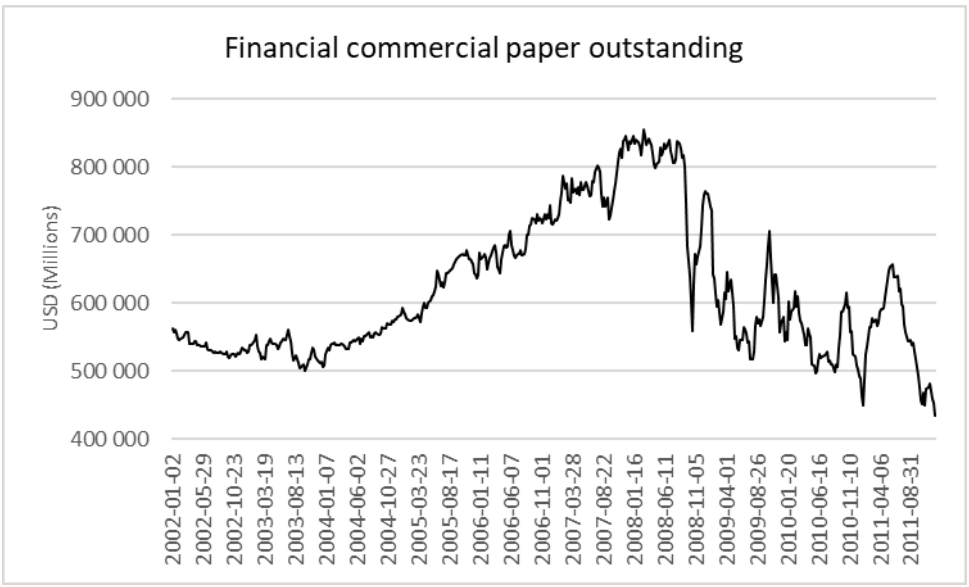


Figure 2. Volume of total financial commercial paper outstanding in the U.S. financial markets. Weekly values, seasonally adjusted. Financial commercial paper is subgroup to total commercial paper outstanding. Adapted from Board of Governors of the Federal Reserve System (2020a).

Ivashina & Scharfstein, (2010) find out, that this happened, because the increase did not occur due to a growth in new loans, but due to an increase on the drawdowns on already

existing credit lines by corporate borrowers. Chari et al. (2008) back-up these findings, showing that signs for drawdowns and concerns over the future and flight to quality were visible in the beginning of the crisis (Chari et al., 2008). This meant, that prior commitments of corporate lending made by banks were declined, because the borrowers began to feel concerned about their ability to access their funds at any time needed. These drawdowns on credit reduced the liquidity on the banking sector and reinforced the spectrum of the new kind of broader bank run (Ivashina & Scharfstein, 2010). The situation worsened, when the bankruptcy of Lehman Brothers intensified the flight to quality and to government securities, which were considered as safe havens (Hördahl & King, 2008). Fittingly, Gorton & Metrick (2012) classify the financial crisis of 2007-2008 as a system wide bank run.

Differing from Gorton & Metrick (2012) views on the depiction of a system wide run[1], Brunnermeier (2009) finds the crisis been closer to a traditional financial crisis, with the only differentiating factor being the amount and role of securitization, and its effect leading to vast interconnectedness in the financial markets. He emphasizes, that even though deposit insurance has made bank runs almost improbable, the runs can occur on other financial institutions, thus highly resembling traditional bank runs. For example, in 2008, the failures that Bear Stearns and AIG faced were their own kinds of bank runs, which were focused to those specific financial institutions (Brunnermeier, 2009).

As seen in the global financial crisis, during crisis periods, banks usually can drain out of liquidity. This **liquidity shortage** can lead up to capital position deterioration. To meet their liquidity needs, banks are forced to have fire-sale priced asset disposals. This is especially devastating when combined with the increasing delinquency rates from financially weakened borrowers, that culminates into banks' asset quality decline (Laeven & Valencia, 2020). When the asset values declined in the U.S., especially leveraged investors were forced to sell their assets to maintain their leverage levels and portfolio values. Accelerated asset selling in the financial markets furthermore decreased the asset prices

[1] Gorton & Metrick (2012) also put emphasis on the repurchase agreements (see chapter 3.4.1)

and prompted more selling. Overall, during the crisis, the asset prices were decreasing and dropping down, which tightened the available capital on the market for financial institutions due to heightened lending standards and margins. In addition, the financial institutions act as both the borrower and the lender, which meant rising interconnectedness due to increasingly interlaced networks between the financial institutions and banks. The vast interconnectedness in the markets increased the **counterparty risk**, when financial institutions and banks were unable to affirm the actual risks and counterparties, that they were connected to through their securities and investments. Especially in September 2008 after the bankruptcy of Lehman Brothers, the concerns over counterparty risks were extremely heightened. The financial markets were hit by profusion of defaults, liquidity loss with dry ups, declines and consequential bailouts (Brunnermeier, 2009).

The banking sector and the financial markets in the U.S. had some severe fundamental frictions from the early on. Brunnermeier (2009) sees, that two pre-existing aspects on the financial markets were fundamental for the liquidity dry ups causing a severe financial crisis. Firstly, frictions in the markets will cause limitations on optimal risk sharing, causing the liquidity risk not being optimized. Thus, the optimal risk diversification through securitized assets, like mentioned by Reinhart & Rogoff (2008) does not work as expected. Secondly, the frictions can inhibit the flows of funds in the markets from professional and skilled investors, and instead lead them up to less informed investors. (Reinhart & Rogoff, 2008; Brunnermeier, 2009.) Furthermore, the network and counterparty risks could have been mitigated and stabilized by a central regulator or author, who would have kept track of which financial institutions owns what. But because the vast amount of securitization was reasonably a new situation to the financial markets, and most of the agreements had been made over the counter, there was no one to really know, who owned what to whom (Brunnermeier, 2009).

Quite commonly used in academic literature, the problems in the liquidity and dry ups during the crisis can be inspected through non-performing loans (NPLs). The total NPL to

loans -ratio was 5% in the U.S. between the years 2007 and 2011. Surprisingly, when compared to previous crisis periods, the overall median ratio for high-income countries during crises periods is slightly above 11%. In addition, Laeven & Valencia (2020) assess, that in 70% of crises, the ratio never surpasses 20%. The 5% -ratio for the U.S. would not by itself fulfill the previously discussed condition of minimum 20% NPL-ratio as an indicator of significant bank distress (Laeven & Valencia, 2020). However, one could ask, whether 20% margin for high-income countries' crises is a suitable limit since the global financial crisis like mentioned previously, was one of the first severe global financial crises to hit high-income economies. There is no denying, that in the U.S. the liquidity problems and growing defaults affected the severity of the crisis. Thus, as Laeven & Valencia (2020) have assessed, the reviewing of only one of the conditions cannot fully showcase the entirety of a crisis (Laeven & Valencia, 2020).

As the financial crisis kept on pushing forward, the U.S. banks started to **hoard funds for precautionary reasons**. According to Brunnermeier (2009), this happened due to two reasons. Firstly, banks own funding needs shot up when drawdowns started to arise in the financial markets. Secondly, the accessibility for the interbank short-term funds market became more unpredictable when the uncertainty of other banks' problems increased (Brunnermeier, 2009). When the probability and potential for unexpected losses increase, the risks in the markets increase. Furthermore, when the market risks increase, bank regulators require banks to hold more capital. As a result, the banks need more capital to safeguard themselves against the increasing risks of insolvency and higher capital requirements (Klaassen & van Eeghen, 2015). Indeed, Brunnermeier (2009) emphasizes, that as the crisis deepened and the concerns of the counterparty credit risks grew higher, increasingly more trading parties, like financial institutions and banks, had to hold additional funds in their balance sheets. The dropping asset prices, and inflated selling also affected the margins and increased the cost of borrowing for many securities. As a consequent, the asset prices decreased even further. As of effect, the markets faced a vicious interconnected spiral of dropping asset prices, increased selling, higher margins, and tighter lending (Brunnermeier, 2009).

Overall, during the financial crisis U.S. suffered a 30% GDP output loss between the years 2007 and 2011 (Laeven & Valencia, 2020). Merely during 2008, the overall U.S. stock market lost about $8 trillion and the crisis in the financial market affected the credit lending of every firm, financial institution, and local governmental institutions (Brunnermeier, 2009). In autumn 2008, the U.S. household wealth had fallen 17%, and every month nearly 800 000 were lost (U.S. Department of the Treasury, 2019). Systemic banking crises are rarely limited to a single country but develop into wave of crises spreading into various countries. This time it was no different (Laeven & Valencia, 2020). Even though the global financial crisis started in the United States in the autumn of 2007, it quickly began to spread globally. The extreme financial stress in the money markets and the severe problems in the volatility and in other market segments caused the crisis to spread to the euro area in the beginning of 2008. From there it continued to other economies in the third quartile of 2008, and lastly reached the emerging markets during the last quarter of 2008 (Lo Duca & Peltonen, 2013). The crisis was infecting the global economy (Brunnermeier, 2009).

Laeven & Valencia (2020) define in their database the end date of the crisis period as the year before both real GDP growth and real credit growth are positive for at least two consecutive years. For the global financial crisis in the U.S. they define the systemic crisis to have been lasted from December 2007 to 2011[2]. Nevertheless, for the U.S., even though technically the actual crisis period was over, the crisis and its effects were far from over.

[2] The month of the ending year has not been specified in Laeven & Valencia (2020). Since their definition is extensively and commonly used in the academic literature for the historic crisis definitions, the further assessing of a specific ending month of the crisis for the U.S. is not needed. In addition, further definition is not necessary for the purpose of the study of this paper.

2.1.1 Crisis policy responses in the U.S.

Laeven & Valencia (2020) define, that for high-income countries most used policy responses to resolve financial crises are an extensive mixture of recapitalization, liquidity support and guarantees on bank liabilities. This was also the case of the global financial crisis in the U.S., which had to mainly resort to all the three policy responses. In addition to these, asset purchase was included in the policy response mixture, as well as an extreme form of recapitalization, that occurred as outright nationalizations.

Usually in the case of bank distress and bank runs, countries respond by deploying extensive **liquidity support** to the banking sector. This has been depicted by Laeven & Valencia (2020) as a typical policy respond throughout the years during the previous banking and financial crises. They define liquidity support as "the ratio of central bank claims on the financial sector to deposits and foreign liabilities". In the U.S., the peak of this ratio between the years 2007 and 2011 in total was 4.7%. Interestingly, when the difference is compared to the year before the beginning of the crisis, the ratio stays on exactly same 4.7%. This is measured by calculating the change between the maximum and the average of the ratio from the year before the start of the crisis. This clearly indicates, that during the precrisis years, the liquidity support in the U.S. economy was essentially 0% (Laeven & Valencia, 2020). Through this, it can be seen how severely sparse liquidity suddenly became in the financial markets during the financial crisis, and how important role the liquidity support had for depositary institutions.

To relieve the adverse effects on the financial markets and economic activity from onwards from the start of the crisis in August 2007, the Federal Reserve started to initiate a series of aggressive policy actions. These included **unconventional open market programs**, that had as the overall goal to improve the functioning and stability of the financial markets and to promote economic growth (Brave & Genay, 2011). In December 2007, the Federal Reserve created the Term Auction Facility (TAF) (Brunnermeier, 2009). It operated by auctioning term funds to depositary institutions against a wide variety of

collateral, including collateral which might have had very little market value left (Board of Governors of the Federal Reserve System, 2007: Cecchetti, 2009). The purpose of TAF was to decrease liquidity constraints by enabling the efficient allocation of funds for the banks who truly needed them, as well as to distribute the funds to a broader range of counterparties against a broader range of collateral (Cecchetti, 2009). It also was set to improve the overall liquidity of the financial markets (Armantier, Krieger & McAndrews, 2008). By May 2008, the value of auctioned funds had increased to 150 billion USD (Cecchetti, 2009). Only after creation of TAF, the liquidity in the financial markets, especially on the interbank market, was able to have been revived to some extent (Brunnermeier, 2009). However, the efficiency of TAF has been questioned on the academic literature (see e.g. Taylor & Williams, 2009).

Another open market program resembling TAF was Term Securities Lending Facility (TSLF), that also was set to promote liquidity in the financial markets. It operated in the similar manner as TAF but differed by offering liquidity to the Federal Reserve Bank of New York primary dealers (see Chapter 3.4) (Federal Reserve Bank of New York, 2009). The liquidity offered was Treasury's general collateral with a 28-day term (Hördahl & King, 2008; Federal Reserve Bank of New York, 2009). The facility was introduced in March 2008. The increased demand of government securities, and the decreasing willingness for cash providers to accept collaterals especially in the repo markets were the main reasons for the Federal Reserve to initiate TSLF (Hördahl & King, 2008). In its peak in the end of 2008 the lending through TSLF exceeded over 200 billion USD (Fleming, Hrung & Keane, 2010). Furthermore, Fleming et al. (2010) and Mamun, Hassan & Johnson (2010) find TSLF having a positive impact on the repo markets. At the same time to TSLF, the Federal Reserve introduced the Primary Dealer Credit Facility (PDCF). The facility was similarly aimed to ease disruptions in the repo markets by providing overnight discount window loans to primary dealers (Brave & Genay, 2011).

In addition to liquidity support in the U.S., **recapitalization** acted as a crucial traditional policy response to mitigate the crisis, to ameliorate the declined banks' solvency and to

lessen the increasing delinquency rates. It is a policy respond, that has been used in most of the previous crises, but in the financial sector it is also the most important origin of direct fiscal costs of government intervention. Recapitalization can be done in three different ways depending on the state of the bank or institution. To viable institutions recapitalization can be done either publicly or privately, insolvent institutions can face dispersion, and in the case of severe financial stress an outright nationalization can be also an option. Recapitalization can have its downside to the institutions as government capital injections, that usually include both preferred and common equity, and often comes along with restrictive conditions. These conditions can include limited or prohibited future dividend payments or required board seats for government representatives. These often lead governments to own the majority share of the banks' and institutions capital. Laeven & Valencia (2020) describe this kind of situation as nationalization, even though it has been done through recapitalization and not necessary primarily initiated as an outright bank nationalization. The U.S. experienced bank recapitalization worth 3.6% of total GDP during the financial crisis. In addition, comprehensive bank nationalization was done. (Laeven & Valencia, 2020.)

After the failures in the financial markets, including the fall of Lehman Brothers, the reactive measures for the remaining solvent banks had to be replaced by proactive coordination by the Treasury Security (Brunnermeier, 2009). The solution was a set of **emergency programs** put forward by the Treasury, the Federal Reserve, and the Federal Deposit Insurance Corporation (U.S. Department of the Treasury, 2019). One massive and critical emergency program was Troubled Assets Relief Program, TARP, consisted of a $700 billion bailout plan from the Federal Reserve, that was aimed to recapitalize banks, purchase troubled mortgage-backed securities, help homeowners and stabilize the banking industry (Brunnermeier, 2009; U.S. Department of the Treasury, 2019). During the global financial crisis, TARP had an important role on implementing bank recapitalization. Compared to the bank distress episodes before the global financial crisis, the recapitalization processes deployed through TARP were much quicker during the financial crisis than before (Laeven & Valencia, 2020). TARP was also critical in the bailout of AIG.

Overall, the broader set of emergency plans were aimed to help keeping the interest rates low, broaden the guarantee base in the money markets and provide liquidity and capital, amongst other measures (U.S. Department of the Treasury, 2019).

Laeven & Valencia (2020) find that the third common policy response amongst high-income economies is significant **bank guarantees**. During the financial crisis, the U.S. government granted to various targeted banks limited or full guarantees on either specific or most bank liabilities. The guarantees were meant to stanch and facilitate the liquidity pressures on both the banks and the liabilities and were also meant to give more time for the policymakers to develop more comprehensive policy decisions and restructuring plans. From October 2008, extensive bank guarantees were issued. The guarantees reached 50 billion USD, and they covered the money market funds. They also covered a full guarantee on transaction deposits and on newly issued senior unsecured debt. When compared to the previous crisis episodes, guarantees, especially if used simultaneously with liquidity support, helped to reduce the liquidity pressures, which the banks were facing. These guarantees were left in place for many years with only gradually being removed to help the policy responses to work effectively.

Often, the expansionary fiscal and monetary policies are used in high-income countries to mitigate the impact of crisis on the real economy. Especially, the countercyclical approach is used. One way to utilize countercyclicality is through the interest rates. By cutting the short-term interest rates down, the government can boost the liquidity supply. Indeed, Laeven & Valencia (2020) find, that generally, while before the crisis the median short-term interest rate tended to be around 5%, one year after the start of the crisis the median rates dropped to very close to zero. This could be achieved, because the fiscal space and monetary policies were flexible and developed enough to adapt and use the countercyclicality without further damaging the economy[3] (Laeven & Valencia, 2020). In

[3] On the contrary to high-income economies, middle- to low- income countries usually are forced to act procyclically during the episodes of crises due to the more binding constraints of the economy. In the interest rates, this can be seen in increasing median short-term interest rates after the start of the crisis, thus heightening the impact of the crisis. (Laeven & Valencia, 2020.)

addition, TAF targeted to decrease the short-term interest rates compared to the medium- and long-term rates, thus having decreasing effect on the liquidity constraints and dry ups (Cecchetti, 2009).

When studied the prerequisites of a severe systematic financial crisis definition -constructed by Laeven & Valencia (2020)- there can be found some significant factors. Laeven & Valencia (2020) define **fiscal costs** of banking crises as all fiscal outlays, that are linked to the government interventions, which are meant to stabilize the banking system. These include capital injections in financial institutions, operating costs of agencies and other entities and any other fiscal costs, that are related to the restructuring of the financial sector and has directly attributed to the rescue of financial institutions. For the U.S. between the years 2007 and 2011, the fiscal outlays consisted 4.5% of GDP and covered 2.2% of all financial sector assets. Thus, the restructuring costs exceeded the limit of 3%, that Laeven & Valencia (2020) have set as one of the margins for the definition of a significant banking crisis.

Furthermore, the advanced and flexible use of fiscal and monetary policies in high-income countries often lead to significant increases in public debt. Laeven & Valencia (2020) use the public debt as a broader measure of fiscal costs during the banking crises, which is affected directly by discretionary fiscal policies and automatic stabilizers. During the years of 2007 to 2011, the public debt to GDP- ratio in the U.S. increased to 21.9% When compared to the precrisis years, the median increase for change in public debt for similar economies is 21.1%, which shows that the global financial crisis was slightly above the median and showing signs of banking sector distress.

A consequence for the various market operations and policy actions implemented by the Federal Reserve was the overall expansion of assets in the Federal Reserve balance sheet. While in the summer of 2007 the Federal Reserve's balance sheet almost completely consisted of the U.S. Treasury securities, in the end of 2007, the market liquidity started to dry up and the asset volume of the U.S. Treasuries started to slowly decrease. To

address the situation of the market dry-up, the Federal Reserve began to introduce liquidity to the markets through various policy actions. In the end of 2008, the volume of U.S. Treasury securities had shrunk to less than a third of its precrisis volume. However, the total balance sheet asset volume had remained close to the precrisis value until June 2008, and by the end of 2008, it had more than doubled. Overall, at the end of 2008, the U.S. Treasuries consisted only a minor fraction of the total asset volume, with majority of the assets coming from the policy and market operations. These included large-scale asset purchasing, discount window borrowing, TAF, TSLF, PDCF, credit extensions to Bear Stearns and AIG, as well as other facilities and commercial paper holdings aimed to increase the liquidity of the money and financial markets (Hördahl & King, 2008). In the summer of 2009, the overall size if the U.S. balance sheet assets covered 19% of the nominal U.S. GDP (Brave & Genay, 2011).

All in all, the announcements of unconventional programs and the policy actions taken by the Federal Reserve improved the initiated market segments, and significantly improved the broader financial conditions[4] (Brave & Genay, 2011). In summer 2009 the financial conditions began to improve and slowly stabilize. As a response, the Federal Reserve started to reduce the amounts and increase the prices of the funds through its programs. In May 2010 most of the unconventional programs had been terminated, and by June 2011, all of them had ceased to exist (Brave & Genay, 2011). Liang, McConnell & Swagel (2018) find, that compared to the previous crisis episodes, and to the expectations, the U.S. policy responses made a difference, and in overall the U.S. economy performed relatively well. However, they emphasis, that the macroeconomic costs were very high, and that the policy responses might have generated better economic outcomes, if they had been initiated earlier before a full-set panic (Liang et al., 2018). Similarly, Brave & Genay (2011) discover, that the Federal Reserve took policy actions more likely during the weeks, when financial and economic conditions worsened.

[4] For a full review of all the policy actions and unconventional Federal Reserve programs, see Brave & Genay (2011).

However, Furman (2018) assesses, that the policy responses, especially fiscal measures, had an integral part on mitigating and abbreviating the crisis, as well as decreasing the overall potential output losses. Indeed, the U.S. economy endured the crisis better than other countries (Furman, 2018). The global financial crisis was severe in many countries, especially the low- and middle-income countries suffered from the consequences much longer. Globally, the high-income economies were able to correspond to the global financial crisis more efficiently. (Laeven & Valencia, 2020).

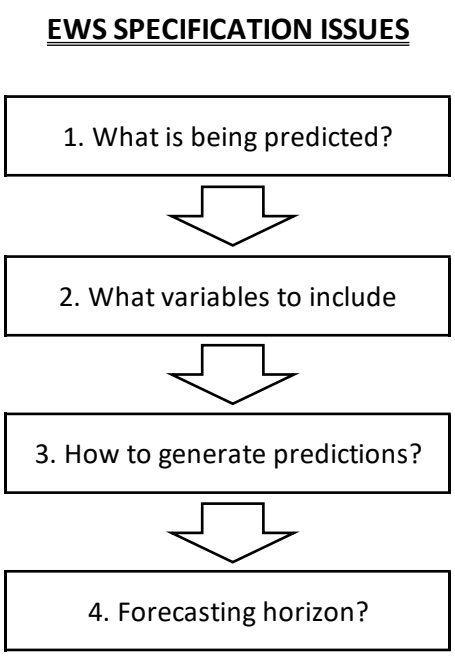
2.2 Early warning indicators

Early warning indicators (EWIs) of financial and banking crises are used in predicting and identifying states in the financial markets, when entities and financial instruments are vulnerable to shocks and triggers, which may precede and lead to financial and banking crises (Peltonen et al., 2018). The use of EWIs gained prominence after the Asian crisis in the 1990s, and ever since a new variety of EWIs have been proposed to be used in the prediction (Danielsson, Valenzuela & Zer, 2018). The academic literature lists a broad range of macro, financial and banking sector indicators, that are traditionally used to identify vulnerabilities in the systemic risk (Peltonen et al., 2018). These systemic risks can be predicted by assessing domestic and global macro-financial vulnerabilities, which in turn can lead up to systemic events. Lo Duca & Peltonen (2013) define systemic events as states of extreme financial stress in the markets, that leads to “negative real economic consequences”. They also define the prediction of systemic events as prediction of “periods of extreme financial instability with potential real costs”. Within this framework the contributing factors to the systemic events and the potential vulnerabilities can be assessed and predicted, and their relative importance and probabilities on causing systemic events can be identified (Lo Duca & Peltonen, 2013).

Early warning indicators have a crucial role in implementing time dependent countermeasure policies in the financial markets. These policies can be, for example,

macroprudential policies, like capital buffers aiming to reduce and proactively act on the forthcoming formidable losses (Drehmann & Juselius, 2014). By knowing the sources which the systemic risks are stemming from, the policy makers can choose the correct policy responses and avoid situations, where financial instability would impair the financial system and materially start affecting economic growth and welfare (Lo Duca & Peltonen, 2013). In addition, for the banking sector and financial markets, understanding the early warning indicators of the banking crises is crucial for the banks' risk management (Sohn & Park, 2016). Even though domestic policies can mitigate some of the risks, internationally coordinated policy actions and cooperation plays a crucial role on globally preserving financial stability and preventing the systemic events from spreading across financial segments, economies, and countries. Unfortunately, as we all have seen, this was not the case with the global financial crisis, and the effects of the systemic risks widespread all around the world (Lo Duca & Peltonen, 2013).

EWIs are used in **early warning systems (EWS)**. These are empirical models based on the EWIs. However, constructing an empirically viable EWS model is challenging (Rose & Spiegel, 2009). EWS models must be designed to reflect the current times to efficiently monitor vulnerabilities. The process of specification a good and efficient EWS model includes number of issues and decisions, that should be carefully assessed to construct an efficient model. Picture 1 lists these issues by assessing an **EWS modelling process**. Firstly, it must be determined what is being predicted: What kind of crisis (banking, currency etc.) the model is made to predict? What is the measure, that the model is predicting (bank profitability with ROE, real economy with GDP, currency market with exchange rates etc.)? What kind of quantitative change or event is considered as "crisis"? For example, is it a sudden large change over a short period of time, a surpass over a threshold value or sudden large losses? These questions might be difficult to operationalize but are critical in addressing the purpose of a forecasting model (Berg et al., 2004).



Picture 1. The process of EWS model construction through prespecified issues, that the model should be based on and address as efficiently as possible. (Berg et al., 2004.)

After identifying the set and definitions of crisis, the next step is to define a set of variables, that are useful in predicting crises. A list of variables that indicate common symptoms for a crisis should be viewed based on data of historical crises and theoretical models. However, this appoints a danger of "overfitting" the model through "data-mining". In other words, the predictor variables should not be assembled by adding all previous useful and plausible variables since sometimes more comprehensive assessments of all available qualitative and quantitative market information are not better to simpler EWS models (Berg et al., 2004). The benefit of hindsight could appear in indicators giving good warning signals for the sample period. This kind of model would be however unlikely to capture the buildup of new systemic risks leading up to forthcoming crises (Danielsson et al., 2018). The models thoroughly built on what is already known to work well, might highly predict the sample crisis but would not be useful on predicting both past and future crises. Instead, the focus on assessing the set of variables should be on the noticeable market symptoms so that the ultimate different causes of the crises would not define the predicting abilities of the model. In addition, the predictive variables of EWS

models are constrained by the availability of data. This emphasizes the importance of choosing variables, that reflect and fit the best way the data and assessed vulnerabilities (Berg et al., 2004).

The third step of the process is to choose the methodology, that will model the previously assessed variables. What kind of econometric model is used in the prediction? A common method used is signaling approach, which predicts exceeding of a threshold value. Another common method is continuous variable methods through e.g. different regression models, which predicts the marginal increase/decrease in the dependent variable, when an increase happens in the independent variables. Thus, regression models assess the correlation between the variables. The statistical method chosen to analyze EWIs is an essential empirical decision. The fundamental question is whether the EWS model will produce a statistically and economically significant prediction of a forthcoming crisis. (Berg et al., 2004.)

The last step is to define the forecasting horizon, meaning how far in advance the prediction is to be made. The time horizons can differ from one to three months in short-term periods, and to two years for a long-term prediction. Usually private sector models tend to prefer shorter horizon to predict profitability of a crisis. Instead, larger (governmental) institutions, such as International Monetary Fund etc. use long horizons to have a sufficient lead time on initiating policy adjustments based on the predictions. (Berg et al., 2004.)

However, the historical data shows, that previous EWS models before the financial crisis had not been especially efficient on predicting the timing of crises (Rose & Spiegel, 2009). Common EWS models used in the early 2000s were DCSD -model by Berg, Borensztein, Milesi-Ferretti & Pattillo; KLR -model by Kaminsky, Lizondo & Reinhart, Goldman Sachs' GS-WATCH; EMRI -model by Credit Suisse First Boston and Deutsche Bank's DB Alarm Clock. These EWS models had different analysis horizons, and they used several econometric methods, including signaling approach and probit and logit regressions. However,

they focused on somewhat similar sets of predictor variables, including overvaluation, export growth, M2 reserves and multiple stock market variables. In addition to these models, large global institutions like IMF had their own EWS models[5] (Berg et al., 2004).

The specification of EWS models are guided by economic theory. However, the main contributors are largely empirical, and depend on the objectives of the user. Thus, the models are prone to critical judgement and precariousness. In addition, the time horizon and previous historic episodes largely affect the objectives of the EWS models. For example, in the beginning of the 21st century, the EWS -models (including the above-mentioned models) were mainly focused on assessing vulnerabilities, that might lead to currency crises, due to the strong stimulus, that had followed the Mexican and Asian crises in the 1990s. This affected some of the most common EWS models to be constructed in some parts quite similarly and analyzing similar predictors instead of assessing market vulnerabilities more broadly and from multiple angles. (Berg et al., 2004.)

Drehmann & Juselius (2014) further define three main features, that feasible EWIs should have: **appropriate timing, stability, and ease of interpretation**. These features corroborate the important EWS specification process issues described above. Firstly, appropriate timing for EWIs should be between 18 months to five years before the crisis, in order for the policymakers to be able to react and implement, and for the actions based on the EWIs to actually have time to be efficient. Secondly, stability is essential for the EWIs, and they should be produced through stable and persistent findings, that have sound statistical forecasting power. Lastly, the EWIs and their results should be easy to interpret to allow a correct implementation based on the findings. They should be able to guide and help policymakers to navigate in uncertainty, and to give guidance on the policy decisions. In general, policymakers tend to ignore forecasts, that are too complex or difficult to decipher. In addition to setting the appropriate timing for the EWIs, Laeven & Valencia (2020) emphasis, that proper identification of the crises dates is crucial. The prediction of crisis and the implementation of policies designed to resolve and mitigate

[5] More information about the models, see Berg, Borensztein & Pattillo (2004).

them depend fundamentally on the identification of the dates when the actual crises occur. Misinterpretation and the use of inappropriate crisis dates may transmit misinformation by depicting a causal link between the crisis event and the economic variables, when in fact, there is none, and thus obscure the real genuine relationships.

2.2.1 Early warning indicators in the academic literature

In the years preceding the global financial crisis, there were no clear indicators of the forthcoming crisis, and the banking systems of the western economic markets were reporting high profits and strong balance sheets. During the first six months of the years 2006 and 2007 the Federal Reserve declared the financial markets to be in favor of steady financial stability, and the economic markets to have a generally positive outlook. The only dissenting remarks announced in the financial markets were the occasional notes made by the Federal Reserve of the possible negative financial risks in the economic markets. Nonetheless, in the financial markets there were no coherent clear signs of a severe stress in the banking sector. On the contrary, the information available on the financial markets drew a picture of a healthy and functioning banking system (Cabral, 2013). In addition, Chari et al. (2008) emphasize, that the general bank credit did not decrease, and seemed not to be affected by the onset of the crisis, showing no clear warning signals of the turmoil in the financial markets. Christofides, Eicher & Papageorgiou (2016) emphasize, that the global financial crisis was essentially not predictable with historic and prevailing early warning models and indicators.

The academic literature about the indicating remarks and the causes of the financial crisis is broad. The published academic literature and studies about the EWIs are variable but versatile, and they use different economic indicators. The results and recommendations of robust EWIs vary depending on the problem and the perspective of which each specific research is focused on finding results and offering guidance. Furthermore, the results depend whether the academic studies have been constructed to predict EWIs on

a bank (and other entities) -level, or whether the predictions are focusing on the macro -level, e.g. country -specific forecasting. In addition, generally the empirical methods and models used are various. However, even though many academic studies might differ on their methods, preferences, perspectives and recommendations, some resemblances on the overall results can be found. (See e.g. Drehmann & Juselius 2014; Lee, Posenau & Stebunovs, 2017; Peltonen et al., 2018.)

Specific and detailed knowledge is requisite to derive estimates with optimal empirical models. However, forming the models and gaining the required knowledge can be arduous due to possible lack of historical experiences and knowhow of the context of the problem. For instance, for the macro country -level analyses, Drehmann & Juselius (2014) estimate the cost and benefits of macroprudential policies in the time of crises for 26 countries[6] and link them to early warning indicators. They find that using utility functions and ROC curve, credit-to-GDP gap and debt service ratio are the most robust and useful EWIs, the former to be used on long horizons and the latter on short horizons. Lee et al. (2017) use very similar time span and country-level data sample in their study as Drehmann & Juselius (2014), with only few changes in the sample of 26 countries. However, they find that an aggregate index of different market sector vulnerabilities outperforms credit-to-GDP gap as an early warning indicator on the long horizon, contradicting the previous academic findings and Basel III using credit-to-GDP gap as a variable for the best option for EWIs. These differences between the two studies can be explained by the different study methods (time series analysis for Lee et al., 2017) and due to minor differences in the data sample.

In addition to Drehmann & Juselius (2014) and Lee et al. (2017), Sohn & Park (2016) find, that credit growth works better than credit-to-GDP gap as an early warning indicator for predicting banking sector crisis. However, instead of focusing on the macro-level, Sohn & Park (2016) use bank-level data of U.S. banks and bank dependent firms. Specifically, they study the correlation between the early warning indicators and bank related stock

[6] Drehmann & Juselius (2014) use the 26 countries listed by Laeven & Valencia (2013).

returns. As empirical method, they utilize lead-lag regression analysis to modify their method to take into consideration the anticipatory nature of early warning indicators instead of merely predicting the same period concurrent correlations.

There can be found a variety of academic studies about bank profitability and efficiency on estimating precrisis causes and effects. Majority of these studies are focused on bank -level analysis. Moussu & Petit-Romec (2017) utilize OLS regression analyses to assess the correlation between precrisis ROE -values and bank losses during the crisis. Their results find that banks' ROE -values strongly predict bank losses. However, even though their analysis is based on bank-level data, it includes banks from 28 different countries (including developing countries), thus making their results applicable for multiple different economies. Aebi, Sabato & Schmid (2012) study the effects of precrisis corporate governance to U.S. bank performance during the financial crisis. They include lagged regression analysis of ROE in their study methods to conclude, that poor bank performance during crisis could have been assessed proactively through more efficient risk management measures. More traditional academic literature by Berger (1995) finds, that capital-asset ratio is a strong predictor of ROE. The analysis is done by utilizing substantially large data of more than 80 000 insured U.S. banks from a six-year period. The results are found with lagged regression analysis, and the results determine, that capital-asset ratio has a significant positive correlation with future levels of ROE from as far as three years prior. Additionally, de Bandt et al. (2014) define using a sample of French banks and fixed effect -regression and lagged values, that capital measures are significant indicators of future ROE -values and have a positive correlation. The indicating effect of capital is especially significant with two -year lag, construing, that capital measures take time to affect the bank performance.

However, not all the academic EWI literature focuses only to cross-country or bank -level data. On the macroeconomic aspect, Peltonen et al. (2018) find, that banking sector centrality in the financially interconnected macronetworks and credit risk are efficient EWIs. These macronetworks are constructed by linking firm- and sector -level data to cross-

country data, thus forming a combined analysis of both macro- and micro -aspects. The networks contain early-warning information, which works as significant and close to real-time macroprudential warning indicator for crises. The results are derived from using multiple financial instruments (e.g. loans, bank deposits and securities) and the role of different types of risk (e.g. financial funding and liquidity risks) as estimators for the interconnectedness of macronetworks. In addition, the study emphasizes the importance of incorporating new measures to standard EWS models to regard the characteristics and interconnectedness of new banking crises.

Similarly to Peltonen et al. (2018) including a more broader perspective on precrisis analysis, Lo Duca & Peltonen (2013) emphasize on incorporating several market segments to broaden the analysis and making it identify truly modern day systemic events rather than focusing only on segment specific events. They use 28 countries in their study but focus specifically on joint global and domestic macro-financial vulnerabilities. Even though it is possible to observe tensions on several market segments in the economy on the occurrence of a negative shock, the parallel dependence of the variable depends on how systemic and broad the shock truly is. The co-movement among variables is higher the broader and larger the shock is. However, they also test their EWS -model to predict the financial crisis in the U.S. Lo Duca & Peltonen (2013) find that even though "stand alone" variables on asset price misalignment and credit booms are generally useful EWIs (as generally used in country-level analyses), they are outperformed by joint indicators of domestic and global macro-financial vulnerabilities such as credit cycle and equity valuations both combined to macro-overheating[7]. Truly, on their study these joint EWIs were able to predict the global financial crisis five quarters before the markets started to show signs of stress in August 2007.

Furthermore, Chari et al. (2008) remind that, especially during the onset of the global financial crisis too straightforward conclusions based on specific analysis of economic

[7] "Macro-overheating" in this sense meaning "the percentage deviation from trend of the real GDP at global level" (Lo Duca & Peltonen, 2013).

data without hard evidence of broader view and analysis, might have led policymakers to do too hasty decisions and implement expensive market interventions without clearly displaying how these interventions would have fixed the market failures (Chari et al., 2008). The interactions among indicators are truly important, and additionally justify using ratios on EWI modelling rather than absolute values as early warning indicators (Lo Duca & Peltonen, 2013).

Differing from more intricate models and findings (e.g. Lo Duca & Peltonen, 2013, and Peltonen et al., 2018), Reinhart & Rogoff (2008) find, that even "simpler" indicators would have predicted accumulating stress in the market as long as four years before the start of crisis in 2007, if only there had been enough attention paid to the strikingly similar development of indexes and yields. The study uses on country-level prediction but focuses on the prediction of the crises in the U.S. by benchmarking the U.S. economy to other economies. Indeed, Reinhart & Rogoff (2008) emphasize, that these early warning indicators could have been assessed, if benchmarked to the previous significant large-scale crisis periods[8]. According to their study, in the years preceding the global financial crisis, the development and growth in asset and housing prices, real economic growth, current account per GDP and real per capita GDP all followed fully comparable curves and developments to the previous major crises, even, at times, exceeding the historical remarks alarmingly (Reinhart & Rogoff, 2008). Lee et al. (2017) similarly assess that peaking asset valuation imbalances and variations could have signaled early warnings of forthcoming crisis and financial stress as early as couple of years before the crisis.

Even though Lo Duca & Peltonen (2013) emphasize the use of joint indicators as EWIs, their results do partly bare some resemblance with Reinhart & Rogoff's (2008) findings. Although, like mentioned previously, the joint indicators outperform "stand alone" indicators, Lo Duca & Peltonen (2013) remind, that domestic and global credit and equity

[8] Reinhart & Rogoff (2008) benchmark their analysis by using the data of the preceding "The Big Five" Crises: Spain (1977), Norway (1987), Finland (1991), Sweden (1991) and Japan (1992) (parenthesis depict the starting year). In addition, they include 13 other slightly less significant crises to their comparative analysis.

price growth rates and misalignments were (amongst some other) significant early warning indicators in 2006 on predicting the forthcoming global financial crisis, and they were important factors on contributing to the systemic risk. Overall, they find, that credit indicators worked better in general as early warning indicators than money aggregates.

However, Rose & Spiegel (2009) assess more than 60 factors comprising 107 countries from other academic literature, that have been linked to the causes of the financial crises in 2008 all over the world. However, they find that almost none of these (country-level) factors acted as a potential cause for the financial crisis, and the only variable they find to be a robust predictor of the crisis severity is the size of the equity market run-up before the crisis. Even more rigorous results are found by Christofides et al. (2016), who study whether the global financial crisis could have been predicted globally at all by using various cross-country EWS -models and studies from 95 countries from the past 60 years[9]. Their results show that none of the various previous models and indicators could have predicted the crisis in any of the countries. However, their analysis shows, that different early warning signals for banking, balance of payments, exchange rate pressure and recession aspects of 2008 financial crisis could have been assessed, but none of the different country- and micro-level -indicators could not have predicted the global financial crisis as a whole on their own.

[9] Christofides et al., (2016) use an extremely extensive dataset to review, whether the financial crisis could have been predictable based on historic crisis literature. Their data includes 83 published studies from the past 60 years (documented by Frankel & Saravelos, 2012) and data revisions from national accounts and data from World Bank and IMF.

3 Bank profitability and funding

The following chapters review the theory and academic discussion of the variables, that are used in this study to assess early warning indicators and their correlation to the bank profitability. The discussion includes banks' return on equity, which in this study is the metric used to describe bank profitability. For the explanatory factors, discussion of the volumes of mortgage-backed securities, repurchase agreements and federal funds follow.

3.1 ROE

Return on equity (ROE) is a profitability measure, that is defined as net income to total equity (Aebi et al., 2012). ROE has been used since the 1970s as a **central measure for performance** in the banking industry (Moussu & Petit-Romec, 2017; Pennacchi & Santos, 2018). To achieve improved values of ROE, banks need critical evaluation of the markets, business activities and the operating models that they have chosen (Klaassen & van Eeghen, 2015). Even today, target ROE -values are set at bank level, and throughout banking industry the values are used as key indicators and benchmarks. Based on the set targets, resources are allocated inside and across the banking systems (Moussu & Petit-Romec, 2017). Furthermore, higher levels of ROE have a revitalizing effect on bank lending, thus encouraging banks to target higher ROE -values. However, the real performance improvements achieved by higher ROE -values take time to materialize on real economy. Thus, the improvement on performance and profitability might not be seen immediately during the same period on banks' accounts and balance sheets (De Bandt et al., 2014).

ROE, however, has one major deficiency: **it completely ignores risk**. Returns can be boosted by taking more risk, which in the short run poses limitations on the evaluations of the metric (Klaassen & van Eeghen, 2015). That raises a question, why do banks use ROE as their target measure for bank performance? ROE is across the banking industry relatively available and has a good comparability. Instead of ROE, Risk-Adjusted Return

on Capital (RAROC) would include the assessment of risk, but instead lacks the two aforesaid features. It also does not have a clear clarity how it relates to shareholders' returns (Klaassen & van Eeghen, 2015). Another performance measure for banks could be earnings-per-share (EPS). However, banks tend not to use this measure as their target, since it can react negatively to excessive maximization of shareholder's capital. On the contrary, ROE has a positive correlation, and usually draws more optimistic picture of the banks' performance (Pennacchi & Santos, 2018).

Similar correlation is defined by de Bandt et al., (2014), who focus on the effects that banks' capitalization has on ROE. The results conclude that an increase in capital will lead to a significant increase on the level of ROE, although the economic effect of the increase is only moderate (de Bandt et al., 2014). Thus, the use of ROE communicates with the investors more consistently within the banks' own targets, and additionally can smoothen the yield returns and make them seem better than they are without depicting the whole truth of the performance of the bank (Pennacchi & Santos, 2018). Nevertheless, the positive correlation between increase in capital and ROE is usually achieved by an increase in efficiency (De Bandt et al., 2014).

As creditors are interested in bank solvency, the shareholders' interest is in banks' ROE. In addition to ROE, the creditors interest in solvency adds it to be as well on banks' target. However, Georgiou (2009) finds, that solvency and ROE can be conflicting targets, and that ROE outperforms solvency in maximization. This means, that as solvency increases, ROE increases as well. However, when ROE has reached it maximized value, any further increase in solvency declines ROE driving it further away from the maximized value. As long solvency and ROE stay under or within this critical value, the two measures have no conflict. Any higher levels of solvency will conflict with ROE by decreasing and affecting negatively to the banks' performance and profitability. Due to this, many banks tend to focus on maximizing ROE at the expense of their solvency.

Banks overly reliance on ROE as a performance measure is a focal incentive for **banks to excessively take risks**. The reliance and use of ROE are derived from the banks risk management approach towards bank capital. The banks charge capital according to each asset's risk and expected losses. In addition, the excess capital is accounted for, and regarded as inefficient. Within this framework, the bank capital is adjusted to the risk and excess reserves, and the target is set as obtaining the highest return for each asset's capital charge. However, to assess the targets for bank performance, the evaluation depends on defining how value creation and risks affect the capital. Higher risks obtain higher returns, but misaccordingly hidden or underestimated risks can seem like value-enhancing, if the risks have not yet materialized. This misconception and negligence can increase the excessive risk taking, as ROE can be boosted by artificial enhancement through higher risks and undervalued capital charges with underlying hidden risks. In addition, often the bank regulations allow and even encourage this distortion, and regulatory constraints favor the underestimated capital charges. The excessive risk taking will cause ROE to pose as a source of systemic risk. (Moussu & Petit-Romec, 2017.)

Typically, in academic literature results that utilize ROE have similar results, when studied with return on assets (ROA). Thus, these two measures are often treated alike, and results only for either ROE or ROA are reported, although in general ROE seems to be preferred to be the one presented on results (Tregenna, 2009; Aebi et al., 2012). Similarly, in this study, in some parts discussion is included about ROA depending on whether the academic literature of these topics has focused either on ROE or ROA.

3.1.1 ROE and financial crisis

In the decades and years preceding the financial crisis, ROE was used as a central measure of bank profitability and performance in the U.S. (Moussu & Petit-Romec, 2017). The U.S. commercial banks had experienced an upward development of ROE since the

1940s[10]. Before the financial crisis, bank profitability and ROE were especially high, and by the beginning of the 21st century, profitability had reached its new historical high (Tregenna, 2009).

On the contrary to previously mentioned views from de Bandt et al. (2014), the higher U.S. profits did not accumulate from higher efficiency. Instead, the base of high profits was built on unstable grounds, and the banks' performance was not efficient enough to have a strong fundamentally positive effect on the banks' profitability. Tregenna (2009) finds, that the 1980s deregulatory developments in the U.S. markets opened up the banking sector and pushed the banks to be more concentrated. The loosening restrictions from deregulatory movements also allowed banks to use non-traditional funding more extensively. High concentration in the U.S. banking sector was affecting banks' ROE -values by increasing them, but at the same time significantly more increasing the vulnerabilities of the banks. The higher profits arising due to bank concentration were at the expense of the rest of the economy. The interest rates increased, and investments and growth were depressed. The banks and the banking sector were left more exposed. Furthermore, the concentration and growing capital in the banking sector exposed some institutions to too-big-to-fail -dilemma.

The excessive reliance on ROE encouraged the banks to overinvest in riskier assets, which contributed as one of the fundamental causes for the financial crisis (Moussu & Petit-Romec, 2014). Because banks were targeting constantly higher ROE values, questions were arisen on how much of banks' reported profitability was actually "real", and how much was with other measures enhanced (Tregenna, 2009). Due to this, before the crisis the financial markets and banking sector had too little bank regulation, which contrarily was needed to accommodate to the increasing risks. A comprehensively stronger bank regulation would have been needed for the financial markets and banks to have been operating more efficiently (Tregenna, 2009).

[10] With exception of late 1980s and early 1990s. However, these drops in the profitability did not affect on the overall development, and the levels continued rising until 2006 (Tregenna, 2009).

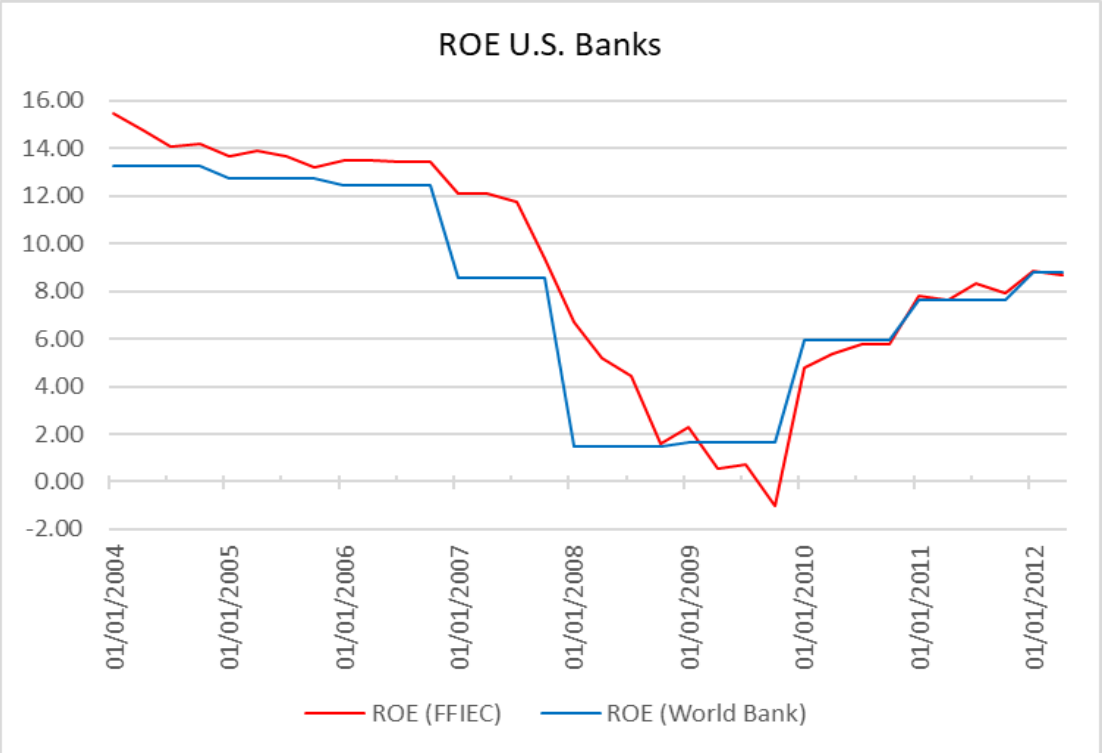


Figure 3. Return of equity for U.S. banks. Percent, not seasonally adjusted. Two different sources and methods for ROE are depicted. Annual data from World Bank shows U.S. commercial banks' net income to yearly averaged equity. The data is collected from Bankscope. Quarterly (end of period) data from Federal Financial Institutions Examination Council (FFIEC) shows net income to average of total equity capital. The data is annualized and collected from Reports of Condition and Income for All Insured U.S. Commercial Banks. Adapted from World Bank (2020); Federal Reserve Bank of St. Louis and Federal Financial Institutions Examination Council (2020).

Figure 3 displays the **annual and quarterly ROEs for U.S. commercial banks** from World Bank and Federal Financial Institutions Examination Council (FFIEC). As can be seen from the graphs, the average ROE was between 12% and 15% in 2004 until the beginning of 2007. During the first quarter of 2007, the ratio started to slowly decrease, and as the crisis started in August 2007, the commercial banks experienced crashing ROEs in their bank performance. Even though in summer and autumn 2008 actions were taken in the markets to improve the market conditions, the commercial banks' ROE had only slight periods of improvements keeping the ratio above zero but below 2% from the end of 2008 until the end of third quarter of 2009. Nonetheless, these efforts did not manage to completely stop the plummeting, and during the last quarter of 2009, FFIEC reported ROE crashing below zero to -1.03% (World Bank, 2020; Federal Reserve Bank of St. Louis

and Federal Financial Institutions Examination Council, 2020). The sharp decrease in ROE can be explained with large, unexpected losses in the banking sector during the crisis from 2008 to 2010. In 2009, the unexpected losses for U.S. commercial banks covered in total 15% of banks required capital (Klaassen & van Heegen, 2015).

On the contrary to FFIEC reports, the World Bank data on Figure 3 shows the average ratio for years 2008 and 2009 staying above zero in approximately 1.5%. Similar differences between the two graphs are shown from the beginning of the crisis, where the quarterly ratio stays higher than the yearly ratio, before dropping below the yearly average. The difference can be most likely explained by the set of banks included to the two datasets and methods. Since the set and number of banks included to both datasets differ slightly between the datasets, the results can vary according to the included banks. In addition, World Bank relies to annual averages, while FFIEC has more time specific data. Thus plausibly based on the data of Figure 3, it can be concluded, that the volatility of commercial bank ROE during the crisis was between quarters more volatile than between years, which appears as higher changes and drops in the depicted ratio. (World Bank, 2020; Federal Reserve Bank of St. Louis and Federal Financial Institutions Examination Council, 2020.)

In the beginning of 2010, the banks' ROE had a sharp increase from the all-time low to nearly 5%. At the end of the crisis both of the ratios were moving close to each other and experiencing a steady increase. Nonetheless, in the beginning of 2012, the ROE for U.S. commercial banks was still only approximately half from the precrisis levels, standing at 8.8% (World Bank, 2020; Federal Reserve Bank of St. Louis and Federal Financial Institutions Examination Council, 2020). The lower levels of ROE after the crisis can be explained with capital buffers. With more strict capital buffers, the banks' capital assets ratios changed, and the values of ROE were less enhanced through lower levels of balance sheet capital. Artificial boosting of ROE values was less sufficient than during precrisis years. In addition, the large, unexpected losses during the crisis impacted the

recovery of ROE and slowed it down compared to precrisis years (Klaassen & van Eeghen, 2015; Moussu & Petit-Romec, 2018).

Even though increasing ROE mutually increased the bank specific risks, how were the banks not able to detect the risks through their risk management? Before the crisis, majority of the banks did not commit their resources on comprehensive and high-level risk management, but instead had risk assessed only by associated personnel, who did not have a direct ability to influence short- and long-term strategies and the affiliated risks. This shortcoming could be seen by reviewing banks who had a named chief risk officer (CRO) as a part of their executive board. These banks had higher ROE -values during the crisis, inferring that banks who had a direct link with risk and strategy management, were able to maintain better ROE -values throughout the crisis. (Aebi et al., 2012.)

In addition, during the precrisis years, the bank CEOs had incentives through their monetary compensation to maximize ROE as much as they could (Moussu & Petit-Romec, 2017). Similar developments are found by Tregenna (2009), who observes managerial salaries and bonuses incentivized capital expansion and “empire-building”, even if these actions did not benefit banks’ profits and profitability. However, on the contrary to Moussu & Petit-Romec’s (2017) finding, Aebi et al. (2012) do not find any connection between corporate governance and CEO ownership and incentives to have affected ROE during the financial crisis. Instead, their study emphasizes, that before the crisis, the banks were pushed by their board of directors to maximize the shareholder wealth. The effects though are in line with Moussu & Petit-Romec’s (2017) academic theories. The associated risks were not understood but seen as means to create wealth. Only as the crisis began, the underlaying risks were realized (Aebi et al., 2012).

The financial crisis revealed the **excessive and hidden risks** the banks had taken during the several years preceding the financial crisis. These risks materialized in increasing losses and sharp decreases in ROE. Moussu & Petit-Romec (2017) find, that the high precrisis levels of ROE had a significant impact on the destruction of value during the

financial crisis. In addition, they find that before the crisis, similar short-term bank performance metrics[11] delivered similar results to ROE, suggesting that not only the capital structure and funding strategies increased the risks, but also the asset tradeoffs had an important role on heightening the affiliated risks.

3.2 Subprime mortgages

To understand properly mortgage-backed securities and the risks affiliated to them, as well as to understand why mortgage-backed securities with subprime loans caused such a stir in the financial markets, it is important to understand the functioning and design of the underlying subprime mortgage loans.

Subprime mortgage loans are a financial innovation, that are designed to serve and be profitable to the public, who cannot obtain or access mortgage financing to buy their own homes. These people are typically poorer and/or minority, and usually have lack of creditworthiness, documented income, or equity for mortgage down payment (Gorton 2010, p. 63; Gorton & Metrick, 2012). In addition, the typical subprime borrower could have prior mortgage delinquencies, bankruptcy filing or foreclosure from within the previous 3 to 5 years and 40% or higher debt-to-income -ratio (Kendra, 2007). Generally, these kinds of borrowers are considered as too risky to be qualified for more usual and stable mortgages. The subprime mortgages were designed to fill the demand for housing finance for this kind of public (Gorton, 2010, p. 146; Gorton & Metrick 2012).

The operational idea of subprime mortgages is for both the lender and the borrower **to benefit from the house price appreciation** on short term basis. The fundamental feature of a subprime mortgage is, that every two to three years the borrower is highly urged through the design of the security to refinance. Most of the subprime mortgages are

[11] Moussu & Petit-Romec (2017) analyzed alternative definitions for ROE, such as return on assets (ROA), operating return on assets (OROA) and return on risk-weighted assets (RORWA).

described as adjustable-rate mortgages (ARMs). Typically, they have amortization of 30-years and a hybrid structure that changes from fixed to floating rate. Most common structures are “2/28” or “3/27”. This means, that the first two or three years the interest “teaser” rate is fixed. After this period, on the “reset date”, the interest rate will increase and switch into a floating rate. The new higher rate is added to a benchmark rate, usually LIBOR (London Interbank Offered Rate), and due to the floating of the benchmark rate, the new reset rate becomes a floating rate (Gorton, 2010, pp. 74-75). The idea of the initial fixed teaser rate and the subsequent floating reset rate is that during the maturity of the teaser rate, the homebuyer will generate capital through the increasing market prices. In the end of the initial teaser period the interest rate will rise significantly. Even though the new reset rate is much higher, potentially to the homebuyers it is still affordable. Nevertheless, the monthly mortgage payments rise tremendously on the reset date, which essentially acts as an incentive to refinance before the end of the teaser period (Gorton, 2010, p. 75; Gorton & Metrick, 2012).

The subprime mortgages are designed in a way, that the borrowers of the loans will financially benefit from the appreciation of the house prices. To also protect the lenders, subprime mortgages have extremely high prepayment penalties. Whereas a typical fixed prime mortgage has a prepayment penalty of zero, vast majority of subprime mortgages have high prepayment penalties. This is designed to prevent the borrowers from quickly extracting equity that they have gained during the maturity of the loan. To avoid future foreclosures and to also, reciprocally, benefit from the possibility of realization of the situation of prepayment, the lenders want to have the right to end the mortgage early. The high prepayment penalties are the solution to restrict the actions of the borrowers and give more rights to the lenders. Subprime mortgages use the appreciation of the house prices as the prerequisite to enable the mortgages being rolled into another mortgage through gained equity. The goal of the security is to necessitate the borrower to refinance, and, through refinancing, turn the capital gains into collateral of new mortgages. This process generates the financial basis and collateral for the next subprime mortgages and bonds. (Gorton, 2010, pp. 63, 74, 76.)

As the mortgages are subprime and aimed to people with scarce resources to finance a home, the features and design of the subprime mortgages fundamentally leaves little options for the homebuyer, and forces the homebuyer to refinance his/her mortgage by using the capital created during the maturity time (Gorton & Metrick, 2012). The initial fixed rate period and refinancing makes a subprime mortgage a short-term financial instrument, because through refinancing the borrower will have a string of short-term subprime mortgages instead of one long-term mortgage. As long as the house prices are rising, every time the subprime mortgage is refinanced, the more equity is built up, and the lower the interest rates become (Gorton, 2010, pp. 78, 80).

3.2.1 Subprime mortgage loans and the financial crisis

In the years preceding the crisis, low lending standards and cheap credit incited the booming housing frenzy. This created more fundaments for a crisis to start developing (Brunnermeier, 2009). In 2007 the financial crisis was set, when a **sharp overall decline in the housing prices** caused an enormous increase of delinquencies in mortgages, setting the stage for systematic liquidity crisis (Brunnermeier, 2009). As Figure 4 shows, delinquencies in single-family residential mortgages started to increase in number as early as in the autumn of 2006, and by the summer of 2007, the delinquency rate had already exceeded the precrisis levels (Federal Reserve Bank of St. Louis, 2020f).

In summer 2007, **derelictions in the mortgage markets** forced banks to write down hundreds of billions of dollars in bad loans. Onwards from July 2007 house prices and sales continued to drop, and the losses of the subprime mortgages had started to realize. In November 2007, it became clear in the financial markets, that the total loss in the mortgage markets was greater than previously anticipated. The earlier estimate of a loss of $200 billion was an underestimation, and it had to be re-evaluated upwards. The banks had to even further write-down their assets in addition to several new larger write-

downs (Brunnermeier, 2009). The ratio of delinquencies of residential mortgages sky-rocketed all the way until the beginning of 2010, when the delinquency ratio hit 11.5% mark. As the Figure 4 shows, even though the ratio slowly started to decrease, it took 10 years to reach the precrisis level, and even still nowadays (2020) it hovers barely above it (Federal Reserve Bank of St. Louis, 2020f).

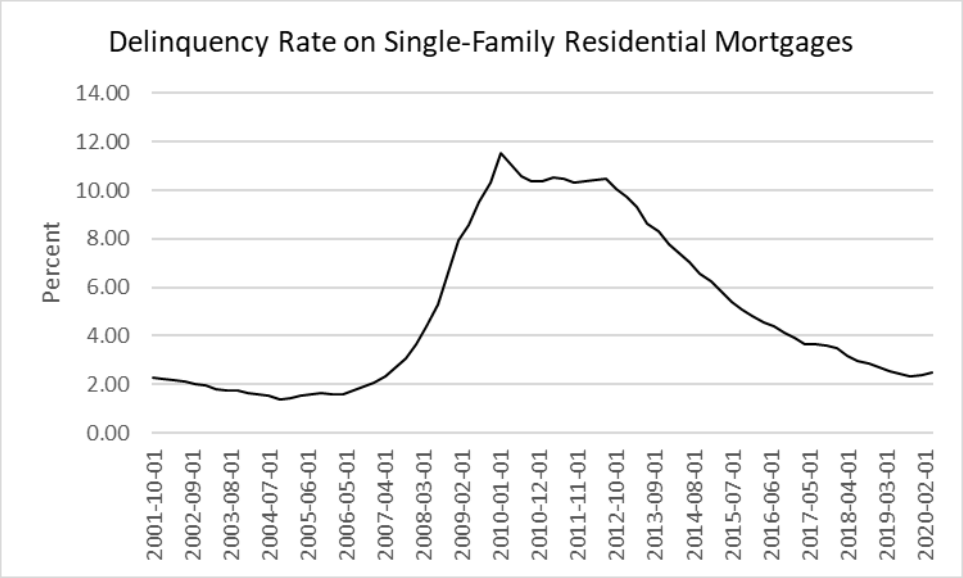


Figure 4. The delinquency rate on single-family residential mortgages, that were booked in domestic U.S. offices from all commercial banks. Adapted from Federal Reserve Bank of St. Louis (2020f).

As consequence to what was happening in the subprime markets, the U.S. domestic banks started to tighten their standards for subprime mortgage loans. While in the autumn 2007 approximately 56% of the domestic banks had tightened standards for subprime loans, the ratio started quickly to rise. In the beginning of 2008 71% of the banks had tightened their lending standards. The worries considering the subprime loans steadily reached the whole U.S. markets, and by October 2008, 100% of U.S. domestic banks had tightened lending standards for subprime mortgage loans. (Federal Reserve Bank of St. Louis, 2020d.)

But how could the forthcoming burst of the house bubble develop unforeseen? The rapid growth and continuous growing trend of the house prices exceeded the levels from the

previous large-scale crises during the years preceding the crisis (Reinhart & Rogoff, 2008). Figure 5 depicts the **growing trend of U.S. national house prices** through S&P CoreLogic Case-Shiller U.S. National Home Price Index. The index is a monthly composite of single-family home price indices, and it measures the value of single-family housing within the U.S.[12]. The index clearly shows, that since the beginning of the century, the house prices had constantly risen without no sign of stopping. In July 2006, the house prices had increased nearly 85% since 2000. From there, the index shows some mild decline, before plummeting in August 2007 (S&P Dow Jones Indices, 2020a; S&P Dow Jones Indices, 2020b). The growing trend compared to historical values and slight declines since the summer of 2006 should have been seen as warning signals, but instead were ignored in the financial markets (Reinhart & Rogoff, 2008; S&P Dow Jones Indices, 2020a).

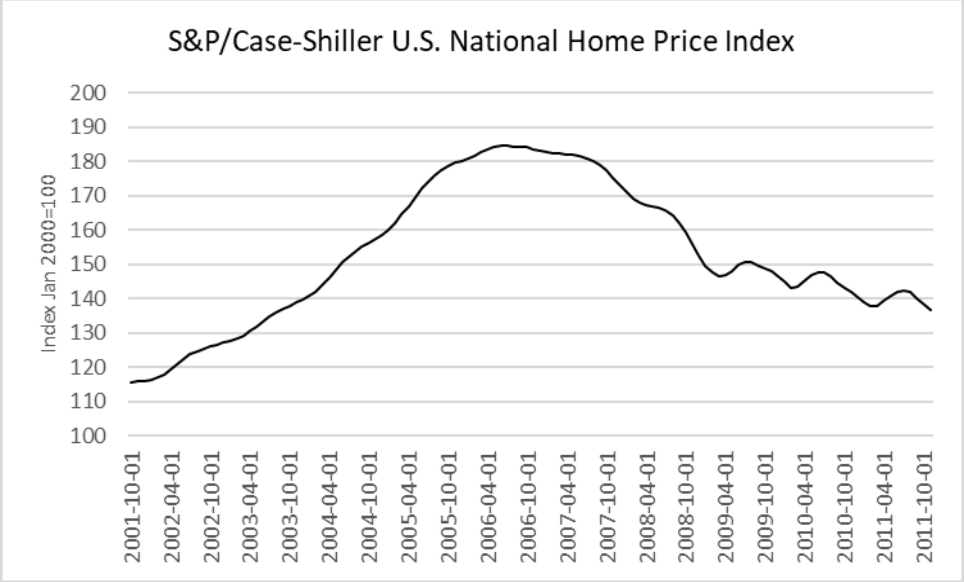


Figure 5. The value of single-family housing within the U.S. Given the constant level of quality, the percentage changes in the indices measures corresponding percentage changes in the U.S. national housing market prices. In the index January 2000=100. Adapted from S&P Dow Jones Indices (2020a); S&P Dow Jones Indices (2020b).

Reinhart & Rogoff, (2008) argue, that during the preceding years, the extreme run-up in the housing prices was not seen by the analysts as a bubble, but rather as justified and

[12] More information about the S&P CoreLogic Case-Shiller U.S. National Home Price Index can be found at S&P Dow Jones Indices (2020b).

natural development by financial innovation. This included largely the subprime mortgages. It was to be believed, that the run-up in housing and other equity prices could be sustainable due to the growth in productivity and decrease in associating risks. In addition, the U.S. was enjoying a steady inflow of capital from the Asia and petroleum exporters. The productivity growth and high returns on physical and financial investments were believed to continue the trend for years ahead.

What really happened, was that the burst of the asset price bubble caused a negative shock on the economy and the effects of the burst and the consequential tensions in the financial markets could be observed throughout the markets (Lo Duca & Peltonen, 2013). Reinhart & Rogoff, (2008) strongly criticize, that instead of understanding the reality of the financial markets, the market participants were lulled in by the flexible economy and the innovations in technology. However, even though broad range of academic literature emphasizes the importance of booming housing prices as an important contributor to the crisis, Rose & Spiegel (2009) do not find any significant evidence in the change in real estate prices between 2003 and 2006 being a potential cause of the financial crisis. Thus, they do not find any statistical evidence for the house price growth predicting the crisis.

3.3 Mortgage-backed securities

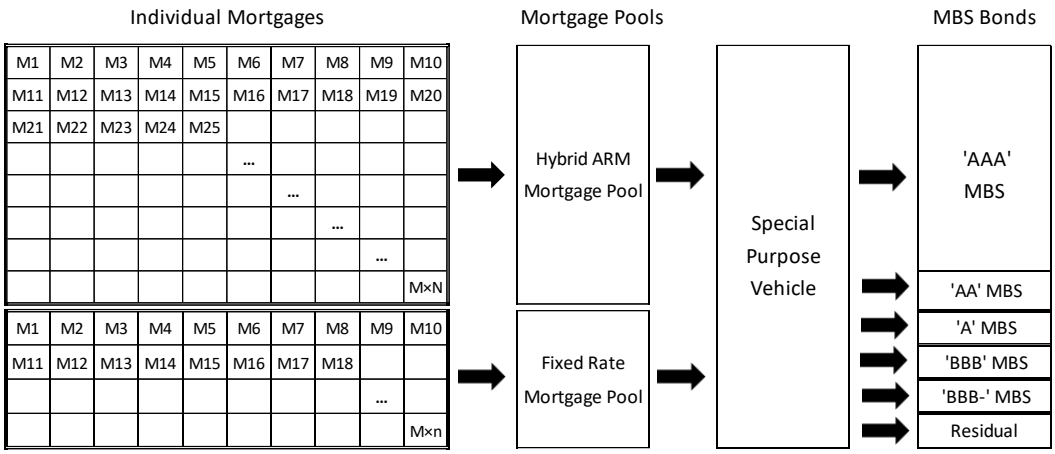
Asset-backed securities (ABS) are securitized financial instruments. They were the biggest fixed-income market in the U.S. in the 2000s, in its totality exceeding in 2004-2006 the entire value of the issued corporate debt in the U.S. The biggest subclass of asset-backed securities in the U.S. are **mortgage-backed securities (MBS)**, which were used especially in the early 2000s for mortgage financing in the subprime market. Approximately 80% of the subprime mortgages were financed with mortgage-backed securities in the years of 2005 and 2006 (Gorton & Metrick, 2012).

Mortgage-backed securities are financial securitized bonds, that have been aggregated

from and secured with residential or consumer mortgages, typically with subprime mortgages (Gorton, 2010, p.63). **The securitization process and design of MBSs** is depicted in Picture 2. MBSs are structured by first accumulating multiple individual mortgages into bigger mortgage pools, which are pooled according to their interest rate type (Gorton, 2010, p. 84). Often these pooled mortgages include thousands of them (Gorton & Metrick, 2012). The next step is to sell the pooled mortgages to Special Purpose Vehicle (SPV) (Gorton, 2010, p. 20). An SPV is a non-physical robot company and a legal entity. It has been created by a firm, who transfers assets to the SPV. SPV's sole purpose is to execute some specific purpose, activity, or series of transactions, that have been assigned and restricted in advance (Gorton & Souleles, 2005). One of the fundamental causes for SPV to exist is to create securitization to the financial markets (Gorton, 2010, p. 21). After the SPV has purchased the pooled mortgages, it then issues the MBS bonds on the markets by generating rated tranches[13] (Gorton, 2010, p. 21).

The SPV finances its purchases by issuing investment-grade securities in the capital markets with different layered seniorities called tranches. MBS tranches are designed to build a capital structure to the pooled assets and mortgages, that spread the risk of loss according to the seniority and credit ratings (Gorton & Metrick, 2012). Depending on the risk levels of the assets, the securities are pooled differently and addressed to investor groups with different risk preferences (Brunnermeier, 2009). The first losses are realized on the bottom junior tranche layer, called equity tranche or "toxic waste", and the tranche is paid only after all the other tranches have been paid first. The tranches move up in seniority, and the safest tranche, called super senior tranche, has relatively low interest rate, but pays out the investors first above all other tranches. The highest top tranches are pooled out of high-quality securities to receive an AAA-rating (Brunnermeier, 2009; Gorton & Metrick, 2012).

[13] In addition to mortgage-backed securities, pooled tranches often also included other type of loans, corporate bonds, and other assets, e.g. credit card receivables. (Brunnermeier, 2009.) In this work, the focus is on the MBS loans.



Picture 2. The securitization process of mortgage-backed securities from mortgages with different interest rates. Adapted from Kendra (2007).

The structural problems and risks of MBSs particularly are seen with the **diversification of the tranches**. Through the securitization process, AA- or higher rated MBS tranches with pooled investment-grade securities, including collateralized debt obligations (CDOs), usually include fractions of tranches with low credits ratings, usually BBB or lower. These lower rated trances have been cut to smaller pools and combined to investment-grade tranches, usually with AAA- or AA-ratings (Brunnermeier, 2009; Gorton & Metrick, 2012). Because the assets are pooled to the tranches, the diversification decreases the idiosyncratic risk of the securities, and the tranches receive a better credit rating, than the individual securities would receive (Brunnermeier, 2009).

Like other ABSs, MBSs are dependable for payments of the cash flows created from the pooled assets (Gorton, 2010, p. 68). The securitization process of MBSs and refinancing the mortgages work as the fundamental way to finance the new subprime mortgages, which is done by creating securitized collateral out of the original subprime mortgages (Gorton & Metrick, 2012). The refinancing of new subprime loans through MBSs relays completely on the appreciation of the underlying mortgage, making the MBSs extremely sensitive to the market and house price movements (Gorton, 2010, p. 81). Other asset-backed securities, that are structured similarly as mortgage-backed securities are other pooled securities, that are collateralized for example with credit card receivables,

student loans and equipment loans (Gorton & Metrick, 2012).

3.3.1 Mortgage-backed securities and the financial crisis

During the precrisis years, there was overdemand for investment-grade securities. However, the markets could not wholly respond to the demand. The solution was excessive pooling of assets into tranches. By slicing the lower graded tranches and packing them into investment-grade tranches with highly rated securities, the supply of investment-grade securities could be synthetically manufactured, and the demand could be met through securitization. (Gorton & Metrick, 2012.)

Through structured financial products, the risks could be shifted and spread amongst those in the market who wished to countenance it. This allowed the markets to experience lower rates on mortgages and other loans. In addition, institutional investors were able to hold more diverse selection of assets, which they were not able to hold before due to regulatory requirements (amongst other limitations). For example, by investing in AAA-rated tranche, that had been pooled from BBB-rated securities, investors were able to invest in broader rating-classes, instead of holding on to possible AAA-rating regulatory quality requirements. Due to the strong urge and demand for securitization, the interest rates for credit fell and the standards for lending loosened. (Brunnermeier, 2009.)

Figure 6 depicts the **large volume and the growth on demand of the MBS markets** before and during the crisis. The commercial banks' market volume of MBSs had steadily grown since prior to the crisis. In May 2004, the volume shifted above 800 billion USD and by the beginning of the crisis in autumn 2009, it had increased to closer to one trillion USD (Federal Reserve Bank of St. Louis, 2020c; Board of Governors of the Federal Reserve System, 2020c). However, high levels of financial stress can lead to a slowdown of the economy. When the housing bubble finally popped in July 2007, this impact came into realization. The concerns about the value of structured products and the decreasing reliability of credit ratings caused the short-term ABS market starting to run dry. The

banks funding liquidity, that was critical for the market efficiency, dried up. The financial institutions and banks experienced major downgrading for many of their assets, including several pooled tranches consisting of mortgage-related products. Following, several money market participants became reluctant on lending to each other (Brunnermeier 2009; Lo Duca & Peltonen, 2013).

At the same time due to demand for securitized assets, and the different bonds and securities being securitized into more and more layers and connected to growing numbers of different assets and securities, in the financial markets it became increasingly more difficult for the investors to estimate and assess, what exactly an investment-grade tranche or pool of assets and CDOs actually were consisted of (Gorton & Metrick, 2012). Baglioni (2012) finds, that ABSs caused the losses to be distributed around the markets, without the participants having a clear picture of the risks these securities were containing (Baglioni, 2012). The complex bundling of these obligations was thought to spread the risk efficiently. Instead, the overly complex securitization and bundling drove the instruments to become illiquid and nontransparent, thus magnifying the impacts on the financial markets (Reinhart & Rogoff, 2008). To make matters worse, there was little concern on the markets over monitoring the loans and securitized assets. Since the assets were mainly short-term and the risk was divided through many market participants -not to forget about the lack of transparency of the asset-ratings- financial institutions had little incentive on monitoring loans and taking a better look on approval of loan applications (Brunnermeier, 2009).

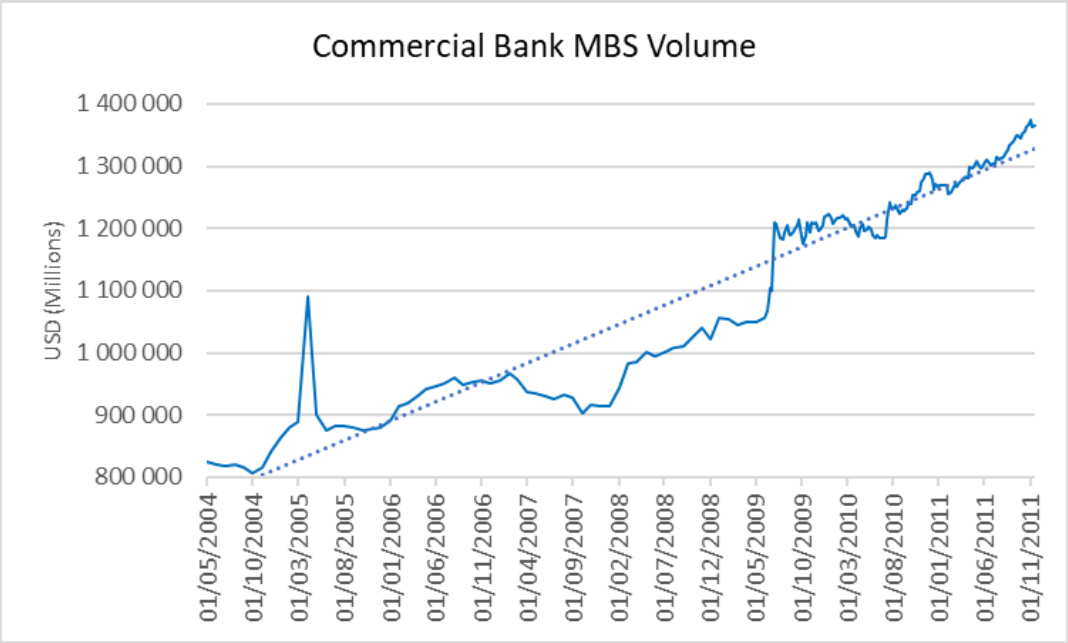


Figure 6. The volume of MBS securities for U.S. commercial banks. Collected from the Federal Reserve. The data has a discontinuity in July 2009. From July 2009 the data is weekly volumes of MBS loans for all commercial U.S. banks. The collateral is Treasury and agency securities and other assets. However, the currently available data from the Federal Reserve only covers the MBS volume for all commercial banks since July 2009. There is no currently available data from before that. For that reason, the values before July 2009 are estimated by using the combined Federal Reserve volumes for large and small domestically chartered banks (adjusted for mergers). These values are currently the only available Federal Reserve values for the months before July 2009, which cover a broader range of collateral, and include both large and small banks. However, the data is monthly volumes, as well as the set of banks might slightly differ from the set of all commercial banks after July 2009. For these reasons, a linear trend line is added to further depict the overall development of the MBS volume. The trend line has a R^2=0.9243, suggesting the values prior July 2009 to be utilizable as estimates. Additionally, curved polynomial trend lines were tested, but the results were very close to the results given by the linear line. Thus, the linear line was used instead to add clarity to the overall trend. Nonetheless, the exact values from prior July 2009 should not be reviewed too precisely, and instead the focus should be on the overall trend and development of the MBS loans. Adapted from Federal Reserve Bank of St. Louis (2020c); Board of Governors of the Federal Reserve System (2020c).

The negative effect of securitization and interconnectedness of several securities increased volatility and margins in August 2007. Before the crisis, asset-backed commercial paper was overcollateralized. The overcollateralization worked as a cushion for risk, making asset-backed securities almost risk-free. However, the situation turned upside down in August 2007, when the crisis hit. Instead of making the securities risk-free, overcollateralization turned ABSs, including MBSs, exceedingly risky. Asymmetric information in

the markets considering the collateral of the ABSs made investors and financial institutions careful and overly afraid to accept assets as collateral. Rolling over debt for structured investment vehicles became hard, when investors feared that the good investment-grade assets had the risky, less valuable assets as collateral. Unwillingness of rolling over debt in the financial markets grew tremendously, and during 2007 the asset-backed commercial paper market dried up completely. These **dry-ups** also had much broader implications, especially affecting the short term -debt- and repo-markets (see Chapter 3.4.1) (Brunnermeier, 2009). Following the collapse and distress in the subprime mortgages (amongst other types of similar securitized products), the U.S. markets were hit by a banking panic (Ivashina & Scharfstein, 2010). However, even though academic literature emphasizes the dry-ups of the asset-backed commercial papers, the decrease in MBSs was in fact rather small compared to the overall volume of the MBS markets, and the panic was more severe than the drop in the MBS volume. Figure 6 visualizes this. Even though, the start of the crisis decreased the volume temporarily, the fitted trendline shows, that the overall demand was at the same time increasing (Federal Reserve Bank of St. Louis, 2020c; Board of Governors of the Federal Reserve System, 2020c).

In spite the volume of the drop in the ABS and MBS securities, the slowing down and decrease in MBS markets had a big impact to the financial markets. The distress in the banking system caused fears and concerns about the liquidity and solvency of banks and financial institutions, affecting subsequently even further the asset prices by dramatically decreasing them (Ivashina & Scharfstein, 2010). To provide support to mortgage lending and housing market as well as to improve conditions of the credit markets, the Federal Reserve announced purchases of MBSs and housing agency debt up to 600 billion USD through Large-Scale Asset Purchase (LSAP) program. In March 2009, the Federal Reserve had expanded the purchase volume to up to 1.75 trillion USD (Gagnon, Raskin, Remache & Sack, 2011). In addition to LSAP, the introducing of TSLF eased the depositary institutions struggling with illiquid MBSs by accepting them as collateral against the borrowed funds, and thus improving the banks' asset variety on their balance sheets (see Chapter 2.1.1) (Hördahl & King, 2008). With the help of unconventional programs, the crisis did not affect too much on the market volume, and by July 2009 the MBS volume

had increased to above 1.2 trillion USD (Hördahl & King, 2008; Federal Reserve Bank of St. Louis, 2020c; Board of Governors of the Federal Reserve System, 2020c).

After 2009, the volume of MBSs continued to grow, and by the end of the crisis in the last quarter of 2011, the volume was nearing 1.4 trillion USD. The Figure 6 shows, that even though the crisis might have temporarily slowed down the growth of the MBS markets for commercial banks, it did not have a long-term effect on it. On the contrary, at the end of the crisis the volume and growth of the demand of MBSs increased even further along. (Federal Reserve Bank of St. Louis, 2020c; Board of Governors of the Federal Reserve System, 2020c.)

But were the problems of securitization and bundling of subprime mortgages into MBS bonds really that "special" and different? Gorton (2010) sees that the problem indeed was not the securitization itself, but the particular **design of the subprime mortgages**, that was made highly sensitive to the house prices and easily contracted and passed to other financial structures. Gorton (2010) deviates from majority of academic literature by emphasizing, that securitization was not the cause of the problems. On the contrary, it should be viewed favorably and was, and still is, an efficient form of financing. During the years around the financial crisis, the financial markets and the traditional U.S. banking system was shifting further away from being central to the savings and investment processes. Instead, the centrality was moving towards the capital markets, which offered more flexibility and risk decentralization via structured and securitized products and instruments. (Gorton 2010, p. 146.)

In addition, Reinhart & Rogoff (2008) draw a clear parallel to the 1980s U.S. debt crisis, which was greatly caused by the recycling of petro-dollars from the oil-exporters to the emerging-market borrowers e.g. to Latin America. In 2007 the developing economies instead of existing outside the U.S. economy, existed within the U.S. borders, when more than one trillion dollars was directed to the subprime-mortgage market. Like learned before, the subprime-mortgage market consisted of the poorest and the least

creditworthy borrowers inside the U.S. boarders, thus making it somewhat comparable to a developing economy on its own. Even though the concept is not spot on similar, the mechanism is the same, and it can be understood, why the risks of this market segment should have been observed.

3.4 Repurchase agreements

Repurchase agreements (repos) are short-term, often overnight, collateralized loans, in which a security is exchanged to cash (Cecchetti, 2009; Afonso et al., 2011). Afonso et al. (2011) describe repo agreement as a financial instrument, which approves the use of a security as a collateral for a cash loan. The investors and financial institutions can purchase a security from a bank, which the institutions can use as the collateral from the bank for their own investment (Afonso et al., 2011). The definition of repo depends whether the depositary or financial institution is the lender or borrower of the cash. From the borrower's perspective, the agreement is called a "repo", and from the lender's perspective, the agreement is called a "reverse repo"[14] (Bech et al., 2012). As a term, it is settled that the participants revoke the transaction by repurchasing the security on a predetermined time and price in the future (Cecchetti, 2009).

Repos are frequently **collateralized with securitized bonds** (Gorton & Metrick, 2012). The Federal Reserve allows three kind of collateral to be used in their repo agreements: U.S. Treasury securities, U.S. agency securities and AAA-rated collateralized mortgage-backed securities. In average, The Federal Reserve accepts three times more likely U.S. Treasury, and twice as likely U.S. Agency securities as collateral, than what it accepts AAA-rated collateralized MBSs (Cecchetti, 2009; Federal Reserve Bank of New York, 2020c). Most common collateral used in the U.S. repo markets are Treasury securities, which consist around two thirds of the market. However, agency debt and MBSs are as

[14] In this study, the focus in on repo agreements instead of reverse repos.

well widely accepted as collateral (International Capital Market Association, 2020). In general, repos are funding instruments, that are especially used in the banking sector for short-term liquidity funding, thus making repo markets extensive short-term liquidity markets (Gorton & Metrick, 2012). The maturity of repo is usually one day (overnight) but can be set even to 14 days (Cecchetti, 2009). Thus, repo loans act as an alternative source for overnight and short-term liquidity, alongside federal fund loans and discount window lending (see Chapter 3.5) (Afonso et al., 2011).

Repos are traded in the **Open Market Trading Desk** of the Federal Reserve Bank of New York, who initiates the repo operations and sends every morning a message to **19 primary dealers**, to whom the Desk states its terms and collaterals for that day's repo transactions. The primary dealers participating in repo transactions are the only ones who are legitimized by the Federal Reserve to trade the agreements directly with the Desk. They are primarily investment banks (Cecchetti, 2009; Federal Reserve Bank of New York, 2020c). Until the early stages of financial crisis, the 19 primary dealers included Lehman Brothers, Bear Stearns, and Merrill Lynch amongst others (Federal Reserve Bank of New York, 2020d). After receiving the message from the Desk, the primary dealers send their counteroffers back to the Desk, which include their prices, quantities, and the collaterals for their repo agreements. Finally, the Desk decides, how much of the offers from the primary dealers it accepts and issues the repo by purchasing the offered collateral securities from the primary dealers. The collateral protects the Desk against market and credit risk. At the same time the Desk agrees to resell the securities at a later specified date. (Cecchetti, 2009; Federal Reserve Bank of New York, 2020c). After the Federal Reserve has issued the repos through the primary dealers, the agreements can be traded in the financial markets. The repo market participation is broad, and includes depositary institutions and banks, U.S. government agencies, institutional investment funds and money market mutual funds, in addition to the primary dealers and the Federal Reserve System (Bech et al., 2012).

Repo issuances are typical **open market operations** used by the Federal Reserve, by which it adjusts the cash reserves of the banking system by injecting or drawing back liquidity through the repo agreements (Afonso et al., 2011; Federal Reserve Bank of St. Louis, 2020b). When the Federal Reserve issues repos, it purchases a security from the primary dealer. The dealer receives cash, and the Federal Reserve receives the collateral. Thus, the repo conducted by the Federal Reserve supplies reserve balances to the banking system for the length of the agreement. On the contrary, when the Federal Reserve issues reverse repos, it borrows cash against a sale of a security. The Federal Reserve receives cash, and the counterparty receives the collateral, thus absorbing reserve balances from the banking system (Federal Reserve Bank of St. Louis, 2020b). Due to the daily repo agreements the Federal Reserve can maintain a fraction of its funds on very short-term, which enables flexibly the adjustment of the funds and liquidity circulating in the financial markets. In addition, the daily transactions make the Federal Reserve to be regularly in touch to the entities operating in the financial markets. If stress on short-term funding starts to occur in the financial system, the Federal Reserve is capable to notice through the offers it receives from the primary dealers in its daily operations (Cecchetti, 2009).

Hull (2006, p. 77) describes repo rate as the difference of the sell price and repurchase price of the security underlying the repurchase agreement. Similarly, Cecchetti (2009) defines the repo rate as the interest rate, that the borrower pays for overnight loans, which are collateralized with U.S. Treasury securities. A decrease in the prices of the repos' collateral securities will result in undercollateralization of the repo (Hördahl & King, 2008). To address this risk, the margin of the collateral in the repo agreement is set as the repo **haircut** (Hördahl & King, 2008; Gorton & Metrick, 2012). In essence, the haircut is the difference between the value of the cash and the value of the collateral. Typically, the level of the haircut mirrors the quality of the collateral and can also vary according to the counterparty, thus depicting the creditworthiness of the collateral provider (Adrian, Begalle, Copeland & Martin, 2013). The haircut thus defines the amount of

collateral required in the agreement for implementing the repo transaction (Gorton & Metrick, 2012)

Usually the security that the repo agreement is based on has a higher market value, than is the value for the purchase and sell price on the repo agreement. In case the bank that issued the repo agreement cannot hold on to its obligation of the repurchase or becomes insolvent, the investor has the right to annul the repo agreement and hold on to or sell the security used as the collateral (Afonso, Kovner & Schoar, 2010; Gorton & Metrick, 2012). Due to this, repo agreements can limit the exposure to counterparty risk. The agreements are seen as bankruptcy protected, because the other participant can always either terminate the contract and hold on to the collateral or keep the cash, depending on whether the participant was on the receiving or issuing end of the agreement (Gorton & Metrick, 2012; Adrian et al., 2013). Generally, well bundled repo agreements include very little credit risk (Hull, 2006, p. 77).

A unique idiosyncrasy of the repo agreements is a quality called **rehypothecation**. According to this, the depositor of the cash may be entitled to physically have the bond used as the collateral in their possession. If wanting to, the depositor can reuse the bond used as the collateral, and issue it in the markets. Thus, the collateral used in the repo agreement has the money multiplier effect on the monetary circulation. However, rehypothecation can be dangerous, because in the distressed financial markets, the money multiplier effect works in reverse, and causes a formidable deleveraging process (Gorton & Metrick 2012). In addition, if the repo creditors refuse to extend the repo funding, the institutions, that heavily resort to repo funding and to the process of rehypothecation can be this way forced into bankruptcy (Adrian et al., 2013).

3.4.1 Repo loans and the financial crisis

Because most of the repos are traded in the **OTC -markets**, the repo markets are relatively opaque, and data on aggregate repo market activity is not typically available. However, in the academic literature there are some estimates of the repo market volume (Hördahl & King, 2008; Bech et al., 2012). During the last four decades the aggregate demand for repo financing has grown immensely (Gorton & Metrick, 2012). Since 2002, the gross volume of outstanding repos in the U.S. had doubled until the end of 2007, reaching approximately 10 trillion USD. By mid-2018 the gross market capitalization of the U.S. repo market exceeded 10 trillion USD, which roughly corresponded in size to 70% of the U.S. GDP (Hördahl & King, 2008). In addition to the academic estimates, the Federal Reserve Bank of New York registers the volume of repos conducted by primary dealers. This information on repo market volume can be utilized and is being used in empirical studies to approximate the size of the repo markets (Bech et al., 2012).

During the precrisis years, the non-government collateral was one of the main contributors to the extensive growth of the U.S. repo markets. The banks were using repos extensively in their funding strategies, and for example the top U.S. investment banks funded approximately half of their assets through repo markets (Hördahl & King, 2008). Like described in Chapter 2.1, the maturity mismatch in the short-term markets can prevent rolling over debt. When the financial institutions start to have difficulties in rolling over their asset-backed commercial paper, a run on these funds can occur. This was highlighted in the early 2000s until the beginning of the financial crisis in 2007, when the use of overnight repos as a short-term funding, especially for investment banks, had become more common, and even doubled in volume from the beginning of the decade. In the summer of 2007 warning signs of possible financial distress started to arise when the available funding liquidity started to dry up due to increased volatilities. The worst case hit in August 2007, when the short-term market for asset-backed commercial papers dried up, thus having devastating effects on the repo-markets (Brunnermeier, 2009).

Figure 7 depicts the **overnight and term repo**[15] volumes conducted through the primary dealers. The expansion and increase of the repo markets before the crisis is noticeable in Figure 7 (Federal Reserve Bank of New York, 2020a). Bech et al., (2012) estimate, that before the crisis, the ratio of repos to total assets for commercial banks moved between 1.7% and 2.0%. (Bech et al., 2012). The Figure 7 shows, that in the beginning of 2003, both the overnight and term repo markets were huge, with both overnight and term primary dealer repo volumes being around one trillion USD. While the term repo volume moved between a little less than one trillion and 1.6 trillion USD until collapse of Bear Stearns in 2008, the demand for overnight repos tripled reaching 3 trillion USD in March 2008. While the term repos experienced some smaller drops before the crisis and overall were more volatile, the overnight repos kept their increase even during the beginning of the crisis (Federal Reserve Bank of New York, 2020a). Similarly, by the beginning of 2008, to ratio of repos to total assets had risen to approximately 2.2% (Bech et al., 2012).

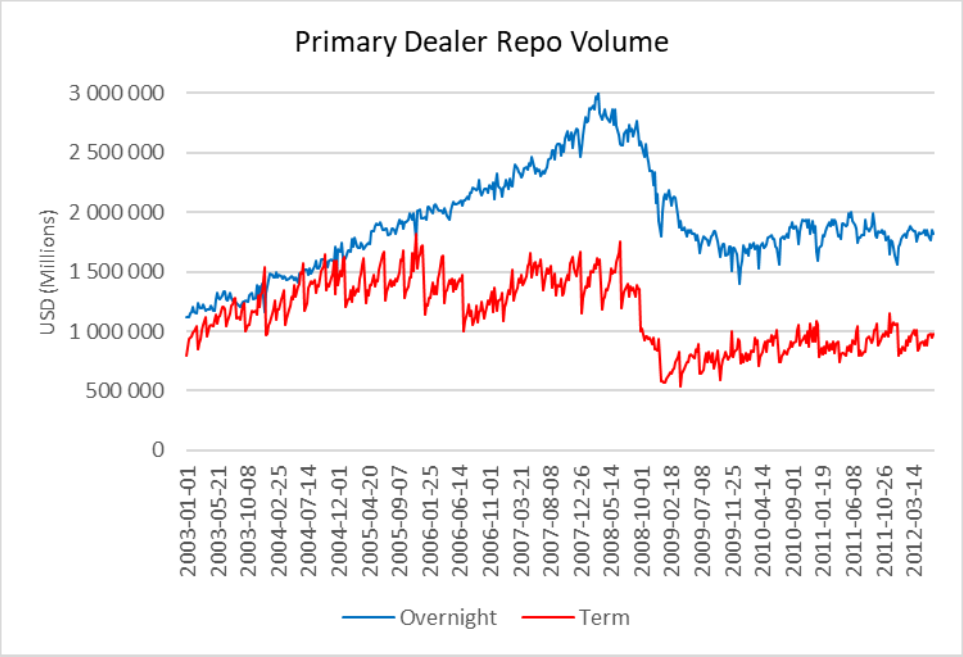


Figure 7. Primary dealer overnight and term repurchase agreement weekly volumes. Adapted from Federal Reserve Bank of New York (2020a).

[15] A term repo is a repo agreement, that has a longer maturity than overnight.

In March 2008, the repo markets were on their peak, and the total primary dealer repo volume reached almost 4.6 trillion USD (Figure 7). However, the collapse of Bear Stearns shook the repo markets, and both the overnight and term volumes decreased drastically (Federal Reserve Bank of New York, 2020a). After March 2008, the crisis intensified, and the repo markets started to become more strained. The markets for term repos dried up as the demand for repos with maturity longer than one week shrank to almost nothing. The financial turmoil was quickly affecting the repo markets (Hördahl & King, 2008).

Only after the bankruptcy of Lehman Brothers in September 2008, the overnight and term repo volumes started to slowly revive after having dropped to 1.6 trillion USD and only 600 billion USD, respectively (Federal Reserve Bank of New York, 2020a). Bech et al. (2012) estimate, that by the beginning of 2009, the total commercial bank assets were consisted of nearly 3.0% from repo agreements. Nevertheless, by the late 2009, the ratio of repos to total commercial bank assets had a dramatic drop down to 1.5% (Bech et al., 2012). Due to the extreme expansion of the repo markets, the overnight primary dealer repo volume never decreased below the precrisis levels but stayed elevated until the end and even after the crisis, fluctuating between 1.7 and 1.9 trillion USD. On the contrary, the term repo volume was affected more severely by the crisis, and settled below the precrisis level, moving around 750 billion USD, and only occasionally reaching more than one trillion USD (Figure 7) (Federal Reserve Bank of New York, 2020a).

However, it is important to note that the volume of primary dealer repos does not give an absolute estimate of long-term aggregate repo market volumes due to the pure size of the repo trading happening outside the primary dealers. For example, while the primary dealer repo volume almost tripled in 10 years from the beginning of the century, the estimated volume of repo trading happening outside the primary dealers quadrupled. Thus, the data from primary dealers depicts a significant fraction of the total repo market volume but does not represent the full volume. (Bech et al., 2012.)

The use of repurchase agreements increases temporarily the reserve balances in the banking system, thus providing the sought short-term liquidity for the banks and depositary institutions (Federal Reserve Bank of New York, 2020c). Especially prior to the crisis, the Federal Reserve used repos as means to provide liquidity, and to directly adjust the supply of reserve balances in the banking system. In addition, the repo operations were used to maintain the federal funds rate close to the target level of the federal funds (Federal Reserve Bank of St. Louis, 2020b; Federal Reserve Bank of New York, 2020c; Federal Reserve Bank of New York, 2020e). Figure 8 depicts the **open market operations conducted by the Federal Reserve** by issuing repo and reverse repo agreements (Federal Reserve Bank of St. Louis, 2020b). At the beginning of the crisis in August 2007, the Federal Reserve initiated large repo operations to inject liquidity into the financial markets (Bech et al., 2012). The Figure 8 shows, how at the beginning of the crisis the Federal Reserve started to inject liquidity to the reserve balances by increasing the volume of the conducted repo operations. Before the crisis, the weekly repo volume was moving between 20 and 40 billion USD, but in the autumn 2007, the volume increased to close to 60 billion USD (Federal Reserve Bank of St. Louis, 2020b).

However, in March 2008, due to Bear Stearns, the Federal Reserve started aggressive repo operations to inject liquidity, and the volume skyrocketed to stay above 100 billion USD and peaking in May 2008 in 134 billion USD. Only after Lehman Brothers in September 2008, the Federal Reserve began to slowly decrease the volume of the repo operations, and in October 2008 the weekly volume had gone down to 80 billion USD, where it stayed until the end of the year. In the beginning of 2009, the Federal Reserve stopped using the direct repo operations to inject liquidity, and since then, the volume remained in zero. (Federal Reserve Bank of St. Louis, 2020b.)

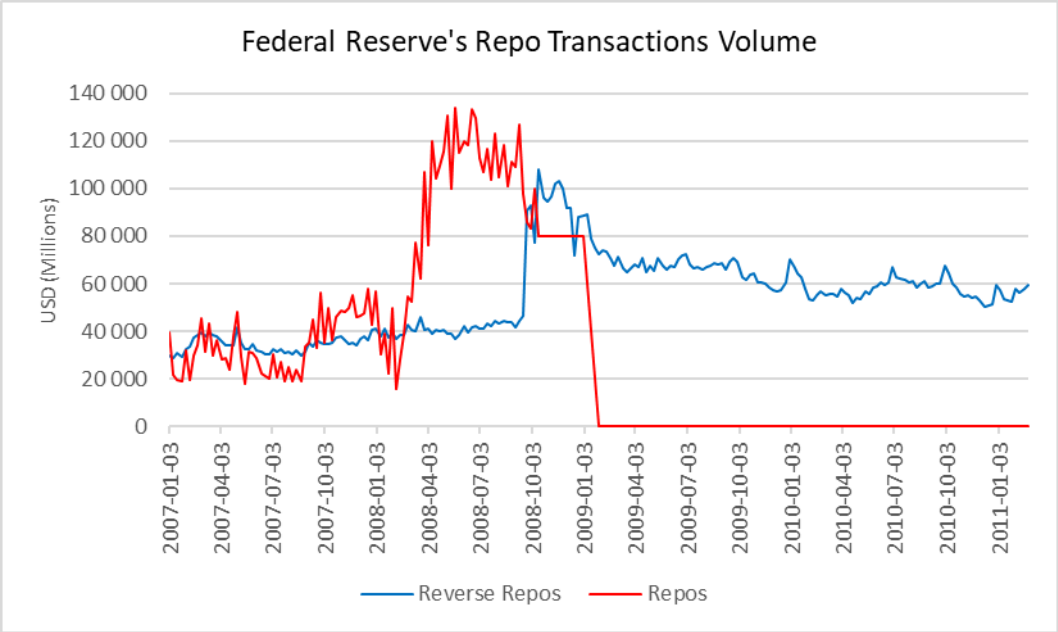


Figure 8. Weekly repo and reverse repo transactions conducted by the Federal Reserve. Wednesday level, not seasonally adjusted. Adapted from Federal Reserve Bank of St. Louis (2020b)

Figure 8 also displays the weekly reverse repo operations conducted by the Federal Reserve, to absorb reserve balances from the U.S. banking system. The figure visualizes the two reverse effects of the repo and reverse repo agreement policies, and how the Federal Reserve conducts the two different repo operations to implement two opposite objectives in the banking system. The weekly volume of reverse repos conducted by the Federal Reserve experienced only a slight increase from 28 billion USD to slightly over 40 billion USD between the beginning of 2007 until the bankruptcy of Lehman Brothers in September 2008 (Federal Reserve Bank of St. Louis, 2020b). Although the reverse repos were a normal part of the Federal Reserve market operations, increasing the transactions in advance would not have served any specific purpose as the markets were experiencing dry ups of liquidity (see e.g. Hördahl & King, 2008).

In autumn 2008 as part of monetary policy, the Federal Reserve increased reverse repos to drain reserves and to insert collateral back to the markets (Bech et al., 2012). Correspondingly, even during the same day, when the Federal Reserve started to decrease the volume of repo operations, it also dramatically increased the volume of reverse repo

operations. The volume jumped to nearly 110 billion USD, as the Federal Reserve began to absorb the liquidity, and instead reinject collateral to the markets (Federal Reserve Bank of St. Louis, 2020b). Furthermore, the Federal Reserve provided financing for the MBSs by providing 28-day term repos, where the collateral was single-tranche agency MBSs (Bech et al., 2012). In the beginning of January 2009 as the Federal Reserve stopped using the weekly repo agreements as a direct market policy to increase the reserve balances, and the repo volume dropped to zero, the reverse repo volume descended to a little over 70 billion USD. Figure 8 shows as the crisis continued, the Federal Reserve was still using reverse repos as part of their open market operations, and the weekly volume stayed heightened until the end of the crisis. The volume stayed elevated from precrisis levels moving steadily around 60 billion USD. Overall, throughout the crisis with exception of September 2008, the weekly Federal Reserve reverse repo volume was less volatile than the weekly Federal Reserve repo volume (Federal Reserve Bank of St. Louis, 2020b). In 2010 and 2011, the Federal Reserve had almost altogether ceased from issuing new reverse repo operations to alleviate the crisis, and no further aid was needed (Bech et al., 2012).

But what caused the financial distress to have such a severe impact on the repo markets, and to generate a strong negative effect to the repos and to the banks operating in the repo markets? The academic literature presents multiple fundamental and structural defects and causes for the extreme built up of financial stress in the repo markets during the financial crisis.

Gorton & Metrick (2012) emphasis, how during the financial crisis the different **interconnected risk levels** of banks increased. At the center of these were the **securitized assets and bonds used as the collateral** in the repo markets. The extensive securitization with collateralization in the banking system and in depositary institutions, as well as the use of restructured and repacked loans and bonds as insurance or collateral for repos deepened and intensified the impact and spread of the crisis throughout the whole banking system. In repo agreements, due to the nature of their deep interconnection to

the various different sectors and institutions of the banking system, even the slightest change or loss in the repo loans could have been reflected widely to many institutions and organizations. Hördahl & King (2008) sees that the risk management practices in the repo markets and the broad use of especially risky repo agreements were one of the defining features of the distress of the repo markets. Additionally, the operational risks in the repo markets were high, but the monitoring of the risks failed.

Hördahl & King (2008) see that during the crisis, the concerns about the counterparties' creditworthiness and the decreasing abilities to realize the value of the collateral in sales, shortened the accepted repo maturities and heightened the demands for high-quality collateral only. At the same time, many repo lenders offering cash pulled away from the markets, thus decreasing the quantity of available short-term funding (Hördahl & King, 2008). The remaining repo lenders started to require more collateral, while unsecured commercial paper holders refused to roll over their debt with the prevailing asset values. This further drained liquidity from the banking system (Brunnermeier, 2009). The reflection was noticeable in different asset-classes, such as in asset-backed securities, which were highly dependable on the repo markets (Gorton & Metrick 2012). For example, the use of MBSs as repo collateral subsided radically as the crisis progressed and stayed low even after the crisis (International Capital Market Association, 2020a). Even though the MBSs usually had to be AAA-rated to be accepted as collateral for repo, the contagion effect of the MBSs consisting of subprime loans and increasing default rates wreaked havoc amongst the repo markets wrecking the valuations of the securities (International Capital Market Association, 2020a).

By the end of 2008, various asset-classes in the financial markets were systematically stopped being used as collateral for the repo agreements due to the decreasing market values and high risk -levels of these assets (Gorton & Metrick, 2012). Especially the dominance of the U.S. investment banks in the repo markets was a significant factor on the severeness of the distress of the repo markets. Their business models included highly leveraged positions, which were financed with repos. When the crisis progressed and

the risk aversion and concerns in the markets increased, the investment banks found themselves short of funding, when a large part of their collateral pool was not accepted anymore on the repo markets (Hördahl & King, 2008).

Gorton & Metrick (2012) rationalize, that the problems in the subprime mortgage markets triggered a systemic crisis, and the problems escalated in the repo markets. The participants and institutions in the repo markets did not know, how widely and in what amount the subprime loans and their risks had spread to the markets. This led to **fears of the collateral liquidity** in the repo markets drying up, which in turn led to increases in the repo haircuts and massive withdrawal of funds (Gorton & Metrick, 2012). However, the increasing risks and concerns did not only affect the use of MBS securities as repo collateral. What the distress in the financial markets caused in August 2007, was that even the assets thought to be safe for the use of collateral became information sensitive, thus becoming too uncertain in price to be used as financial collateral. The assets and wealth thought to be collateralizable turned out to be uncollateralizable. This happened for example for U.S. Treasury Agency bonds, that in August 2007 were not anymore accepted as repo collateral (Gorton, 2010, pp. 145, 147).

As policy actions for the distressed repo markets and decreasing collateral values, the Federal Reserve increased the supply of government securities to be used as collateral on repos. In 2008, the Federal Reserve widened the accepted collateral and broadened the collateral schedules to address the negative exposure that the illiquid assets on the banks' balance sheets were causing. The main policy tools for these were the introduction of TSLF and PDCF (see Chapter 2.1.1) (Hördahl & King, 2008; Brave & Genay, 2011). However, these policy tools expanded the Federal Reserve's balance sheet, and overall decreased the general asset quality in the markets. Nevertheless, from April to September 2008 the financial market conditions improved through Federal Reserve's repo market operations. Also, the available collateral for repos increased. However, even though the repo markets seemed to be reviving, the lenders were still unwilling to accept nothing else than highest-quality collateral. The bankruptcy of Lehman Brothers in

September 2008 once again set back the repo markets, and the market conditions deteriorated extensively. The Federal Reserve had to respond by increasing liquidity provision and government intervention to recapitalize banks. Slowly, the repo markets started to see improving conditions and the cash lenders began to return to the markets (Hördahl & King, 2008).

Nevertheless, the problems in the repo collaterals were not the only fundamental causes for the severe stress. Like Gorton & Metrick (2012) and Ivashina & Scharfstein (2010) define, a **short-term debt market bank run** was one of the defining factors of the financial crisis and were emphasized with the **role of securitization**. These short-term debt markets included repo loans (Ivashina & Scharfstein, 2010). In securitized banking repos served as the main source of funding. Differing from the traditional bank runs, during the global financial crisis the withdrawals were focused on securitized loans, especially to the repo agreements instead of bank deposits. Thus, due the wide spread of repos in the banking system, according to Gorton & Metrick (2012) the financial crisis occurred on the collateralized loans and bonds on the securitized banking. Repos were linked through collateralization to restructured and reallocated securities, which were used overall as usual instruments for allocation and transmission of funds in the banking system. For example, investment banks Lehman Brothers, and Bear Stearns, as well as Merrill Lynch used securitization as central mode of their operations. In addition, J. P. Morgan, Bank of America, and Citigroup, used securitized bonds on their operations alongside traditional banking.

The vast spread and interconnectedness occurred, when Gorton & Metrick (2012) find, that the first market wide systematic deviation in the typical repo markets activity signaling the crisis happened in September 2007, when the fears of the banks insolvencies as well as insolvencies of the collaterals of the repo loans caused the first **“run on repo”**. This meant, that the lenders refused to give short term debt with the comparable prevailing historic lower repo haircuts and rates. Similar effects have been reported by Brunnermeier (2009), who describes, that the commercial paper holders were increasingly

unwilling to roll over their short-term papers. Like Hördahl & King (2008), also Gorton & Metrick (2012) emphasize, that especially vulnerable during the crisis were the investment and dealer banks, who had repo financing in an important part of their operations and financing. Equally, commercial banks began to lose their trust on borrowing from the repo markets and became increasingly cautious (Gorton & Metrick, 2012).

As the concerns about the liquidity of the securities used as collaterals in repos started to ascend in the financial markets, the **repo haircuts began to increase** as a result to the heightening risks in the markets. The increasing risks and haircuts in the repo markets forced banks to hold higher fractions of funds in reserves for repo loans in their balance sheets. Due to the increasing repo haircuts the withdrawal of funds in the repo markets increased in proportion to the growing haircuts, which exacerbated the growing insolvency and deficit of funding in the financial markets (Gorton & Metrick, 2012). The shortage of short-term funding forced the banks to search also other alternative ways for liquidity (see e.g. Chapter 3.5.1). Even though Figure 7 does depict a collapse in the primary dealer repo volume during the crisis, the volume still stayed high due to the pressing need for short-term bank liquidity (Baglioni, 2012; Federal Reserve Bank of New York, 2020a). Overall, the growing risks and increasing demand of repo financing and accelerated sell of the collaterals decreased the market values of the securities used as collaterals in the repo markets (Gorton & Metrick, 2012). The dropping asset prices, and increased selling further affected the margins and caused repo haircuts to rise even more. This consequently decreased even further the asset prices in the financial markets (Brunnermeier, 2009. A **destructive self-sustaining cycle** of increasing repo haircuts, decreasing asset prices and accelerated selling had formed (Brunnermeier, 2009; Gorton & Metrick, 2012). Step by step, the decreasing market values and increasing haircuts drew the crisis struck U.S. banking system into insolvency (Gorton & Metrick, 2012).

Furthermore, when the repo haircuts rose, the money multiplier effect of **rehypothecation became negative** and caused destructive deleveraging process on the financial markets (Gorton & Metrick, 2012). After the bankruptcy of Lehman Brothers in September

2008, the rehypothecated assets were assessed. What occurred, was that for Lehman Brothers, and likely as for many other banks, the operational procedures to manage re-hypothecated assets were inadequate. It became clear, that some banks and their clients did not fully understand the nature of rehypothecation. These difficulties also manifested in serious delays on retrieving the existing rehypothecated collateral (International Capital Market Association, 2020b). Eventually, the loss of rehypothecated assets caused an outflow of similar assets on other sectors and firms, culminating into a freeze of assets and aggravation of financial funding stress (Senior Supervisors Group, 2009).

As a consequence of all the stress in the repo markets, the banks were enforced to maintain bigger fractions of the value of the repo agreements in their cash reserves, which inhibited and decreased as a whole the value of the securities from being fully reinstated to the monetary circulation (Gorton & Metrick, 2012). While Gorton & Metrick (2012) call this kind of occurrence as a "run on repo", the process can be also described as a **deleveraging forced by the markets**. The effect was the rational outcome of the negative multiplier effect of repo rehypothecation, which led to several bankruptcies and forced bailouts. The perfect examples of this were Lehman Brothers and Bear Stearns (Adrian et al., 2013).

3.5 Federal funds loans

The U.S. Federal Reserve System is decentralized into 12 geographical districts, each operating independently through the incorporated Federal Reserve Bank, but under the supervision of the Federal Reserve Board of Governors and conducting mutual policies by Federal Open Market Committee (FOMC). The banks and depositary institutions can borrow and lend from the Federal Reserve System through their **district Federal Reserve Bank**. Based on their accounts' total balances, depositary institutions are required to keep certain amount of cash in hand or in an account at the Federal Reserve Bank, thus meeting the reserve requirements set by the Federal Reserve. The Federal Reserve Bank

account balances exceeding the reserve requirements can be lend forward in the financial markets to other depositary institutions. These markets are called the federal funds markets. (Board of Governors of the Federal Reserve System, 2017.)

The federal funds -markets are bilateral interbank OTC -markets, where the banks lend and borrow to each other (Afonso et al. 2011; Ashcraft et al., 2011). The loans are domestic uncollateralized loans of reserve balances of the Federal Reserve banks (Afonso et al. 2011; Federal Reserve Bank of New York, 2020b). The depositary institutions hold their federal fund loans in their district Federal Reserve Bank in the balances meant for the federal fund loans (Board of Governors of the Federal Reserve System, 2017; Federal Reserve Bank of New York, 2020b). The primary purposes for the banks to use the federal funds market on daily basis are to clear financial transactions, to meet reserve requirements and to avoid having an overdraft account. In short, the federal funds market works as markets for short-term funding, especially for overnight funding (Afonso et al., 2011; Ashcraft et al., 2011). In addition to their primary purposes, the federal funds market operates as a channel of implementing the monetary policy. The Federal Reserve can increase liquidity in the financial markets by buying government bonds and thus decreasing the rate of the federal funds by giving the banks excess liquidity for trade. Likewise, the Federal Reserve can decrease liquidity by selling government bonds and thus increasing the federal funds rate, causing the banks to have less liquidity to trade with each other (Federal Reserve Bank of St. Louis, 2020e).

Majority of the federal fund loans have an overnight maturity, but it can be also set longer. Most of the overnight federal fund loans are traded verbally without a written contract, and the loan terms are negotiated directly with each other, or indirectly by using a federal funds broker. This way the transaction costs can be reduced, and the lending and transaction is precipitated in the markets, where time is scarce. The verbal agreements rely heavily on the relationships and the common trust of the participants, and often the credit lines are only informally marked between the borrowing and lending institutions. The federal funds are considered as deposits, and they are accounted

likewise. But on the contrary to traditional dank deposits, the federal funds are exempted from reserve requirements. Thus, the federal funds are considered as short-term liquidity. In addition to federal funds loans, banks can have a quick access to short-term liquidity through repo loans or Federal Reserve discount window. (Afonso et al., 2011.)

The federal fund transactions are traded in U.S. dollars. The borrowers are depositary facilities and banks, and the lenders are depositary facilities or other entities, primarily government-sponsored enterprises such as federal agencies or government securities dealers (Afonso et al., 2011; Federal Reserve Bank of New York, 2020b). The federal fund rate is determined, when the depositary institutions trade federal funds with each other overnight (Federal Reserve Bank of St. Louis, 2020e). The importance of the federal funds can be seen from the rate. The federal fund rate indirectly affects long-term interest rates including mortgage, loan, and savings rates, thus acting as a somewhat anchor and benchmark for the short-term funding markets (Bech et al., 2012; Federal Reserve Bank of St. Louis, 2020e).

Cecchetti (2009) specifies, that banks have **three interrelated reasons to hold reserves** at the Federal Reserve banks. First, the banks are required to do so through the reserve requirements set by the Federeal Reserve (Cecchetti, 2009; Board of Governors of the Federal Reserve System, 2020b). Secondly, the banks need the reserves to operate in the banking sector, and to make payments to other banks. Additionally, the banks need funds to enable the public to make withdrawals. Lastly, the Federal Reserve funds act as the banks' precautionary reserves in the case of a financial distress (Cecchetti 2009). If needed, the Federal Reserve banks can take actions based on the ongoing daily loans, and with a short notice require additional collateral or account monitoring in real time (Fedwire Funds Service, 2020).

The federal funds transactions are mainly transferred and operated through **Fedwire**. Fedwire is a large value transfer system, meant for real-time gross settlement payments. It is operated by the Federal Reserve (Furfine, 2001; Ashcraft et al., 2011). The bank or

depositary institutions can use Fedwire to access their district Federal Reserve account. As a Fedwire -customer, the institutions and banks can transfer their federal funds from their Federal Reserve accounts to other banks' accounts, and mutually receive payments from other banks' Federal Reserve accounts (Ashcraft et al., 2011; Fedwire Funds Service, 2020). Small federal fund transactions can be executed without Fedwire as book transfers (Furfine, 2001). The small federal fund transactions, as well as small banks who do not have an account at the district Federal Reserve Bank, can use account at a mutual correspondent bank to execute the transactions (Furfine, 1999; Afonso et al., 2011).

Fedwire is open from 9:00 p.m. until 6:30 p.m. the following day, thus being open almost 24 hours per day (Fedwire Funds Service, 2020). When large volumes of federal fund transactions are transferred through Fedwire, it will accumulate **payment shocks** to the banks operating through Fedwire. During the morning hours, most of the federal fund payments and big payment shocks are not realized, but the majority of the payment and liquidity shocks happen in the afternoon. Ashcraft et al. (2011) define, that typically the daily payment shocks realize through Ferdwire between 3 p.m. and 5 p.m. At the end of the day few payments and shocks can still be realized. The large banks are active through Fedwire in the last 90 minutes on the federal funds markets, reallocating funds by borrowing and lending their federal funds as needed. At 6:30 p.m. Fedwire and with that the vast majority of the federal funds markets are closed.

In the case of the bank accounts still being overdraft after the federal funds markets have closed, the banks and depositary institutions can borrow from the **Federal Reserve discount window**, which serves as another option for overnight and short-term funding (Afonso et al., 2011; Ashcraft et al., 2011). Therefore, discount window borrowing is considered to act as a close approximation of the latent and unmet demand of federal fund loans (Afonso et al., 2011). Discount window borrowing has a similar effect as open market operation tool to contract and expand the volume of funds circulating in the banking system (Cecchetti, 2009). Borrowing from the discount window is collateralized, but the banks and depositary institutions can borrow against collateral, that would not be

allowed or funded otherwise in the financial markets. Essentially, the Federal Reserve allows practically anything to be accepted as discount window collateral, but the lending rate is set higher than the federal funds rate. (Cecchetti, 2009). Although the discount window borrowing is an option for the banks to meet their liquidity requirements, borrowing from the discount window is historically meshed with negative stigma. This means, that the banks fear that borrowing from the discount window is a signal of the borrower's lack of creditworthiness and solvency (Afonso et al., 2011; Brunnermeier, 2009). Usually the banks borrow from the discount window only, if they have liquidity needs that are severely unmet. (Afonso et al., 2011). Consequently, discount window borrowing is widely associated as a lender-of-last-resort (Cecchetti, 2009).

3.5.1 Federal funds and the financial crisis

Banks can lend to each other through the **interbank markets**, where banks with surpluses can lend to banks with deficits. During the financial crisis the dependency between the financial institutions and banks caused strains to the depositary institutions and to the whole financial markets, when suddenly banks could not anymore finance their operations with the funds gained from the interbank markets. In addition, the shortage of liquidity in the financial and interbank markets increased interest rates (Mishkin, Matthews & Giuliodori, 2013, pp. 29, 148). The decline in the U.S. productivity growth and the drop in the housing prices worsened the situation of the credit contraction. This heightened the financial distress that prevented banks from efficiently operating on the U.S. credit markets (Reinhart & Rogoff, 2008). Afonso et al. (2011) find that the increase in counterparty risk highly affected the banks during the crisis and weakened several banks' ability to access the federal funds market. This also increased further constraints for banks trying to access the markets.

Because federal fund transactions happen in the OTC-markets, there are no centralized supervision or collection of the aggregate data of the volume of the daily federal funds.

In addition, small minority of the loans are made through book transfers, thus making it virtually impossible to trace each transaction (Furfine, 1999; Afonso et al., 2011). Overall, there are no open databases containing the historical aggregate volume of the federal funds, that would extend all the way through the precrisis years. However, because vast majority of the federal funds are overnight funds and transferred through Fedwire, an estimation of the funds can be calculated. In academic literature, commonly used method for **federal fund volume estimation is an algorithm first developed by Furfine** (1999)[16], and since then, it has been widely used in federal fund volume estimation[17]. Since online there are no historical centralized databases of the aggregate federal fund loans, the theoretical part of this study utilizes the estimations of previous academic studies.[18]

Compared to the repo markets, the federal funds markets are generally much smaller in volume. This does not however make them any less important (Bech et al., 2012). Figure 9 visualizes the generalized movements and levels of the federal funds volume. Before the financial crisis, the aggregate volume of overnight federal funds lending typically moved between 300 and 400 billion USD (Ashcraft et al., 2011). When the crisis began in August 2007, the Federal Reserve started through open market operations inject liquidity into the federal funds market (Bech et al., 2012). In August 2007, the volume increased to 450 billion USD. From there it continued to rise until early 2008, when it reached 550 billion USD. When Bear Stearns collapsed in March 2008, the aggregate volume of overnight federal fund lending decreased, but never collapsed to the precrisis level of early autumn of 2007. Instead, it kept the heightened levels staying between 450 and 500 billion USD all the way until the end of September 2008 (Ashcraft et al., 2011).

[16] A specific review of the algorithm has been excluded in this study. For more information about the method, see Furfine (1999).
[17] Various academic studies use either the Furfine (1999) algorithm, or slightly modified ones based on the original. See e.g. Demiralp, Preslopsky & Whitesell (2006), Bartolini, Hilton & McAndrews (2010), Afonso, Kovner & Schoar (2011), Ashcraft, McAndrews & Skeie (2011) and Bech, Klee & Stebunovs (2012).
[18] For the empirical part, bank specific datapoints from Thomson Reuters Worldscope -database are used.

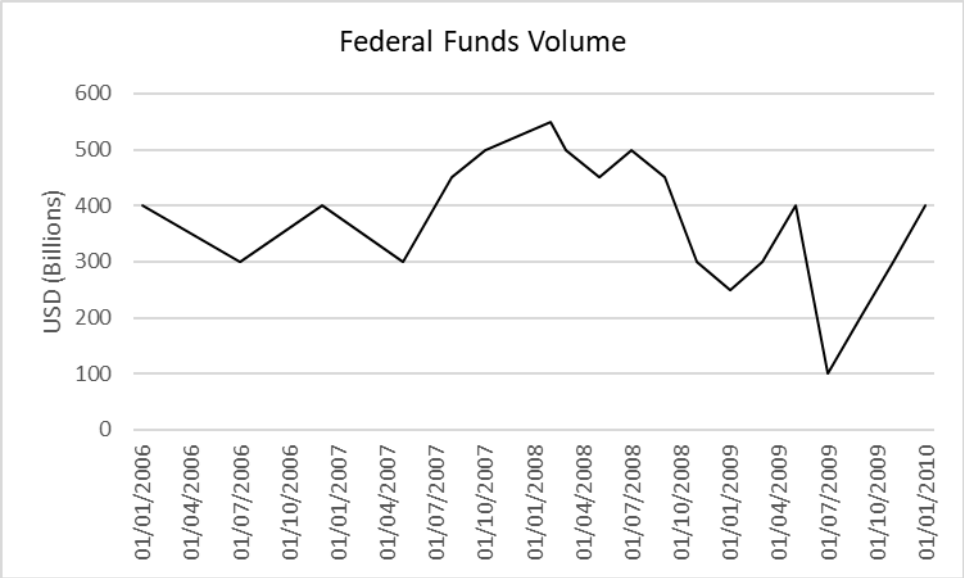


Figure 9. Federal funds Fedwire volume. A visual illustration of the approximate federal funds volume development before and during the financial crisis. The figure is not an absolute presentation of the values, and is only meant to serve as a generalized example of the levels of the federal funds movements. In addition, the figure does not represent the volatility of the federal funds, but rather depicts the general limits and levels the volume of the funds was following. The figure is constructed to depict and visualize the written description of the federal funds development from the paragraph above. The data points are also based on the written description, which are collected from the calculated estimations of the academic studies by Ashcraft et al. (2011) and Bech et al. (2012).

However, Afonso et al. (2011) emphasize, that even though the federal funds markets were not profoundly disturbed by Bear Stearns in spring 2008, there were disruptions in the markets in the autumn of 2008. These occured and were highly affected by the bankruptcy of Lehman Brothers in September 2008. The borrowing of federal fund loans did not increase in the interbank markets for the banks, who had the heightened needs for the federal funds. On the contrary, its stayed approximately the same as for the banks, who had no constraints or only reduced access to acquire overnight liquidity. Thus, the federal funds markets did not expand to respond to the grown demand. Hördahl & King (2008) even go so far as to remark, that the bankruptcy of Lehman Brothers caused the unsecured interbank lending markets to shut down. Overall, the increased bank constraints on federal fund borrowing and heightened risk volatility, increased the unexpected payment shocks during the crisis (Ashcraft et al., 2011). Ashcraft et al. (2011)

define, that mean level of unexpected federal funds payment shocks through Fedwire was approximately 125 billion USD from August 2007 to the end of October 2008.

In autumn 2008 after the bankruptcy of Lehman Brothers, the federal funds markets started slowly to show signs of amelioration, and the Federal Reserve started to drain liquidity from the markets. As the crisis furthered on, the market volume decreased, but still stayed heightened. However, the volatility of the volume increased. The market volume moved between 200-400 billion USD from 2009 until the late 2010, with occasional drops to as low as 100 billion USD (Bech et al., 2012). These developments are depicted in Figure 9. However, due to being only a visualization to help outline the values of federal funds volume into a continuous timeline, the increased volatility is not fully depicted in the Figure 9 presentation.

When compared to the total commercial bank assets, Bech et al. (2012) have estimated the development of the federal funds -ratio during the financial crisis. The ratio of federal funds to total assets for commercial banks during the precrisis years was starting from 3% and steadily decreased to approximately 1.7%. When the crisis started in 2007, the ratio began to increase, but surprisingly increased only to approximately 2.6% never reaching the original precrisis level of 3%. In 2008, when the volume of the federal funds started to decrease in the markets, similarly the ratio of federal funds to assets for commercial banks had a dramatic drop. In the beginning of 2010, the ratio was only barely hovering above 0.5%.

Ashcraft et al. (2011) explain the increase in federal funds volume in the early months of the crisis by the growth of excess reserves, heightened constraints on borrowing and increased liquidity risks of unexpected payment shocks. The banks with heightened constraints were increasing their daytime borrowing and holding **precautionary reserves** to be prepared in case of potential payment shocks. At the end of the day, the banks could lend forward the federal fund reserves, if there had not been payment shocks during the daytime. Mutually, the banks who had more extensive daytime federal funds

borrowing abilities or did not have heightened risks for payment shocks, were able to increase their daily borrowing volumes, and thus accomodate to the increased lending needs from the sellers. Bech et al. (2012) find, that the increasing precautionary reserves held by the depositary institutions were beneficial for the financial markets. If the reserves had been lowered to cover only the required operational balances, the federal funds rate would have risen dramatically, and thus affected negatively to the borrowing of the federal funds.

In addition to unexpected payment shocks, the increase of the federal funds lending volume can also be explained with **increased volatility of liquidity risks** and shocks. An example of this was the heightened problems with rolling over outstanding securities, especially asset-backed securities. The problems with rolling over debt increased the sudden liquidity and payment shocks. This drove banks to resort to other forms of short term funding (Baglioni, 2012). For example, the demand for federal funds was affected due to the problems in the repo markets (see Chapter 3.4.1). When the repos became scarcer, the demand for overnight borrowing through federal funds markets increased. Likewise, the federal fund lenders decreased their supplies when the repo markets started to dry up (Afonso et al., 2011). By self-insuring themselves with federal funds, banks were able to shelter themselves better against payment and liquidity shocks (Ashcraft et al., 2011; Baglioni, 2012).

This caused the banking system to have a **”flight to overnight”**, when the demand for short-term, especially overnight funding accelerated during the crisis. However, the increased demand of short term funds in the U.S. financial market and in the federal funds markets, exacerbated the already existing roll-over risks (Baglioni, 2012). On the contrary to Ashcraft et al. (2011) as well as Baglioni’s (2012) findings, Afonso et al. (2011) do not find evidence of liquidity hording, especially for riskier banks during the financial crisis, neither do they find significant correlation between excessive liquidity hoarding and the bank constraints. Instead, they emphasis the fears over the uncertainties of the future as the explaining factor for the difficulties many banks encountered when trying

to access the federal funds markets. This was presented as an increase in counterparty risks.

Nevertheless, the number of banks, that were daily borrowing federal funds remained quite stable throughout the crisis. From the beginning of 2007, the number moved between 150 and 200 participating banks. Only after the fall of Lehman Brothers the number started to decrease slightly, and by the autumn of 2009, there were approximately 100 banks participating daily to the federal funds markets. However, the number of lenders experienced much sharper fall. From the beginning of 2007 there were more banks, that were lending than borrowing federal funds, the daily number fluctuating between 250 and 350 banks. In March 2008 after Bear Stearns, the number slightly decreased to fluctuate around 250 and 300 banks. However, in September 2008 after the bankruptcy of Lehman Brothers, the daily participants fell sharply. In the beginning of 2009, there were only between 100-115 banks, that were lending federal funds, and the number remained the same all the way until the end of 2009. The markets had approximately the same number of borrowers and lenders but experienced a lack of overnight funding for the unmet demand. (Afonso et al., 2010.)

Afonso et al. (2011) find that smaller banks were less frequent federal funds borrowers. However, after the failure of Lehman Brothers, the smaller banks seemed less affected on their federal fund borrowing, while larger banks accessed the federal funds market less than before. Having difficulties in accessing the federal funds markets and the least willing ones to do so, were the banks, who had high levels of NPLs and worst performance. This did not affect the lenders though, and the lending of federal fund loans was much less affected than borrowing. On the contrary to other academic literature, Afonso et al. (2011) find, that this happened, because **banks were sheltering against counterparty risk** exposure and there was noticeable general rationing in the financial markets. Contrasting the views of liquidity dry ups (see e.g. Brunnermeier, 2009) Afonso et al. (2011) see, that instead the financial markets suffering a complete freeze, the federal funds markets were deliberately reducing exposure to poorly performing banks and

putting higher price for potential credit risks. Therefore, lenders of federal funds were able to screen out the poorly performing banks amongst the mass of borrowers.

The banks, who failed to have access to the federal funds markets were left to have **discount window borrowing** as the only option for short-term liquidity. Afonso et al. (2011) find a connection between bank profitability, specifically with ROA and discount window borrowing. According to their study, during the financial crisis discount window was used only by banks, who had poor performance and low rates of ROA. This continued even after the collapse of Lehman Brothers. The same correlation with distressed lending was seen with banks holding a substantial amount of NPLs. Afonso et al. (2011) emphasize, that the stress and disturbances in the financial markets were not even in autumn of 2008 that significant, that would have made the stable and solvent banks to turn to discount window borrowing to satisfy their liquidity needs.

Figure 10 depicts the **volume of loans through discount window** to domestic U.S. banks. Until the beginning of the financial crisis, due to the negative stigma, banks were avoiding discount window borrowing, and the volume of discount window borrowing was low before and even after the beginning of the crisis. The aggregate daily volume was merely around 200 million USD. The borrowing banks were generally associated with poor performance, solvency and ability to access short-term debt and liquidity markets. Even though the Federal Reserve emphasized, that discount window borrowing should belong to a normal part of banking business, the deeply seated historical practices and presumptions ensured, that the stigma never completely faded away. As the crisis started in autumn of 2007, the volume increased and rose steadily until the third quarter of 2008, when it reached 200 billion USD. However, despite the crisis, the majority of banks were still hesitant to borrow from discount window, thus preventing the daily volume from jumping and instead keeping the growth steadily moderate (Cecchetti, 2009; Federal Reserve Bank of St. Louis, 2020a).

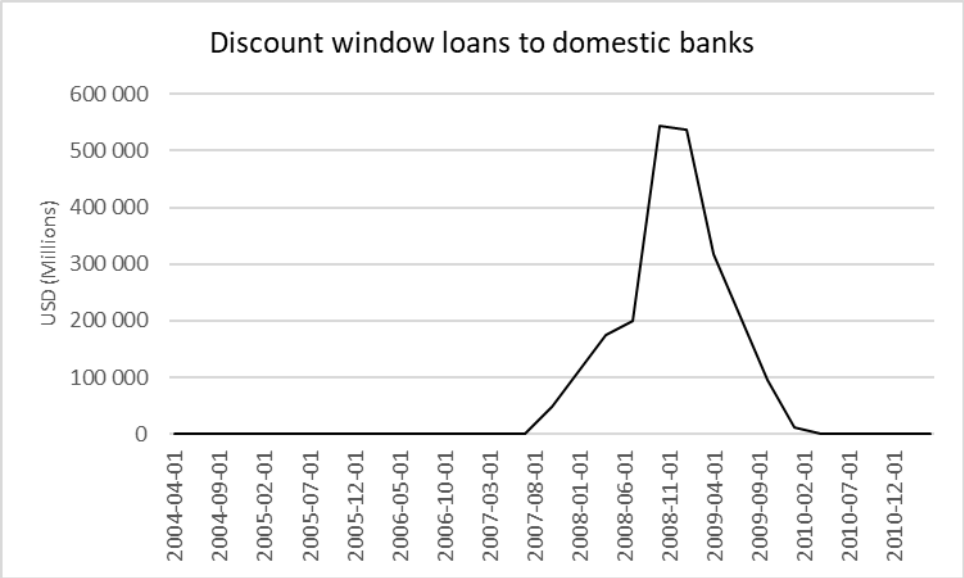


Figure 10. Volume of loans to domestic banks through the discount window. Quarterly, not seasonally adjusted. Asset volume. Adapted from: Federal Reserve Bank of St. Louis (2020a)

The Federal Reserve acted from early on to the downturn of equity prices and started to stimulate the markets (Reinhart & Rogoff, 2008). Due to the severe distress in the financial markets, the Federal Reserve wanted to expand the discount window borrowing. On August 17, 2007, the Federal Reserve answered to the decreasing short-term and funding liquidity by broadening the variety of collateral for discount window borrowing and increased the lending period to 30 days (Brunnermeier, 2009). Furthermore, by lowering the discount interest rates, the borrowing from the discount window became cheaper, and the banks were more willing to borrow the funds, thus expanding the aggregate volume of the discount window loans (Ashcraft et al., 2011). From July 2008, the volume skyrocketed, and by November it had peaked to 544 billion USD (Figure 10) (Federal Reserve Bank of St. Louis, 2020a). The massive boom was the effect of the market operations. The expansion worked. (Ashcraft et al., 2011). The concerns on the federal funds markets started to alleviate. Furthermore, lending and borrowing quickly ameliorated, when on September 16, 2008 the loan for AIG was announced (Afonso et al., 2011). In the beginning of 2009, the discount window borrowing started to steadily decrease, reaching the precrisis levels during the spring of 2010 (Federal Reserve Bank of St. Louis, 2020a).

4 Data and Method

This chapter depicts the data and methods used to conduct the empirical analysis.

4.1 Data

The analysis focuses using microeconomic bank-level -data. The data is **annual banking panel data** including 656 U.S. banks from 2004 to 2008. The data is collected from Thomson Reuters Worldscope -database. Due to license restrictions the available data had some limitations on the selection of variables, thus partly limiting the collectable and usable data for empirical analysis. In addition, the data was only annually available to some variables, which limited the empirical analysis to annual basis instead of e.g. quarterly or monthly analysis.

The data includes banks (commercial, savings, cooperative banks), other depositary institutions, and some holding companies and financial institutions (from now on, the comprehensive data is just addressed as “banks”). All the banks, whose data on majority was unusable (e.g. not announced, missing or errored datapoints) were by default omitted. In addition, banks whose data was not complete enough to perform an unbiased regression or had missing key variables were omitted.

The data consists both small-medium and large banks. However, it is important to note when studying the empirical results, that majority of the small banks were omitted from the original data due to inadequate or missing datapoints. Even though the final data still includes some small banks, majority of the sample banks are large banks. Therefore, the results should be viewed to appertain mainly large banks, and caution should be exercised when reflecting the results to small banks.

The data is announced in USD. Datapoints announced in other currencies were a very small minority, all representing U.S. -branches of non-U.S. banks without a throughout consistency in the announced currencies. Therefore, it would not have brought any additional value on modifying and adding these sample points to the regression and were instead omitted.

All the omissions and exclusions of data from the regression analysis were done prior analysis, to avoid any pre-analysis influencing or wittingly modifying the empirical results. In addition, to avoid "data-mining", the variables used in the empirical analysis were defined prior to analysis, and hence many potentially usable and significant variables were left out from the empirical models.

The empirical analysis was done by using Stata. **Table 1 lists and depicts all the variables used in the empirical analysis.** Return on equity is used as the dependent variable (connoted in Stata as ROE). In addition to the dependent variable, the analysis is constructed from three independent variables and seven control variables. Federal funds ($fedfunds$), MBS securities (mbs) and repos ($repos$) are used as independent variables. The three independent variables are depicted in volumes. The following variables are used as the control variables: Tier 1 ($tier1$), total deposits ($deposits$), total capital ($capital$), bank size ($banksize$), loans to assets -ratio ($loansassets$), NPL -ratio (npl) and treasury securities ($treasury$). Equally to independent variables, the control variables have been constructed by using volumes. The NPL -ratio and treasury securities were added as control variables due to their daily importance and comprehensive effects and impacts on the whole U.S. banking system. The rest of the control variables were chosen based on previous academic literature on similar studies.[19]

[19] See. e.g. Tregenna (2009), Aebi, Sabato & Schmid (2012), de Bandt, Camara, Pessarossi, & Rose (2014) and Moussu & Petit-Romec (2018).

Table 1. List and depiction of variables.

Variable	Variable Type	Depicted as	Ratio used in empirical analysis
ROE	dependent	Ratio (of volumes)	Net Income/ Total equity
Federal Funds	independent	Volumes	Federal Funds/ Total Assets
MBS securities	independent	Volumes	MBS securities/ Total Assets
Repos	independent	Volumes	Repo agreements/ Total Liabilities
Tier 1	control	Volumes	Tier 1/ Risk Weighted Assets
Total Deposits	control	Volumes	Total Deposits/ Total Assets
Total Capital	control	Volumes	Total Capital/ Total Assets
Bank size	control	Logarithm (of volumes)	ln (Total Assets)
Loans to assets -ratio	control	Ratio (of volumes)	Total Loans/ Total Assets
NPL -ratio	control	Ratio (of volumes)	NPL -loans/ Total Loans
Treasury securities	control	Volumes	Treasury securities/ Total Assets

All the (independent and control) variables have been however transformed into ratios, that are used in the empirical analysis. This is done to avoid multicollinearity[20], that results from the different bank sizes. In addition, using ratios instead of absolute values of the volumes take into consideration the interactions amongst indicators, which improves

[20] See the following chapter for further description and analysis of multicollinearity.

the predictions usability, as described by Lo Duca & Peltonen (2013). Most of the variables were divided with the volumes of total assets or total liabilities, depending on the variable (see Table 1). An estimate for bank size variable was constructed by taking natural logarithm from each banks' balance sheet volume of total assets. The same method is used by e.g. Tregenna (2009), de Bandt et al. (2014) and Moussu & Petit-Romec (2018).

For more detailed list and depiction of variables, Table 6 in Appendix 1 aggregates all the variables and shows additional comprehensive information. The table presents in more detail how the variables are computed in the Worldscope-database, and it summarizes how they have been addressed with in the empirical analysis.

4.2 Method

The method used is **multiple linear regression (MLR) model**. MLR model estimates, how various simultaneous factors affect the dependent variable in ceteris paribus. In other words, the model studies the relationships and correlation between the independent (explanatory) variables and the dependent (explained) variable (Wooldridge, 2018, pp. 20, 60, 63). The multiple linear regression model is the most widely used empirical analysis tool in economics. In addition, the regression is typically formulated using **ordinary least squares (OLS)** for parameter coefficient estimation. OLS -method generates the estimates by minimizing the sum of squared residuals (Wooldridge, 2018, pp. 61, 64). The OLS method follows Gauss-Markov Theorem, which makes the method preferable to other methods. Under the theorem, the OLS estimators for β_j are the **best linear unbiased estimators (BLUE)**. The theorem is constructed from five assumptions, that are listed in Appendix 2.[21] (Wooldridge, 2018, pp. 89, 92).

[21]More detailed information about linear regression models, see e.g. Montgomery, Peck & Vining (2012) and Wooldridge (2018).

The multiple linear regression (OLS) model is following:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + u, \quad (1)$$

where

y is the dependent (explained) variable

β_0 is the intercept

$\beta_{j,}\ j = 1, 2, \ldots, k$ are the regressor coefficients

$x_{j,}\ j = 1, 2, \ldots, k$ are the independent (explanatory) variables

u is the error term.

(Wooldridge, 2018, p. 63; Montgomery, Peck & Vining, 2012, p. 68.)

To consider the EWI aspect of the variables, the independent variables need to be modelled to predict the causality to the dependent variable of the following year. To take this inter-periodicity into account, the independent variables are changed into lagged variables by adding a **lag of t-1**. The lagged variables provide a simple way to account historical values and factors, which affect and cause differences in the current factors and dependent variables.

The lags are added to equation (1). The model becomes

$$y_t = \beta_0 + \beta_1 x_{t-1,1} + \beta_2 x_{t-1,2} + \ldots + \beta_k x_{t-1,k} + u, \quad (2)$$

where

y_t is the dependent variable at period t

$x_{t-1,j,}\ j = 1, 2, \ldots, k$ are the independent variables lagged with t-1.

(Wooldridge, 2018, p. 283; Sohn & Park, 2016.)

This way, the method will predict the correlation between the last period's independent variables and the current period's dependent variable. Similar lagged time-adjusted

regression analysis is used for example by Lo Duca & Peltonen (2013) and Sohn & Park (2016) with their studies on the early warning indicators.

The MLR OLS -model is then supplemented with additional **control variables**. These variables act as independent variables, but they are not on the focus of the EWI analysis (Wooldridge, 2018, p. 21). Instead, they are added to the model to improve the causal inference of the analyzed independent variables. By adding control variables, the regression model can be assigned to take into consideration other factors affecting the dependent variable without having to add every single variable, that has an effect to the outcome. However, control variables should not be focused on the results analysis, because the results will also reflect all the correlations, that these variables have with all the other independent and dependent variables. In other words, adding control variables will improve the overall efficiency and explaining power of the regression model by including other explaining factors, that differ from the focused independent variables. These control variables are meant to stand in and represent all the other possible explaining causes of the dependent variable. However, due to interconnectedness of all the variables, the regression model should not have too many control variables, because instead of affecting genuinely only the dependent variable, the control variables include non-causal correlation of all the other variables. Consequently, the analysis of the results should mainly focus on the independent variables instead of on the control variables (Hünermund & Louw, 2020). Because the control variables in this study do not serve as an estimate for EWIs and are included in the regression model to supplement the unanswered effects of other unincluded variables, in this empirical analysis a lag is not used in the control variables.

In addition to control variables, to factor in time-variable, a **year dummy -variable** is added. By adding a dummy-variable, the regression accounts for the fact, that the sample population may have different distributions in different time periods. A dummy -variable is a binary variable, that has a value of one if the variable is taken into consideration in the regression. If the variable is not accounted for in the regression, the dummy-

variable is zero. Usually a year dummy -variable is used in regression analysis when a time-variant is wanted to be included. The year dummy is added for all but one year, which is chosen as the base year. (Wooldridge, 2018, pp. 403, 405.)

When added the control and dummy variables, the regression model (2) becomes

$$y_t = \beta_0 + \beta_1 x_{t-1,1} + \beta_2 x_{t-1,2} + \ldots + \beta_k x_{t-1,k} + \beta_{k+1} z_{t,(k+1)} + \ldots + \beta_{k+K} z_{t,(k+K)} + \delta_2 Y_2 + \ldots + \delta_i Y_i + u, \quad (3)$$

where

$k + K = n$ is the sum of the number of independent and control variables, total number of variables in the regression

$\beta_{q,} \quad q = 1, 2, \ldots, K$ are the control variable coefficients

$z_{t,q,} \quad q = 1, 2, \ldots, K$ are the control variables at period t

$\delta_l Y_{l,} \quad l = 2, 3, \ldots, i$ are the dummy variables for each year, except the base year.

When the variables, that are used in this study are placed to the regression model (3), the **empirical regression equation becomes**

$$ROE = \beta_0 + \beta_1 fedfunds(L) + \beta_2 mbs(L) + \beta_3 repos(L) + \beta_4 tier1 + \beta_5 deposits + \beta_6 capital + \beta_7 banksize + \beta_8 loansassets + \beta_9 npl + \beta_{10} treasury + \delta_{2005} year(2005) + \delta_{2006} year(2006) + \delta_{2007} year(2007) + \delta_{2008} year(2008) + u. \quad (4)$$

The time adjustment of (t-1) -lagged independent variables is denoted with (L). By adding a lag to the variables, the model can observe the early warning indicator -aspect of the three independent $fedfunds$-, mbs-, and $repos$ -variables. In addition, the need for time-adjustment through lags can be justified, because the real ROE performance improvements take time to materialize in real life. The lags take into consideration the

additional time it takes for the independent variables to impact the dependent variable ROE (de Band et al., 2014). A similarly constructed OLS -regression as model (4) is used e.g. by Moussu & Petit-Romec (2017) on predicting bank losses during financial crisis.

In addition, the clustered standard errors are used. The rationale for this is to eliminate the possibility for heteroscedasticity. If a cluster effect is not used, the usual OLS standard errors for panel data are incorrect and allow heteroscedasticity through cluster correlation. By clustering the standard errors, the regression is consistent with the Gauss-Markov assumption of variance homoscedasticity. (Wooldridge, 2018, pp. 82, 450.) The clustering is done to all the banks, in total to 656 banks.

A 95% confidence interval is used. The results of the multiple linear regression model and the discussion and analysis of the results are in Table 5 in Chapter 5.3.

For the regression results to be unbiased, it is important to know, whether the independent variables are correlated to each other. High correlation between two or more independent variables is called **multicollinearity**. Even though multicollinearity might not bias the whole regression model, it will affect the coefficients of the independent variables, and thus lead to serious effects on the least-square estimates (Wooldridge, 2018, p. 84; Montgomery et al., 2012, p. 288). Often, as result of existing multicollinearity, the regression coefficients will have large variances and covariances, and the variable estimates tend to be too large. This leads to incorrect results and inadequate estimates of the individual model parameters (Montgomery et al., 2012, pp. 289-290).

To detect multicollinearity, **variance inflation factor (VIF)** is used. VIF is computed as

$$VIF_n = (1 - R_n^2)^{-1}, \tag{5}$$

where

n is the number of regressor variables

R_n^2 is the R^2 for regressor n on all variables variables.

VIF measures the combined effect of the dependences among the regressor variables to each independent- and control variables. The more the variance is explained by others, the higher the VIF is. Large VIF -values indicate multicollinearity. Typically, the limit is set at 10, sometimes even at 5. A value of VIF=10 indicates, that $R_n^2 = 90\%$ (de Bandt et al., 2014; Montgomery et al., 2012, p. 296). The VIF values exceeding the limit will indicate, that the regression coefficients are poorly estimated, and multicollinearity is a problem for estimation of β_n (Montgomery et al., 2012, p. 296; Wooldridge, 2018, p.86). Table 2 presents the VIF values for each regressor variables.

Table 2. The VIF values for each variable. (L) -depicts the (t-1) -lag. The VIF -values show that multicollinearity is not considered a problem for the regression model and variable estimation.

Variable	VIF	1/VIF
Federal Funds (L)	1.15	0.8666
MBS (L)	2.00	0.5009
Repos (L)	1.46	0.6830
Tier 1	1.59	0.6300
Deposits/Assets	4.00	0.2500
Capital/Assets	3.44	0.2906
Bank size	1.42	0.7049
Loans/Assets	2.19	0.4557
NPL	1.18	0.8508
Treasury securities	1.17	0.8583
year		
2005	1.64	0.6090
2006	1.65	0.6043
2007	1.68	0.5945
2008	1.81	0.5530
Mean VIF	1.88	

From Table 2 it can be seen, that all the VIF values are low, under 10, with the highest VIF value for $deposits$ being only 4.00. Thus, it can be concluded, that the variables are well estimated, and the regression model does not pose bias or problems because of multicollinearity.

What the MLR -model does not take into consideration are the included entities' (banks) individual within effects on the dependent variable. These within factors are the unique characteristics, for example the business practices of the entity, the geographical location, political systems etc. If the correlation is strong, this unobserved effect can impact or bias the independent and dependent variables. To control this, a **fixed-effects (FE) regression model** is used. (Wooldridge, 2018, p. 435; Torres-Reyna, 2007.)

A fixed-effects model is following:

$$y_{it} = \beta_1 x_{it} + a_i + u_{it}, \quad (6)$$

where

i is entity (bank)
t is time
y_{it} is the dependent variable for each entity at each time
β_1 is the regressor coefficient
x_{it} is the independent variable for each entity at each time
a_i is the fixed effect for each entity
u_{it} is the error term.

A fixed-effects model is designed to analyze and assess the causes of change (variance) within an entity (or person). An FE -regression model analyzes the impact of the variables, that only vary over time. The correlation considers the impact withing the entities, and removes the individual within characteristics, that may or may not influence the variables used in the empirical prediction. These individual characteristics are considered as

time-invariants and unique to one entity without correlation with other individual characteristics. The effect of these characteristic is removed, so that the real net effect of the independent variables to the dependent variable can be processed. Because each entity is different, it is assumed that the error term and the constant are not correlated to the others (Torres-Reyna, 2007). This strict exogeneity assumption makes the fixed-effects model unbiased. Additionally, the model assumes that the error terms are homoscedastic and serially uncorrelated (Wooldridge, 2018, pp. 435-436).

When equation (6) is fitted to account for the lagged variables and control variables that have been used in the linear OLS regression analysis, the **FE -model becomes**

$$y_{it} = \beta_1 x_{1,(t-1)} + \beta_2 x_{2,(t-1)} + \ldots + \beta_k x_{k,(t-1)} + \beta_{k+1} z_{(k+1),t} + \ldots + \beta_{k+K} z_{(k+K),t} + \delta_2 Y_2 + \ldots + \delta_i Y_i + a_i + u_{it}, \quad (7)$$

where

$i = k + K$ are all the entities.

Equally to the previous linear OLS -regression, the variables used in this study are placed to the FE -model equation (7). However, this equation has not been written out here due to the large number of entities (656 banks). Equally to MLR -model, 95% confidence interval is used. The results of the fixed-effect regression are presented in Table 5 in Chapter 5.3. In academic literature a similar FE -model is used by e.g. de Bandt et al. (2014) on predicting future ROE -values with banks' capital measures.

The use of FE -model however raises one question: how we can be sure, that the effects for these specific entities are fixed and correlated within the explanatory variable. What if the effects were instead random and not fixed, and would be uncorrelated to all independent variables? The answer for this is to use random-effects (RE) model. On the contrary to FE -model, RE -model allows for time-invariant variables to act as explanatory variables through the effects they have across the entities to the dependent variable

(Wooldridge, 2018, p. 441; Torres-Reyna, 2007). However, while FE -model allows arbitrary correlation between the effects and the independent variables, RE -model does not. Because of this, FE -model is generally for most cases thought to be a better tool to estimate effects in ceteris paribus. In addition, FE -model is more suitable and convincing for policy analysis, that uses aggregate data (Wooldridge, 2018, pp. 444-445).

To test, whether a fixed- or random-effects model is needed, **Hausman test** is done. Hausman test assesses whether there is a significant difference in the independent time-varying coefficients of both FE- and RE -model. The rationale behind Hausman test is to analyze, whether the individual characteristics are truly exogenous, or whether there is correlation across the unique error terms. The null hypothesis is that they are not. The idea is to use RE -model unless the test rejects, meaning that the assumption of the unique error terms is wrong, and FE -model is used instead. Typically, a significance level is set at 5%. (Wooldridge, 2018, p. 444; Torres-Reyna, 2007.)

The comprehensive results of the applied Hausman test are seen in Table 7 in Appendix 3. The results show that the probability for chi squared is zero, thus making the results highly significant with the highest possible significance level. The null hypothesis is rejected with p=0.001, making the FE -model the correct model to be used with the studied entities and sample.

Additional test to analyze whether time-fixed effects are needed at all is executed after running the FE -model regression. This is done through a joint test to define if the dummies for all the years are zero. In case they are, no time-fixed effects are needed. The null hypothesis is that all the dummies are zero. A significance level of 5% is typically used. (Torres-Reyna, 2007.)

The results are depicted in Table 3. The probability for the regression to have all zero dummies, is zero. Thus, as well this time, the results are highly significant with the

highest significance level of p=0.001, and the null hypothesis is rejected. The time fixed effects are needed, making the use of the FE -model overall rational and applicable.

Table 3. A test to define whether all $\delta_i Y_i = 0$. The results show p=0.001 for F-statistic. Thus, the time fixed effects are needed, and the FE-model is used.

(1)	2005.year = 0
(2)	2006.year = 0
(3)	2007.year = 0
(4)	2008.year = 0
F(4, 2060)	= 49.54
Prob > F	= 0.0000

5 Empirical results

The following chapters discuss the results of the empirical analysis. First, a discussion of the expected results is provided. This is followed by the discussion of the summary statistics. Lastly, the obtained comprehensive results of the empirical analysis and discussion of the regression analyses are provided.

5.1 Expected results

Before reviewing the obtained empirical results, **an assessment of the expected results is provided.** These expectations are based on the previously discussed academic literature, and what is known of the structures and designs of the variables as well as how the variables perform in the financial markets. Naturally, the expectations are provided for three independent variables: volume of MBSs, repos and federal funds.

When the causes and warning signals of the global financial crisis are thought, typically one of the first things that come to mind are the subprime loans. As discussed in Chapter 3.2.1, the sharp mortgage asset price depreciation caused the vast losses and delinquencies to spread all over the financial markets. In general, the subprime mortgage market crisis has been widely seen as one of the fundamental sources for the start of the financial crisis. (See e.g. Reinhart & Rogoff, 2008; Brunnermeier, 2009; Lo Duca & Peltonen, 2013.) Because MBSs depend extremely heavily on the underlying subprime mortgages, and the structure and value creation -process of securitization through tranches equally depend on the structure and values of the subprime loans (see Chapters 3.2 and 3.3), a direct connection between the MBSs and subprime mortgages is easily to be noticed. In addition, as discussed previously, the opaque structure of MBSs and their vast interconnected distribution in the financial markets, can be seen to affect even further the condition of the whole banking system. (See e.g. Ivashina & Scharfstein, 2010, and Baglioni, 2012.) As Figure 6 shows, the volume of MBSs during the precrisis years increased. Thus,

it can be expected, that the increase in the MBSs will increase the risks and worsen over time the bank's performance. For MBSs, it is expected that the results will show a strong negative correlation between the volume of MBSs and ROE, and that the MBSs will show signs as being early warning indicator.

When assessed the academic literature of repo loans, the expectations are not equally straightforward as for MBSs. The structure of repo loans being collateralized, and the huge volume of the repo markets do induce some additional risks and spread the loans widely across the financial markets. In addition, the efficient use of repos in the banking sector relies on the available liquidity and collateral as well as trust on counterparties in the financial markets. As Chapters 3.4 and 3.4.1 show, these aspects can raise alarms on the use of repos, and therefore the repo agreements can be seen having an impact on the cause of financial crises. Similar views are supported by various studies in the academic literature. (See e.g. Hördahl & King, 2008; Brunnermeier, 2009; Gorton & Metrick, 2012.) Similarly, as for MBSs, the continuous increase in the repo agreement volume during the precrisis years (see Figure 7) could be expected to be an early warning indicator by having a strong negative correlation with ROE.

However, since repos are used by the Federal Reserve as normal daily open market operations, rationally, there can be expected to exist higher volatility and variation in the repo markets even during "normal" times. With this kind of perspective, it can also be rationalized, that an increase in the repo volumes might not indicate of an onset of a crisis, but rather be part of a normal stabilizing monetary policy of the Federal Reserve System. In addition, since repos are used as an open market operations equally during the crises (for the global financial crisis, see Chapter 3.4.1 and Figure 8), a sudden sharp increase/decrease could, in fact, indicate of highly distressed financial markets. However, the changes in the repo volumes would then happen too late for them to be defined as early warning indicators. In conclusion, based on the academic literature, data, and general knowledge of the structure of the repo loans, it would be almost certain to expect the volume of repos to have a strong correlation with bank performance and profitability.

However, there are conflictions on forming straightforward expectations, whether the correlation would act more as an early warning indicator or a natural part of the Federal Reserve's policy actions.

Lastly, when reviewed federal funds in Chapter 3.5, it is seen that they have similar qualities to repos as being integral short-term funds between banks but also acting as Federal Reserve's usual monetary policy tool. However, on the contrary to repos, if the discount window lending is not regarded, the Federal Reserve uses federal funds as policy tool through affecting the federal funds rate instead of directly issuing federal fund loans in the banking sector. Therefore, this would suggest, that a noticeable change in federal fund volume would not be directly linked to normal daily monetary policy operations, and thus, would more likely be a direct implication of the banks' lending and borrowing capabilities and funding needs. In addition, the academic literature in Chapter 3.5.1 and estimations on the federal funds volume (Figure 9), show that in periods of distress and increased risks and liquidity needs in the financial markets, the depositary institutions and banks rely on excessive precautionary reserves and demand for federal funds. (See e.g. Afonso et al., 2011; Ashcraft et al., 2011; Bech et al., 2012; Baglioni, 2012.) Hence, an increase in federal funds volume would signal of unusual demand for short-term liquidity and possible distress in the financial markets, that prevents banks from operating and achieving funding normally. Based on these notes, it is expected that the federal funds volume will have a significant negative correlation with ROE and could possibly act as an early warning indicator.

5.2 Summary statistics

The summary statistics for all the used variables are presented in Table 4. The observations show the number of observations for each variable in the used sample. The Year - variable has the highest number of observations, 4 728 in total. This number is the highest possible number of observations for each variable, because the missing years are not

naturally included in the empirical analysis, or the specific banks were omitted from the analysis due to too many missing year parameters, as described in the Chapter 4.1. The rest of the variables have lower observation numbers, which are explained by the missing values. Repo -variable has the least observations, in total 4 009. Federal Funds and MBSs have couple of hundred more observations. The control variables also have similar amounts, and when reviewed the observations of all the variables, it can be concluded, that the number of observations change between 4000 and little less than 4600 between the variables. However, the sample has 4 487 ROE-variable -observations, which shows, that in general, the number of independent and control variable observations are sufficient and reasonably consistent with the number of dependent variable observations to perform the regression analyses.

Table 4. Variable summary statistics. The table presents for each variable the total number of observations, mean, median, standard deviation, and the minimum and maximum values.

Variable	Observations	Mean	Median	Std.Deviation	Min	Max
ROE	4 487	7.493	9.480	14.439	-365.070	47.550
Federal Funds	4 226	0.016	0.002	0.037	0	0.978
MBS	4 455	0.092	0.068	0.095	0	0.737
Repos	4 009	0.024	0.005	0.043	0	0.686
Tier 1	4 306	13.229	11.520	6.926	1.300	179.210
Deposits/Assets	4 574	0.746	0.764	0.111	0	0.960
Capital/Assets	4 580	0.179	0.165	0.194	-8.329	0.988
Bank size	4 585	13.728	13.490	1.516	4.248	21.321
Loans/Assets	4 562	0.694	0.712	0.130	0	0.954
NPL	4 400	0.011	0.006	0.019	0	0.503
Treasury securities	4 211	0.026	0.001	0.048	0	0.515
Year	4 728	2005.5	2005.5	1.708	2003	2008

Table 4 shows, the banks have a mean ROE of 7.5% in the used sample with 2 percentage unit larger median of 9.5%. The ROE has also the highest standard deviation of all the variables. This was to be expected due to the high volatility of the banks' ROE -values. However, the large standard deviation also suggests, that the ROE -values had also highest variation between the banks and the years. This can be also seen from the minimum

and maximum ROE -values, with the maximum being almost 48% and the minimum being a devastating -365%, although based on slightly larger median value (compared to mean), there are more ROE -values on the smaller side than there are large two digit -values. These notions are consistent with the discussed academic literature of sharply decreasing ROE -values. In addition, the high volatility and variation suggest, that e.g. the views of Aebi et al. (2012) about some banks with better risk management performing better during the crisis are supported by the data.

The reviewing of the independent variables' means, and standard deviations (Table 4) shows that the variables have rather similar distributions. In addition, all three variables' medians are smaller than the means, telling that in the sample there are more banks with relatively small ratios of federal funds, MBSs and repos to the total assets (to total liabilities for repos) than there are banks with a large volumes of the assets in their balance sheets. Nevertheless, this does not mean, that there would not be at all banks with large volume of these assets in their balance sheets, which is shown with the much bigger maximum values. MBSs has slightly higher mean, median and standard deviation than federal funds and repos. However, for all the three independent variables the mean, median and standard deviation values are less than 0.1. In addition, all the three independent variables have 0 as the minimum, since naturally there cannot be a negative amount of federal funds, MBSs or repos in the banks' balance sheets.

However, the maximum values show, that there are some differences between the banks, as the maximum amount of the securities are slightly different. Even though the maximum percentage of repos per total liabilities and MBSs per total assets are rather high, 68.6% and 73.7% respectively, the maximum of federal funds per total assets is 97.8%. However, the mean percentage for federal funds is 1.6%, which is consistent with the findings of Bech et al. (2012). The low mean and even lower median value but the high maximum of federal funds suggest, that in the markets (and in the sample), there are some (fewer number of) banks, that were more desperately resorting on federal funds than other banks. (See e.g. Ashcraft et al., 2011, and Baglioni, 2012, about banks

hoarding liquidity.) Similar conclusions can be assessed of MBSs and repos. (See e.g. Brunnermeier, 2009, and Bech et al., 2012 about securitized MBS, repos, and securitized assets credit expansion.)

The bank size -variable shows, that the sample distribution has a mean of 13.79 and median of 13.49, with the minimum and maximum being respectively 4.25 and 21.32. The similar mean and median values and standard deviation show, that the sample data is constructed from relatively evenly distributed sample of different sized banks. However, as was assessed in the data description, most of the small banks were omitted from the analysis due to large number of missing or errored values. An assessment of median value with a brief review of skewness and kurtosis of bank size[22] reveals, that, the distribution of bank size has heavier tails and is slightly skewed to the right. From this it can be assessed that majority of the banks are medium sized, even though large banks are also included. However, the larger the banks get, the less banks are included. In addition, small-medium sized banks are still included in the study, but vast majority of the small banks are completely omitted. Therefore, as a conclusion, the empirical results work best for the medium and medium-large banks. Small-medium banks and large banks can still somewhat benefit from the results, but small banks and the few absolute biggest banks in the financial markets should only review the results with high caution in mind.

Table 4 shows, that the other control variables have similar statistics as the independent variables. However, the relationship between mean and median differs depending on the control variable, showing that the variable distributions of the control variables slightly differ from each other. The more noticeable exceptions are, that Tier 1 has rather high minimum values, which are not close to the zero, while capital per total assets has a negative value as a minimum. The higher values of Tier 1 with larger standard deviation can be easily understood, since the volume of Tier 1 capital for banks is always larger

[22] Bank size -variable has skewness of 0.98 and kurtosis of 5.50. However, the review is done only for bank size to have more comprehensive information of the included banks. Any further analysis or review of skewness and/or kurtosis for other variables is left out of this study.

than zero. The variation can be also understood with the different sizes and performance of banks. The negative values of capital per total assets can be checked with a quick review from the original data. The data shows, that there are only two observations (from the total of 4580 observations) included in the capital -variable, which have a negative value, the other observations have a value of 0 or more. Thus, the negative is depicted as the minimum in the summary statistics. However, these two observations have missing ROE -values, hence the two negative values are not affecting the following regressions. Therefore, the capital per total assets can be viewed to have a minimum of 0 and the statistics are thus equally similar ones to the other variables.

Lastly, Table 4 presents that the Year -variable has a minimum of 2003 and maximum as 2008, therefore having a mean and median of 2005.5. Even though the analysis is constructed from a review of years 2004-2008, the year 2003 is included to the sample due to the (t-1) -lags of the independent variables for base year of 2004. This explains, why the mean and median are “halfway” of the year 2005 instead of being year 2006. With this assessment, the standard deviation of 1.71 is consistent with the analysis.

5.3 Results of regression analyses

The empirical regression results for both multiple linear (OLS) regression model and fixed-effects regression model are presented in **Table 5**. The results show that no matter which model is used, federal funds and MBS securities have a negative correlation with ROE. This means, that increase in these variables will decrease banks’ ROE. These results are consistent with the expected results. On the contrary, repo loans have a positive correlation, meaning that an increase in banks’ repos will increase the banks’ ROE. This result suggests more towards the expectation, that repos are a normal efficient policy tools used in the financial markets, rather than an indicator of forthcoming profitability losses and distress. The comparison of the OLS- and FE -model is discussed further on.

When reviewed the **results for linear OLS regression model**, federal funds and MBS securities do not pose a significant correlation to the subsequent ROE values. From Table 5 can be seen, the results are not significant with the 95% confidence interval. This is surprising when compared to the discussed academic literature and expectations of the MBS and federal funds correlation to ROE. A more precise assessment would reveal that the p-value for lagged federal funds is 0.083. Hence, the results would be significant and have a negative correlation with ROE if a p=0.1 would be used. In addition, the coefficient for the federal funds is triple the value for MBSs, meaning that the increase effect in federal funds would decrease the ROE to three times lower compared to the effects of an increase in MBSs.

These results are surprising in two ways: First, based on academic literature and what is known otherwise of the securities, MBS and federal fund volumes were expected to pose a significant correlation to bank profitability. Secondly, in general the academic literature seems to be emphasizing MBSs more than federal funds on their effects on the crisis and bank performance (see Chapters 3.3.1 and 3.5.1). Thus, the results of stronger coefficient value of federal funds compared to the coefficient of MBSs shows, that instead, federal funds have a stronger impact than what MBSs have to ROE. In addition, the results show, that with p=0.1, the results of federal funds would be consistent with the discussed expectations of the securities. However, the significance of the federal funds and ROE would be weak due to poor p-value, and the results are instead accounted not to be significant with p=0.05. For MBSs, the p-value is so poor, that it would not be considered significant with any existing confidence intervals. The Table 4 hence shows, that **neither federal funds nor MBSs would work as efficient early warning indicators** even though an increase in both variables do account for decreases in bank profitability. Nevertheless, for federal funds the correlation is too poor to be used efficiently in early warning monitoring, for MBSs the correlation being even worse and more inefficient, making these two variables statistically unsignificant.

Nevertheless, these results are partly consistent with the academic literature, e.g. Afonso et al. (2011) and Ashcraft et al. (2011) note, that the increasing constraints, counterparty risk and unexpected payment shocks were the underlaying reasons for distress in the federal funds markets, rather than the funds themselves posing a significant risk to the banks. However, for MBSs the results become more mixed compared to the previous academic literature. Gorton (2010) and Brunnermeier (2009) find the structure of MBS securities having been an important factor on the onset of the financial crisis. These results are incompatible with the results of this study. On the contrary, Board of Governors of the Federal Reserve System (2020c) did not report a significance decreasing trend on the market volume of MBSs during the beginning of the crisis, and instead, shows that the overall trend was increasing throughout the crisis. This notion is consistent with the results of the volume of MBSs not posing as significant early warning indicator.

The only significant correlation is with repo loans and ROE, with the highest possible significant level of p=0.001 (Table 5). This result has a strong positive correlation coefficient of 28.77 and is highly significant. This shows that an increase of 1% in repos in banks' assets during the previous period will increase ROE by 28.77%. Thus, banks' repo volume will strongly improve the bank profitability on the following year. Furthermore, the results based on the MLR model suggest, that the banks can actively improve their ROE -values through repo loans, thus strongly encouraging banks to utilize repo loans in respond to their liquidity and financing needs. This result emphasizes the importance of Federal Reserve's decisions to use repos in open market operations.

However, compared to previous literature, the results are somewhat surprising. The results do not find any evidence of negative correlation between repos and bank profitability, neither not suggesting any decreasing effect to ROE values. Thus, repos do not pose any alarming correlation to the cause of the crisis and bank profitability. These results are contradictive with, e.g. Gorton & Metrick (2012), who see the financial crisis having been a run on repo. Nevertheless, the strong positive correlation does not exclude the possibility, that repo loans did affect to the start of the financial crisis. Due to

the strong correlation, it can be concluded, that a sudden decrease or general distress in the repo markets will have a strong negative effect to the financial markets and banking system. If there is a large sudden drop in the repos, the banks should have high concerns over their profitability. Therefore, repos can be used as an early warning indicator, but should be accounted for such only, if there would be a decreasing trend or sudden large drops.

Regardless, as the financial crisis in 2008 showed, these warning signals might not be in time and the volume of repo loans should not be considered as the only factor to look out for. As can be seen from Figure 7 (Chapter 3.4.1), the repo loan volume did keep on rising until March 2008, when the crisis was already in its full mode. Based on the results of the OLS -regression, there should have been no early warning signals coming from the repo markets. Thus, the early waring indicating power would have been only efficient, if before 2007 and 2008, there had been clear drops in the repo markets. These results indicate towards e.g. Hördahl & King's (2008) findings, that the repo loans themselves were not the cause of the crisis but the underlaying risks and risk management and monitoring issues. Therefore, the results suggest more towards the discussed expectation, that repo loans pose a strong correlation as being more Federal Reserve's efficient policy tools in the market than being early warning indicators. This conclusion does not mean that the volume of repos could not be used as an early warning indicator, but rather emphasizes, that if done so, the reviewing should be done carefully and with using other early warning indicators as well.

The F -statistic in Table 5 shows, that the MLR OLS -model is highly significant with the highest significance level of p=0.001. From this can be concluded, that the model is usable and the results reliable. The model can efficiently predict the correlation of bank profitability through delivering estimations of the independent variables. However, when the year dummies are observed, it can be noticed, that the model works better closer the crisis years. The model is statistically significant for years 2006-2008, year 2004

Table 5. The regression results for OLS- and FE -model. The variable correlation coefficients and the parenthesized standard errors are presented. The statistical significance is denoted by the asterisks with the corresponding p-values. F-statistics and R^2 -values are presented for both the models, for FE-model the additional -R^2 -values and intraclass correlation Rho are included. The year 2004 is the base year, thus the coefficient is depicted as zero and the standard error is missing. These values should be interpreted as blanks.

	OLS b/(se)		**FE** b/(se)	
Federal Funds (L)	-18.730		-10.622	
	(10.80)		(8.99)	
MBS (L)	-6.706		-6.563	
	(4.57)		(7.57)	
Repos (L)	28.767	***	9.973	
	(7.21)		(12.90)	
Tier 1	0.082		0.311	***
	(0.08)		(0.09)	
Deposits/Assets	6.608		-33.241	***
	(5.41)		(7.96)	
Capital/Assets	-10.854		9.045	
	(6.47)		(8.05)	
Bank size	1.251	***	5.414	**
	(0.26)		(1.82)	
Loans/Assets	-1.586		3.525	
	(3.61)		(5.83)	
NPL	-278.957	***	-275.080	***
	(49.44)		(13.57)	
Treasury securities	-8.178		-52.066	***
	(8.63)		(10.89)	
year=2004	0.000		0.000	
	(.)		(.)	
year=2005	-0.241		-0.546	
	(0.31)		(0.73)	
year=2006	-0.934	**	-1.441	
	(0.33)		(0.84)	
year=2007	-2.189	***	-3.943	***
	(0.40)		(0.95)	
year=2008	-9.758	***	-12.214	***
	(1.06)		(1.10)	
constant	-7.169		-42.045	
	(8.45)		(27.55)	
F	32.52	***	86.77	***
R-sqr	0.304		0.371	
R-sqr (FE -between)			0.055	
R-sqr (FE -overall)			0.158	
Rho			0.524	

* p<0.05, ** p<0.01, ***p<0.001

being the base year. For 2006 the model's p-value is 0.01, and for both 2007 and 2008 the significance is even higher with p=0.001. The coefficients show a dramatic drop in the bank profitability from year 2006 to 2008, with the drop being more than 10 -times higher in 2008 than in 2006 in ceteris paribus. These results are consistent with the reported developments of ROE before and during the financial crisis from World Bank and FFIEC (Figure 3, chapter 3.1.1). However, it is important to note that the regression does not find any statistical significance for year 2005. From this can be concluded that the model's estimations work **couple of years before the start of the crisis**, but any further estimations through this model would not accumulate statistically significant and reliable results.

Table 5 also presents the **results for FE -model**. When the analysis is switched to FE -model, there is a noticeable decrease in the statistical significance. Now, all the three independent variables (federal funds, MBSs and repos) are statistically not significant with any existing p-values. In addition, the coefficients for both federal funds and repos are weaker in explaining ROE. None of the three factors does not pose any significant correlation to bank profitability in the precrisis years. Thus, the conclusion based on FE -model is, that **none of the three variables are usable early warning indicators**. However, the p-values for years show, that only 2007 and 2008 are highly statistically significant in explaining the decrease in bank profitability, thus year 2006 dropping from the statistically reliable years. This makes the reliable prediction period narrower than the linear OLS -model had, tapering from three years to only two. Deducing from these results, the prediction power of FE -model is usable only just before the start of the financial crisis. Additionally, it is noticeable, that the intraclass correlation Rho of the variance is 52%. This means, that 52% of the variance is due to differences across panels, highlighting the importance of differences of the panels (Torres-Reyna, 2007). Nevertheless, the F-statistic of FE-model remains highly significant with p=0.001, making the FE-model despite of the poor results usable and reliable estimation for the parameters.

But what explains the differences between the two models? When reviewed both of the results for OLS- and FE-model at the same time from Table 5, it is seen that the overall results for independent variables are much weaker and statistically not significant when compared to the MLR OLS -model. Because FE -model estimates how changes within the banks across time affects the future ROE -values, the model has omitted all time-invariant factors of the banks. Based on previous tests whether the FE-model is appropriate model to be used, and whether the time-fixed effects are needed, the usage and results of the FE-model have been noted to be reliable. However, the multiple linear regression model does not account for the fixed time-invariant effects, thus not explaining the effects that the bank characteristics and other fixed static factors have on the bank profitability. There is a significant correlation with lagged repos and subsequent ROE -values only if the unique bank characteristics are included in the regression model. In addition, even though the correlation with federal funds is much weaker with ROE than what repos have, and they are not considered statistically significant in the framework of this study, it can be noted, that the federal funds lose all the potential statistical significance with FE-model. However, the interpretation for MBSs stays the same no matter which model is used. The coefficient for the MBSs for both models is almost the same, but the p-value is so poor, that changing between the models would not bring any statistical significance to the effects of the variable.

This draws a conclusion, that the **time-invariant unique bank specific characteristics** are the fundamental explaining factors of the correlation between the independent variables and their effects on the changes in bank profitability. Early warning systems should be constructed and EWIs considered with an emphasis on the banks' unique characteristics in mind. The repos' high significance to the bank profitability is highly connected to the banks' unique characteristics, and if these underlying factors and their nexus to the effects of the usage and interpretation of the correlation results are omitted from the empirical models, the efficient prediction of early warning indicators is not plausible. Likewise, federal funds lose even their potential weak prediction power, when the funds are considered only by themselves, and not based on the uniqueness of the banks

participating on the federal funds -markets. These interpretations are further affirmed, when the statistically significant years are added to the interpretation. Even though the independent variables lose their statistical significance in the FE -model, the significance for the estimated years remains the same with only 2006 being left out from the list for FE-model. This further suggests that the securities by themselves are not able to predict a crisis, but the underlaying invariant factors and risks are. When these are omitted from the FE-model, the variables lose their significance, but the empirical model stays reliable. The same goes for the fundaments of ROE. Like Klaassen & van Eeghen (2015) emphasize, that ROE does not account for risk, the increase in underlaying risks in securities and bank characteristics are not accounted for within the regressions. Similarly, the underlying high risks in ROE -values are not accounted for. Especially when these unique "characteristics" and factors are omitted in the FE -model, the variables lose their significant predictive powers.

These conclusions are supported by the control variable of bank size. Both the estimators for OLS- and FE -model are statistically highly significant, with the FE -estimator having only slightly less significant p-value. Since the bank size in this case is measured by taking a natural logarithm from total assets, the variable is less likely time-invariant than it would be if it were e.g. simpler qualitative variable. The size of the bank also depicts unique characteristic of the banks. When measured through $\ln(total\ assets)$, the variable is less likely omitted from the FE -model, and suggests through high statistical significance, that bank characteristics have an important role on EWI -modelling. Similarly, the dropping of year 2006 from the statistically significant years in FE -model also suggests, that invariant bank characteristics have even more important role and effect on bank profitability further away from the onset of the crisis. This is an important notion, because it is important to model the EWIs to predict possible future turmoil or alarming changes and trends in the markets early enough before the start of a crisis[23].

[23] See Chapter 2.2 for discussion about timing for EWIs.

The comparison of R^2 of OLS- and FE-model from Table 5 reveals, that both the models explain the variance of ROE with approximately similar extent. The linear regression OLS -model explains 30.4% of the changes in ROE, and FE -model explains 37.1%. The values are not great, and suggests, that there are a lot of factors affecting ROE, that have not been accounted for in the two regressions. However, for OLS -model the statistics is consistent with the previous academic literature. Typically, the academic literature related to assessing bank profitability and the correlations to other measures by using OLS regressions find rather low R^2- statistics (Tregenna, 2009). Due to this, the low R^2- statistic of 30.4% does not differ from other academic findings and should not raise too much concern over the practicality of the OLS -model. It should still be noted, that only repos were found statistically significant (with a weak correlation of federal funds if a confidence interval of 90% would be used instead), thus assessing, that the two statistically significant control variables might have aggregately greater effect on explaining ROE, than the only statistically significant independent variable has[24]. However, any further analysis or more specific impacts of each control variable is left out of this study. This is because the focus should be on the effects of the independent variables. In addition, the detrimental impact of the control variables to the results and possible weakened estimation reliability that is due to the additional non-causal correlations of control variables to other variables should be avoided (Hünermund & Louw, 2020).

However, for FE -model the R^2- statistic should be reviewed with comparison to the statistically significant variables. As has been noted before, Table 5 shows, that none of the independent variables are statistically significant with FE -model. On the contrary, instead of two significant control variables, the FE-model finds five of the seven control variables to be statistically significant. This clearly reveals, that the 37.1% of the explained variance in ROE within each bank over time is mainly due to the control variables, and none of the effects arise from the independent variables. In addition, because the control variables are not lagged variables like the independent variables are, the results

[24] Especially NPLs could have a strong negative effect, with high statistical significance of p=0.001 and extremely strong negative correlation with -278.957 coefficient value.

suggest, that the lag in FE -model will not improve the explanatory power of variables. Table 5 also lists the between- and overall -R^2 -values in addition to the typically used within R^2 -statistic of 37.1%. The between R^2 -value is only 5.5%, meaning that only 5.5% of the variation in the dependent variable between banks is captured by the model. As the name implies, the overall R^2 -value depicts the overall explanatory power of the model on the variation of bank profitability. The overall R^2 is 15.8%. This shows, that based on FE -model, ROE has in total a lot of omitted and unexplained factors, which affect the overall variation and changes in bank profitability. This once again confirms the previously mentioned results, that the bank specific time-invariant unique characteristics have a strong and significant correlation and effects to the profitability of banks and EWI estimation and prediction.

Lastly, it is noteworthy to mention, that the analysis was done by using **in-sample testing**. In-sample testing measures, how well the used OLS- and FE -models fit in the prediction of crisis in the used sample (Berg et al., 2004). The results should be viewed as an estimation of the explanatory power of the variables in this specific sample and time. However, to be usable in forecasting (and early warning indicating), the models should be tested out-of-sample as well. This means, that the existing OLS- and FE -models should be tested by being compared to a new set of observations, that do not belong to the estimation sample. By this way, additional test results of the forecasting capabilities of the models can be achieved (Berg et al., 2004; Wooldridge, 2018, p. 591).

This could have been done for example, by splitting the sample in two periods, e.g. in 2005-2006 as out-of-sample -period and using 2007-2008 as in-sample period. However, the whole period of 2004-2008 was decided to be used as a whole in order to prevent the 2007-2008 periods reflecting too much of the onset of the crisis, and thus possibly predicting significant results, where there might not have been none. And as can be seen after executing the empirical analysis, the model did not find overly significant results by being biased with a completely different sample than intended. Furthermore, for both models, the year -variable was found significant only closer to the onset of the crisis,

suggesting that the estimation power for earlier years is not as reliable with the models in question. Further out-of-sample analysis could be done by e.g. applying the models to predict the couple of last recent years (e.g. 2017-2019). However, because the current results indicate, that it is important to add and consider bank specific characteristics in the models for them to perform better on estimating the variables and correlations, it would not serve any purpose to carry out further even more detailed tests and studies using the models as they are now.

6 Conclusions

On the onset of the crisis, the United States looked like “the archetypical crisis country, only more so”. But due to overly optimistic rationalizations instead of critical review of the reality, the crisis hit the U.S. economy hard in the autumn of 2007. The faith in the sustainable superiority of the economy clouded the markets, and instead created a lullaby, that on the long run could not endure the ongoing trend of development (Reinhart & Rogoff, 2008). There were three defining factors in the financial markets, that fundamentally contributed to the onset and the severity of the global financial crisis: the lack of awareness and oversight of regulators and market participants, overcautious and scared investors, and vastly complex securitized financial instruments, that included high risks but that few if any market operators were fully able to understand. These fundaments were combined with credit boom and extremely high bank profitability during the precrisis years, creating an unstable and shaky financial ground, that was ready to crumble apart at any moment (see e.g. Reinhart & Rogoff, 2008; Tregenna, 2009; Ivashina & Scharfstein, 2010).

The financial crisis became an unpreceded event. This was affected due to early warning indicators used before the financial crisis, that worked poorly and were not efficient enough on predicting the upcoming crisis (see e.g. Rose & Spiegel, 2009; Christofides et al., 2016). Understanding the effects of financial vulnerabilities preceding crises could have helped to understand the framework of the build-up and realization of causes of the crisis (Lee et al. 2017). However, constructing an efficient EWS is challenging (Rose & Spiegel, 2009). Furthermore, based on the available academic literature it would be challenging to derive completely generalized EWI recommendations; initially the whole theoretical framework and scenario, which the findings are obtaining to offer perspicacity, should be evaluated and understood before applying the results to other scenarios, which could possibly differ inconspicuously. In addition, the research methods and EWS models should be evaluated. Even though it is important for EWS models to be able to have a significant forecasting power, and to yield reliable results both in-sample and out-

of-sample forecasting, a wrongly constructed EWS -model and EWIs could find significant results and alarming developments on situations, where there might not necessarily be none. Furthermore, too narrowly focused analysis could lead up to unintentional partial elimination of the aspect of predicting systemic events rather than segment specific events, which could result in errors in interpretation of the results and implementation of countermeasures. Thus, even though results of this study are statistically reliable, they should be critically evaluated in the light of the surrounding criteria and the applied methods.

In the referenced and discussed academic literature, the common consensus is emphasizing the affiliated excessive risks and lending of last resort on the three discussed independent variables. The MBSs increased the risks affiliated to them due to their complex securitization structure and spread the risks extensively around the financial markets without efficient risk diversification. The repo markets were affected by the decreasing asset and collateral values causing heightened concerns and excessive risk aversion in the markets. The contracting funding liquidity and access to short-term assets markets drove banks on resorting more than usual to federal fund loans to attain short-term and overnight liquidity. Based on these outlines, a rational conclusion would be, that increase in the volume of MBS and federal fund financing and a increase or a sharp sudden decrease in the volume of repo financing would indicate early warnings in the financial markets.

However, in this study the empirical analysis of predicting ROE with multiple linear regression and fixed effects -model only finds partial significant evidence on one of these variables. Based on the high significance and strong positive correlation between banks' repo volume and ROE, it is highly useful for banks to use repo loans to improve their profitability and bank efficiency. Due to the strong correlation, any sudden decreases in the repo financing should alarm early warning signals. However, because the correlation between repos is strongly positive, they should be used only as an early warning indicator when a sudden drop in the repos would arise. Thus, the reliability of repos as an early

warning indicator would not be optimal and could leave out potential alarming market developments and scenarios. For federal funds, only a weak correlation is found, but is not accounted as significant. For MBSs there is not found any evidence in this study for them to be useful as early warning indicators and to have any significant correlation with bank profitability. Thus, the results for MBSs are somewhat against the academic literature emphasizing the direct impact of these securities on the start of the crisis.

The overall results suggest that the correlation and fundamental explanatory powers are caused by the invariant time-fixed unique bank characteristics and the underlaying risks of the independent variables, rather than the securities themselves. The question remains: If bank profitability was artificially boosted and high ROE levels were targeted on the expense of other bank functions and measures, how much from the crash in bank profitability and the financial crisis' effects were truly caused by the volume of MBSs, repos and federal funds? As the results show, there is no evidence of none of these factors being comprehensively usable as early warning indicators as they are. On the contrary, the results emphasize that the unique bank characteristics and time-invariant effects had a much more important role on explaining the impact and severity of the crisis, and that these bank characteristics should be heavily noted when defining and assessing the early warning indicators and EWS -models. Thus, it can be concluded, that in the same way as the bank specific characteristics should be included in the construction of the EWIs and EWS models, equally the potential underlaying risks and deficiencies on the bank profitability (or whichever measure is wanted to be used as the explained variable) should be included and accounted for.

In addition, Klaassen & van Heegen (2015) compound a bank performance scheme, that analyzes the main bank financial drivers affecting ROE. Alternatively, using more structured models for ROE, could help banks determine their target levels with the individual ratios in mind, and thus have less exposure on affecting indirectly on the affiliated risk levels (Klaassen & van Heegen, 2015). There is a tradeoff between innovation and opaqueness, but one cannot be harnessed for beneficiary use without making some

compromises on the other (Gorton, 2010, p. 146). To mitigate or even avoid the negative effects associated to financial risks, we should pay more attention to the sectors, that truly are not completely yet understood. Like Gorton (2010, p. 146) puts it: “We should be looking more closely at the sectors that are very opaque”. The same goes for the assets and portfolios that are meant and thought to be safe, but on the occurrence of a crisis, turn out to be risky.

The global financial crisis started over a decade ago, but the repercussions of the crisis can still be seen in many countries. The fiscal costs to the economy, that accumulate from years long clean-up of financial crisis, can, and typically will be enormous. Still today the countries are affected by output losses, higher levels of public debt, government ownership of financial assets and institutions and policy supports to be fully lapsed. Even though there has been plenty of time for some crisis periods to end, and the financial markets have learned from the events, there are still a lot to be learned about on predicting, preventing, and resolving financial crises (Reinhart & Rogoff, 2008; Laeven et al. 2020). Hopefully, this study has offered some insight to the causes and prediction of financial crises, so that in the future, an event like this can be foreseen, and necessary preparations and preventions can be put in to practice before the damage has already been done.

References

Adrian, T., Begalle, B., Copeland, A. & Martin, A. (2013). *Repo and securities lending*. (Staff Reports No. 529). Federal Reserve Bank of New York. Retrieved May 20, 2020 from https://www.newyorkfed.org/medialibrary/media/research/staff_reports/sr529.pdf

Aebi, V., Sabato, G. & Schmid, M. (2012). Risk management, corporate governance, and Bank performance in the Financial Crisis. *Journal of Banking & Finance, 36*(12), 3213-3226. https://doi.org/10.1016/j.jbankfin.2011.10.020

Afonso, G., Kovner, A. & Schoar, A. (2010). *Stressed not frozen: The fed funds market in the Financial Crisis* (NBER Working paper No. 15806). National Bureau of Economic Research. Retrieved August 21, 2020, from http://www.nber.org/papers/w15806

Afonso, G., Kovner, A. & Schoar, A. (2011). Stressed, not frozen: The federal funds market in the Financial Crisis. *The Journal of Finance, 66*(4), 1109-1139. https://doi.org/10.1111/j.1540-6261.2011.01670.x

Armantier, O., Krieger, S. & McAndrews, J. (2008). The Federal Reserve´s Term Auction Facility. *Current Issues in Economics and Finance, 14*(5), 1-10. Retrieved January 04, 2020 from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1169282

Ashcraft, A., McAndrews, J. & Skeie, D. (2011). Precautionary reserves and the interbank market [Supplemental material]. *Journal of Money, Credit and Banking, 43*(2), 311-348. https://doi.org/10.1111/j.1538-4616.2011.00438.x

Baglioni, A. (2012). Liquidity crunch in the interbank market: Is it credit or liquidity risk, or both? *Journal of Financial Services Research, 41*(1), 1-18. https://doi.org/10.1007/s10693-011-0110-2

Bartolini, L., Hilton, S. & McAndrews, J. J. (2010). Settlement delays in the money market. *Journal of Banking & Finance, 34*(5), 934-945. https://doi.org/10.1016/j.jbankfin.2009.10.008

Bech, M. L., Klee, E. & Stebunovs, V. (2012). *Arbitrage, liquidity and exit: The repo and federal funds markets before, during and emerging from the Financial Crisis* (FEDS Working Paper No. 2012-21). Federal Reserve Board, Washington, D.C.: Divisions of Research & Statistics and Monetary Affairs. https://doi.org/10.2139/ssrn.2055188

Berg, A., Borensztein, E. & Pattillo, C. (2004). *Assessing early warning systems: How have they worked in practice?* (IMF Working Paper No. 04/52). International Monetary Fund. Retrieved July 05, 2020 from https://www.imf.org/external/pubs/ft/wp/2004/wp0452.pdf

Berger, A. N. (1995). The relationship between capital and earnings in banking. *Journal of Money, Credit, and Banking, 27*(2), 432-456. https://doi.org/10.2307/2077877

Board of Governors of the Federal Reserve System. (2007, December 12). *Federal Reserve and other central banks announce measures designed to address elevated pressures in short-term funding markets* [Press Release]. Retrieved May 13, 2020 from https://www.federalreserve.gov/newsevents/pressreleases/monetary20071212a.htm

Board of Governors of the Federal Reserve System. (2017, March 03). *Structure of the Federal Reserve System.* Retrieved July 02, 2020 from https://www.federalreserve.gov/aboutthefed/structure-federal-reserve-system.htm

Board of Governors of the Federal Reserve System. (2020a). *Commercial Paper* [Data set]. Data Download Program. Retrieved September 22, 2020 from https://www.federalreserve.gov/datadownload/Chart.aspx?rel=CP&series=62ff82bb5481c033fb9b54baba58e223&lastobs=&from=01/01/2002&to=12/31/2011&filetype=spreadsheetml&label=include&layout=seriescolumn&pp=Download

Board of Governors of the Federal Reserve System. (2020b, March 20). *Policy Tools: Reserve Requirements.* Retrieved May 29, 2020 from https://www.federalreserve.gov/monetarypolicy/reservereq.htm

Board of Governors of the Federal Reserve System. (2020c). *Assets and Liabilities of Commercial Banks in the United States –H.8* [Data set]. Data: Bank Assets and Liabilities. Retrieved October 6, 2020 from https://www.federalreserve.gov/releases/h8/default.htm

Brave, S. A. & Genay, H. (2011). *Federal Reserve policies and financial market conditions during the crisis* (Working Paper No. 2011-04). Federal Reserve Bank of Chicago. Retrieved August 27, 2020 from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1846660

Brunnermeier, M. K. (2009). Deciphering the liquidity and credit crunch 2007-2008. *Journal of Economic Perspectives, 23*(1), 77-100. https://doi.org/10.1257/jep.23.1.77

Cabral, R. (2013). A perspective on the symptoms and causes of the Financial Crisis. *Journal of Banking & Finance, 37*(1), 103-117. http://doi.org/10.1016/j.jbankfin.2012.08.005

Cecchetti, S. G. (2009). Crisis and responses: The Federal Reserve in the early stages of the Financial Crisis. *Journal of Economic Perspectives, 23*(1), 51-75. https://doi.org/10.1257/jep.23.1.51

Chari, V. V., Christiano, L. & Kehoe, P. J. (2008). *Facts and myths about the Financial Crisis of 2008* (Working Paper No. 666). Federal Reserve Bank of Minneapolis: Research Department. Retrieved February 02, 2020 from https://www.minneapolisfed.org/research/working-papers/facts-and-myths-about-the-financial-crisis-of-2008

Christofides, C., Eicher, T. S. & Papageorgiou, C. (2016). Did established Early Warning Signals predict the 2008 crises? *European Economic Review, 81*, 103-114. https://doi.org/10.1016/j.euroecorev.2015.04.004

Danielsson, J., Valenzuela, M. & Zer, I. (2018). Low risk as a predictor of Financial Crises. *IDEAS Working Paper Series from RePec*. FEDS Notes. https://doi.org/10.17016/2380-7172.2169

de Bandt, O., Camara, B., Pessarossi, P. & Rose, M. (2014, March*). Does the capital structure affect banks' profitability? Pre and post Financial Crisis evidence from significant banks in France* (Débats économiques et financiers No. 12). Secretariat General de L'Autorite de Controle Prudentiel et de Resolution Direction des Études. Banque De France. Retrieved October 2, 2020 from https://acpr.banque-france.fr/sites/default/files/medias/documents/201403-does-the-capital-structure-affect-banks-profitability_0.pdf

Demiralp, S., Preslopsky, B. & Whitesell, W. (2006). Overnight interbank loan markets. *Journal of Economics and Business, 58*(1), 67-83. https://doi.org/10.1016/j.jeconbus.2005.04.003

Drehmann, M. & Juselius, M. (2014). Evaluating early warning indicators of banking crises: Satisfying policy requirements. *International Journal of Forecasting, 30*(3), 759-780. http://doi.org/10.1016/j.ijforecast.2013.10.002

Federal Reserve Bank of New York. (2009, June 25th). *Term Securities Lending Facility: Frequently Asked Questions.* Retrieved July 15, 2020 from https://www.newyorkfed.org/markets/tslf_faq.html

Federal Reserve Bank of New York. (2020a). *Primary Dealer Statistics*. Retrieved August 07, 2020 from https://www.newyorkfed.org/markets/gsds/search.html#

Federal Reserve Bank of New York. (2020b). *Federal Funds Data*. Retrieved February 13, 2020 from https://apps.newyorkfed.org/markets/autorates/fed%20funds

Federal Reserve Bank of New York. (2020c). *Repo and Reverse Repo Agreements*. Retrieved February 14, 2020 from https://www.newyorkfed.org/markets/domestic-market-operations/monetary-policy-implementation/repo-reverse-repo-agreements

Federal Reserve Bank of New York. (2020d). *Primary Dealers*. Retrieved February 17, 2020 from https://www.newyorkfed.org/markets/primarydealers#primary-dealers

Federal Reserve Bank of New York. (2020e). *Repo and Reverse Repo Operations*. Retrieved March 10, 2020 from https://apps.newyorkfed.org/markets/autorates/temp

Federal Reserve Bank of St. Louis. (2020a). *Monetary Authority; Loans to Domestic Banks Through the Discount Window; Asset, Level [BOGZ1FL713068703Q]* [Data set]. FRED, Board of Governors of the Federal Reserve System. Retrieved October 3, 2020 from https://fred.stlouisfed.org/series/ BOGZ1FL713068703Q

Federal Reserve Bank of St. Louis. (2020b). *Liabilities and Capital: Liabilities: Reverse Repurchase Agreements: Wednesday Level [WLRRAL]* [Data set]*; Assets: Other: Repurchase Agreements: Wednesday Level [WORAL]* [Data set]. FRED, Board of Governors of the Federal Reserve System. Retrieved October 1, 2020 from https://fred.stlouisfed.org/series/WLRRAL; https://fred.stlouisfed.org/series/WORAL

Federal Reserve Bank of St. Louis. (2020c). *Treasury and Agency Securities: Mortgage-Backed Securities (MBS), All Commercial Banks [TMBACBW027SBOG]* [Data set]*; Other Securities: Mortgage-Backed Securities, All Commercial Banks [OMBACBW027SBOG]* [Data set]. FRED, Board of Governors of the Federal Reserve System. Retrieved October 6, 2020 from https://fred.stlouisfed.org/series/TMBACBW027SBOG; https://fred.stlouisfed.org/series/OMBACBW027SBOG

Federal Reserve Bank of St. Louis. (2020d). *Net Percentage of Domestic Banks Tightening Standards for Subprime Mortgage Loans (DRTSSP)* [Data set]. FRED, Board of Governors of the Federal Reserve System. Retrieved September 28, 2020 from https://fred.stlouisfed.org/series/DRTSSP

Federal Reserve Bank of St. Louis. (2020e). *Effective Federal Funds Rate [FEDFUNDS]*. FRED, Board of Governors of the Federal Reserve System. Retrieved February 13, 2020 from https://fred.stlouisfed.org/series/FEDFUNDS

Federal Reserve Bank of St. Louis. (2020f). *Delinquency Rate on Single-Family Residential Mortgages, Booked in Domestic Offices, All Commercial Banks [DRSFRMACBS]* [Data set]. FRED, Board of Governors of the Federal Reserve System. Retrieved September 3, 2020 from https://fred.stlouisfed.org/series/DRSFRMACBS

Federal Reserve Bank of St. Louis and Federal Financial Institutions Examination Council. (2020). *Return on Average Equity for all U.S. Banks [USROE]* [Data set]. Reports of Condition and Income for All Insured U.S. Commercial Banks. FRED, Federal Reserve Bank of St. Louis. Retrieved October 6, 2020 from https://fred.stlouisfed.org/series/USROE, October 6, 2020.

Fedwire Funds Service. (2020). *Fedwire Funds Service* [Brochure]. The Federal Reserve: Financial Services. Retrieved July 09, 2020 from https://www.frbservices.org/assets/financial-services/wires/funds.pdf

Fleming, M. J., Hrung, W. B. & Keane, F. M. (2010). Repo market effects of the Term Securities Lending Facility. *American Economic Review, 100*(2), 591-596. https://doi.org/10.1257/aer.100.2.591

Frankel, J. & Saravelos, G. (2012). Can leading indicators assess country vulnerability? Evidence from the 2008-2009 global financial crisis. *Journal of International Economics, 87*(2), 216-231. https://doi.org/10.1016/j.jinteco.2011.12.009

Furfine, C. (1999). The microstructure of the federal funds market. *Financial Markets, Institutions & Instruments, 8*(5), 24-44. https://doi.org/10.1111/1468-0416.00031

Furfine, C. (2001). Banks as monitors of other banks: Evidence from the overnight federal funds market. *The Journal of Business, 74*(1), 33-57. https://doi.org/10.1086/209662

Furman, J. (2018, September 11-12). *The Fiscal Response to the Great Recession: Steps Taken, Paths Rejected, and Lessons for the Next Time* [Preliminary Discussion Draft]. 10th Anniversary Event: Responding to the Global Financial Crisis - What we did and why we did it, Brookings Institute: Hutchins Center on Fiscal and Monetary Policy & Yale School of Managements, Washington D.C., United States. Retrieved June 20, 2020 from https://www.brookings.edu/wp-content/uploads/2018/08/12-Fiscal-Policy-Prelim-Disc-Draft-2018.09.11.pdf

Gagnon, J., Raskin, M., Remache, J. & Sack, B. (2011). Large-Scale Asset Purchases by the Federal Reserve: Did they work*? Economic Policy Review – Federal Reserve Bank of New York, 17*(1), 41-59. https://doi.org/10.2139/ssrn.1952095

Georgiou, M. N. (2009, September 27). Solvency and ROE; Are they conflicting targets in banking*? SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1479204

Gorton, G. B. (2010). *Slapped by the Invisible Hand: The Panic of 2007.* Oxford University Press. http://urn.fi/URN:ISBN:978-0-19-973415-3

Gorton, G. & Metrick, A. (2012). Securitized banking and the run on repo. *Journal of Financial Economics, 104*(3), 425-451. https://doi.org/10.1016/j.jfineco.2011.03.016

Gorton, G. & Souleles, N. S. (2005). *Special Purpose Vehicles and Securitization*. (NBER Working Paper No 11190). National Bureau of Economic Research. Retrieved September 03, 2020 from http://www.nber.org/papers/w11190

Hull, J. C. (2006). *Options, Futures and Other Derivatives* (6th ed.). Pearson Prentice Hall. http://urn.fi/URN:ISBN:0-13-149908-4

Hünermund, P. & Louw, B. (2020, October 1). *On the Nuisance of Control Variables in Regression Analysis* (arXiv: 2005.10314v3 [econ.EM]). Cornell University: arXiv. Retrieved October 13, 2020 from https://arxiv.org/abs/2005.10314

Hördahl, P. & King, M. R. (2008). Developments in repo markets during the financial turmoil. *BIS Quarterly Review, December 2008*, 37-53. Retrieved May 28, 2020 from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1329903

International Capital Market Association. (2020a). *6. What types of asset are used as collateral in the repo market?* Retrieved August 03, 2020 from https://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/repo-and-collateral-markets/icma-ercc-publications/frequently-asked-questions-on-repo/6-what-types-of-asset-are-used-as-collateral-in-the-repo-market/

International Capital Market Association. (2020b). *10. What is 'rehypothecation' of collateral?* Retrieved August 03, 2020 from https://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/repo-and-collateral-markets/icma-ercc-publications/frequently-asked-questions-on-repo/10-what-is-rehypothecation-of-collateral/

Ivashina, V. & Scharfstein, D. (2010). Bank lending during the Financial Crisis of 2008. *Journal of Financial Economics,* 97(3), 319-338. https://doi.org/10.1016/j.jfineco.2009.12.001

Kendra, K. (2007, February 20). *Tranche ABX and basis risk in subprime RMBS structured portfolios* [PowerPoint slides]. SlideServe. Retrieved March 02, 2020 from https://www.slideserve.com/bardia/tranche-abx-and-basis-risk-in-subprime-rmbs-structured-portfolios

Klaassen, P. & van Eeghen, I. (2015). Analyzing bank performance -Linking RoE, RoA and RAROC: U.S. commercial banks 1992-2014. *The Journal of Financial Perspectives, 3*(2), 1-22. Retrieved September 10, 2020 from https://ssrn.com/abstract=3083577

Laeven, L. & Valencia, F. (2013). Systemic Banking Crises Database. *IMF Economic Review, 61*(2), 225-270. https://doi.org/10.1057/imfer.2013.12

Laeven, L. & Valencia, F. (2020). Systemic Crises Database II. *IMF Economic Review, 68*(2), 307-361. https://doi.org/10.1057/s41308-020-00107-3

Lee, S. J., Posenau, K. E. & Stebunovs, V. (2017). *The anatomy of financial vulnerabilities and crises* (International Finance Discussion Papers No. 1191). Board of Governors of the Federal Reserve System. https://doi.org/10.17016/IFDP.2017.1191

Liang, N., McConnell, M. M. & Swagel, P. (2018, September 11-12). *Evidence on outcomes* [Preliminary Discussion Draft]. 10th Anniversary Event: Responding to the Global Financial Crisis - What we did and why we did it, Brookings Institute: Hutchins Center on Fiscal and Monetary Policy & Yale School of Managements, Washington D.C., United States. Retrieved June 20, 2020 from https://www.brookings.edu/wp-content/uploads/2018/08/15-Outcomes-Prelim-Disc-Draft-2018.12.11.pdf

Lo Duca, M. & Peltonen, T. (2013). Assessing systemic risks and predicting systemic events. *Journal of Banking & Finance, 37*(7), 2183-2195. https://doi.org.proxy.uwasa.fi/10.1016/j.jbankfin.2012.06.010

Mamun, A., Hassan, M. K. & Johnson, M. (2010). How did the Fed do? An empirical assessment of the Fed's new initiatives in the Financial Crisis. *Applied Financial Economics, 20*(1-2), 15-30. https://doi.org/10.1080/09603100903262541

Mishkin, F. S., Matthews, K. & Giuliodori, M. (2013). *The Economics of Money, Banking & Financial Markets* (European edition, 1st ed.). Pearson Education. http://urn.fi/URN:ISBN:978-0-273-73180-1

Montgomery, D. C., Peck, E. A. & Vining, G. G. (2012). *Introduction to Linear Regression Analysis* (5th ed.). John Wiley & Sons. http://urn.fi/URN:ISBN:978-0-470-54281-1

Moussu, C. & Petit-Romec, A. (2017). ROE in banks: Performance or risk measure? Evidence from Financial Crises. *Finance, 38*(2), 95-133. https://doi.org/10.3917/fina.382.0095

Peltonen, T. A., Rancan, M. & Sarlin, P. (2018). Interconnectedness of the banking sector as a vulnerability to crises. *International Journal of Finance & Economics, 24*(2), 1-28. https://doi.org/10.1002/ijfe.1701

Pennacchi, G. & Santos, J. A. C. (2018). *Why do banks target ROE?* (Staff Reports No. 855). Federal Reserve Bank of New York. Retrieved October 10, 2020 from https://ssrn.com/abstract=3199909

Reinhart, C. & Rogoff, K. S. (2008) Is the 2007 US sub-prime financial crisi so different? An international historical comparison. *American Economic Review, 98*(2), 339-344. https://doi.org/10.1257/aer.98.2.339

Rose, A. & Spiegel, M. (2009, August 03). *Could an early warning system have predicted the crisis?* VoxEU: CEPR. Retrieved August 19, 2020 from https://voxeu.org/article/could-early-warning-system-have-predicted-crisis

S&P Dow Jones Indices. (2020a). *S&P/Case-Shiller U.S. National Home Price Index [CSUSHPINSA]* [Data set]. FRED, Federal Reserve Bank of St. Louis. Retrieved September 29, 2020 from https://fred.stlouisfed.org/series/CSUSHPINSA

S&P Dow Jones Indices. (2020b, April). *S&P CoreLogic Case-Shiller Home Price Indices: Methodology* [Fact sheet]. S&P Global. Retrieved July 22, 2020 from https://www.spglobal.com/spdji/en/documents/methodologies/methodology-sp-corelogic-cs-home-price-indices.pdf

Senior Supervisors Group. (2009, October 21). *Risk management lessons from the Global Banking Crisis of 2008* (Report No 102109). U.S. Securities and Exchange Commission. Retrieved July 10, 2020 from https://www.sec.gov/news/press/2009/report102109.pdf

Sohn, B. & Park, H. (2016). Early Warning Indicators of Banking Crisis and Bank Related Stock Returns. *Finance Research Letters, 18*, 193-198. http://doi.org/10.1016/j.frl.2016.04.016

Taylor, J. B. & Williams, J. C. (2009). A Black Swan in the Money Market. *American Economic Journal: Macroeconomics, 1*(1), 58-83. https://doi.org/10.1257/mac.1.1.58

Thomson Reuters. (2013, December 12). *Worldscope Database - Data Definitions Guide (Issue 14.2)* [Restricted availability]. Retrieved December 29, 2019 from http://lipas.uwasa.fi/~jaty/thomson/thomsonan.html

Torres-Reyna, O. (2007, December). *Panel Data Analysis: Fixed and Random Effects using Stata (v. 4.2)*. Data and Statistical Services: Princeton University. Retrieved October 02, 2020 from http://www.princeton.edu/~otorres/Panel101.pdf

Tregenna, F. (2009). The fat years: The structure and profitability of the US banking sector in the pre-crisis period. *Cambridge Journal of Economics, 33*(4), 609-632. https://doi.org/010.1093/cje/bep025

U.S. Department of the Treasury. (2019, October 20). *About TARP.* Retrieved January 28, 2020 from https://www.treasury.gov/initiatives/financial-stability/about-tarp/Pages/default.aspx

Wooldridge, J. M. (2018). *Introductory Econometrics: A Modern Approach* (Student edition, 6th ed.). Cengage Learning. http://urn.fi/URN:ISBN:978-1-305-27010-7

World Bank. (2020). *Bank's Return on Equity for United States [DDEI06USA156NWDB]* [Data set]. Global Financial Development. FRED, Federal Reserve Bank of St. Louis. Retrieved October 6, 2020 from https://fred.stlouisfed.org/series/DDEI06USA156NWDB

Appendices

The following appendices include the additional variable list, Gauss-Markov Theorem, and the results of Hausman test.

Appendix 1. Variable list

Table 6 provides a descriptive more detailed list of the used variables in the empirical analysis. The first column shows the variable name. The second column lists the type of the variable. Third column gives more comprehensive description of the variable, how the variable has been constructed and what kind of securities or assets are included in the variable. The third column shows the more detailed description, how the variable has been constructed in the Thomson Reuters Worldscope -database. The fourth column shows the ratio of the specific variable, that is used in the empirical analysis instead of the absolute variable values. The fifth column shows the used string name for the variable in Stata regression analyses. The regression names are also the ones depicted in equation 4. In the end of the table, the descriptions of total assets and total liabilities are given. These metrics are not used in the empirical analysis just by themselves, but because they are used to form the ratios out of the variables, a more detailed description is provided. The information is taken from Thomson Reuters (2013) Data Definitions Guide.

Table 6. The additional more detailed descriptive list of used variables.

Variable	Variable Type	Description	Ratio	Regression name
Return on Equity (ROE)	dependent	((Net Income - Bottom Line - Preferred Dividend Requirement)/ Average of Last Year's and Current Year's Common Equity)*100	ROE	*ROE*
Federal Funds	independent	Short term loans from the Federal Reserve Bank made to the bank from their excess balances	Federal Funds/Total Assets	*fedfunds*
MBS Securities	independent	Includes securities from Fannie Mae, Freddie Mac and Ginnie Mae, U.S. Agency MBSs and MBSs available for sale	MBS/Total Assets	*mbs*
Repo Loans	independent	Securities Sold Under Repurchase Agreements: securities sold on a short term basis that are bought back by the bank	Repos/Total Liabilities	*repos*
Tier 1	control	Tier 1 Capital (includes common shareholders' equity and qualifying preferred stock)/ Risk-weighted assets; calculated in accordance with banking regulation, expressed as percentage	Capital Adequacy Ratio	*tier1*
Total Deposits	control	Includes demand, savings, money market and certificates of deposit, securities sold under repurchase ggreements are excluded	Total Deposits/Total Assets	*deposits*
Total Capital	control	Sum of common equity, preferred stock, minority interest, long-term debt, non-equity reserves and deferred tax liability in untaxed reserves	Total Capital/Total Assets	*capital*
Bank Size	control	Natural logarithm of Total Assets	ln (Total Assets)	*banksize*
Loans to Assets -Ratio	control	Total amount of money loaned to customers before reserves for loan losses but after unearned income	Total Loans/Total Assets	*loansassets*
NPL -Ratio	control	Loans that the bank foresees difficulty in collecting, includes: non-accrual loans, reduced rate loans, renegotiated loans, loans past due 90 days or more; divided with Total Loans	Non-performing loans/Total Loans	*npl*
Treasury Securities	control	Includes Treasury bills, notes, bonds and Treasury securities available for sale	Treasury Securities/Total Assets	*treasury*
Total Assets	additional information	The sum of cash & due from banks, total investments, net loans, customer liabilities on acceptances, investment in unconsolidated subsidiaries, real estate assets, net property, plant and equipment and other assets	-	-
Total Liabilities	additional information	All short and long term obligations, includes: current liabilities, long term debt, deferred taxes and income, other liabilities, pension/post retirement benefits, resale agreement securities	-	-

Appendix 2. Gauss-Markov Theorem

The Gauss-Markov assumptions for BLUE OLS estimators.

Assumption 1: Linear in Parameters

The model in the population is written as

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + u \quad (8)$$

where

$\beta_0, \beta_1, \ldots, \beta_k$ are the unknown parameters

u is the unobserved random error term

Assumption 2: Random Sampling

There is a random sample of n $\{(x_{i1}, x_{i2}, \ldots, x_{ik}, y_i): i = 1, 2, \ldots, n\}$ observations.

Assumption 3: No Perfect Collinearity

There are no constant independent variables in the sample, and there are no exact linear relationships amongst the independent variables.

Assumption 4: Zero Conditional Mean

Given any values of the independent variables, the error term u has an expected value of zero.

$$E(u|x_1, x_2, \ldots, x_k) = 0 \quad (9)$$

Assumption 5: Homoscedasticity

Given any explanatory variable, the error term u has the same variance.

$$Var(u|x_1, x_2, \ldots, x_k) = \sigma^2 \quad (10)$$

(Wooldridge, 2018, p. 92)

Appendix 3. Hausman Test

Table 7. Results for Hausman test. The test assesses whether fixed-effects- or random-effects -model is needed, with the null hypothesis being, that random-effects -model is appropriate. A 95% confidence interval is used. (L.) -denotes the lagged independent variables. The chi²=0.000, thus the test yields highly significant results. The null hypothesis is rejected with p=0.001 (* p<0.05, ** p<0.01, ***p<0.001). The conclusion is that fixed-effects -model is the appropriate model to be used.

Variables	Coefficients (b) FE	(B) RE	(b-B) Difference	sqrt(diag{V(b)-V(B)}) se
Federal Funds (L.)	-10.622	-17.713	7.091	5.819
MBS (L.)	-6.563	-7.468	0.904	6.409
Repos (L.)	9.973	26.112	-16.140	10.576
Tier 1	0.311	0.115	0.196	0.066
Deposits/Assets	-33.241	3.214	-36.455	6.088
Capital/Assets	9.045	-9.123	18.168	5.146
Bank size	5.414	1.301	4.113	1.801
Loans/Assets	3.525	-1.123	4.648	4.902
NPL	-275.080	-281.492	6.413	6.565
Treasury securities	-52.066	-13.791	-38.275	8.916
Year				
2005	-0.546	-0.242	-0.305	0.222
2006	-1.441	-0.893	-0.548	0.461
2007	-3.943	-2.250	-1.693	0.628
2008	-12.214	-9.826	-2.389	0.792

b = consistent under Ho and Ha
B = inconsistent under Ha, efficient under Ho

Test: Ho:difference in coefficients not systematic

chi2(14) = 107.17
p(chi2) = 0.0000 ***