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Liquidity Coverage Ratio Management

Analyzing Norwegian Market Dynamics and Optimizing Liquidity Portfolios

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Abstract

This thesis aims to present an in-depth exploration of the Liquidity Coverage Ratio (LCR), and further analyze the optimum allocation of High-Quality Liquid Assets (HQLA) for Norwegian banks. Additionally, we compare our simulated portfolios to our reference portfolios to explore if today's LCR management can improve. To answer the question at hand, we analyze a unique dataset spanning from 2016 to 2023, based on credit margins and realized excess returns for HQLA, which in turn, comprises relevant assets for Norwegian banks liquidity portfolio.

The analysis is separated into two parts, where the first part focuses on data inspection. Here, we utilize correlation-, standard deviation- and variance ratio calculations on credit margins and realized excess return to elucidate the behavior of HQLA under varying financial situations. The second part introduces our simulation analysis where we illustrate our findings for several optimum HQLA portfolio compositions, taking varying constraints into consideration.

Through our research, we find strong tendencies for mean reversion in our dataset. Our calculations indicate that credit margins for HQLA revert to the mean for 52-week horizons. This discovery provides valuable insights for liquidity portfolio managers, as this detail is currently neglected in today's practice. Furthermore, we see that our optimum solutions deviate from our reference portfolios. Consequently, by implementing similar optimization techniques, banks have the potential to enhance their performance in terms of risk and return.

In conclusion, our findings suggest that Norwegian banks can improve the management of their liquidity portfolio. However, it is important to recognize that liquidity portfolio management does not constitute the primary function of banks overall activities. Moreover, although there is clear potential for enhancement in LCR management, it is crucial to adopt a comprehensive approach that considers the wider goals of the LCR requirements. Effective liquidity portfolio management involves not only optimizing returns but also adhering to regulatory requirements and maintaining stability across various market conditions.

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List of Abbreviations

LCR	Liquidity Coverage Ratio
NSFR	Net Stable Funding Ratio
HQLA	High-Quality Liquid Assets
CET1	Common Equity Tier 1
MBS	Mortgage-Backed Securities
CDO	Collateralized Debt Obligation
EEA	European Economic Area
CCB	Countercyclical Capital Buffer
MPT	Modern Portfolio Theory
MVP	Mean-Variance Portfolio
MVA	Mean-Variance Analysis
RWA	Risk-Weighted Assets
VR	Variance Ratio

1. Introduction

1.1 Background and Motivation

Considerable changes have occurred in the worldwide financial environment since the occurrence of the 2008 Financial Crisis. With the banking industry adjusting to an ever-changing regulatory landscape, liquidity management has become a pivotal concern for financial institutions. The liquidity coverage ratio (LCR) has emerged as a significant regulatory indicator, influencing the liquidity approaches of institutions on a global scale.

In the realm of regulatory development, the banking industry in Norway has followed a distinctive path, dealing with regulatory requirements both at the international and national levels (Lund & Nordal, 2017). The effective management of liquidity portfolios has emerged as a crucial priority for banks, necessitating a careful balance between complying with regulatory requirements and optimizing portfolios to achieve favorable risk-return features.

Our motivation within this subject stem from our mutual interest in exploring financial stability and the response by financial institutions to events with financial stress. Notable instances include the COVID-19 pandemic, the Russian invasion of Ukraine, and, particularly relevant to our research, the financial crisis of 2008. Moreover, we want to investigate the level of resilience exhibited by the Norwegian banking industry in the face of financial stress and how high-quality liquid assets (HQLA) are affected under such scenarios.

Central to our research lies an extensive dataset spanning from October 2016 to October 2023. In the context of this specific time frame, our attention is directed towards the analysis of credit margins and realized excess returns for relevant Norwegian HQLA. These key indicators provide valuable insights into the risk and return faced by banks. The motivation for our research is to extract useful insight from the dataset, providing comprehensive knowledge of how Norwegian banks manage the complex relationship between regulatory requirements and the pursuit of risk-return optimization.

1.2 Research Question

The primary aim of this thesis is to explore the eligible liquidity assets and optimal structure for Norwegian banks liquidity portfolio regarding LCR management. To achieve this goal, we have decided to divide our analysis into two parts. Additionally, before analyzing the data, our objective is to provide a comprehensive understanding of LCR and liquidity regulations for Norwegian banks and how they operate.

Part 1 delves into inspection of the dataset. Mainly, our focus lies within credit margins and realized excess return. We present inspections of credit margins, realized excess return, volatility on change in credit margins and variance ratio-test to illustrate the behavior of HQLA assets.

Part 2 of our analysis is based upon a simulation model built in Excel, using the add-in tool solver. Here, we aim to come up with several optimum compositions of HQLA based on different constraints. Further, we are comparing these optimum results to our reference portfolio which is a general composition of the liquidity portfolio for Norwegian banks. However, it is important to note that this reference portfolio has certain restrictions, which we will address in the following chapter.

In conclusion, our thesis is based upon following research questions:

What is the optimum allocation of Hiqh-Quality Liquid Assets (HQLA) in Liquidity Coverage Ratio (LCR) for Norwegian banks, and how does this allocation deviate from our reference portfolio?

1.3 Limitations

While this study contributes valuable insights into HQLA and portfolio management for liquidity reserves, several limitations should be acknowledged. The dataset, although comprehensive, was limited in terms of only consisting of Norwegian assets. As we highlight through our thesis, the reference portfolio, which reflect the average Norwegian bank, is notably invested in foreign companies and banks. In fact, our reference portfolio, stated in chapter 3.3.4, comprises over 20% of these foreign assets. Nevertheless, as an assumption made, we match this limitation by adjusting the reference portfolio to allocate funds in comparable Norwegian assets based on risk and return and their HQLA characteristics.

Additionally, as stated by Norges Bank (2023), the average duration for Norwegian banks liquidity portfolios is around three years. Thus, the duration for the reference portfolio will be close to three years as well. Ultimately, these two limitations and assumptions must be seen as a slight drawback for the accuracy of our findings.

Continuing our research, as for the second analysis, we apply solver in Excel for the simulation of optimum portfolios based on several constraints. It should be noted that these optimum findings are solely based on the input we have constructed through our dataset. Further, as the model only takes risk and return into consideration, we will consider a qualitative discussion combined with the optimum output when making our conclusion.

1.4 Structure

Chapter 2 starts by introducing maturity transformation as the most vital banking operation, before we elaborate on Norwegian banks' balance sheet structure. In chapter 3, we start by discussing the most notable reason for the rise of LCR. We further introduce the Basel framework, before we delve into LCR and all of its characteristics. Chapter 4 gives a practical take on costs the banks need to look after when managing their liquidity portfolio. Further, we introduce a key concept for our analysis which is the Modern Portfolio Theory (MPT) and Mean-Variance Portfolio (MVP). Moreover, we introduce our dataset in chapter 5 where we display descriptive statistics. We begin our analysis part 1 in chapter 6 by highlighting interesting findings in the dataset. Lastly, we focus on part 2, the simulation model before we come up with the conclusion for our thesis.

2. Banking Operations

2.1 Maturity Transformation

In this chapter, we will begin by examining the essence of maturity transformation and its economic benefits. We will then discuss the vulnerability of banks to bank runs and how deposit insurance helps mitigate bank runs. Furthermore, the concept of liquidity risk in relation to maturity transformation, as highlighted by Diamond and Dybvig (1983), will be examined. Finally, we will consider bank deposits and the implication of maturity transformation for LCR management.

Maturity transformation is a fundamental aspect of banking that enables banks to meet the needs of both borrowers and savers. By converting short-term deposits into long-term loans, banks play a vital role in channeling funds to those who need them most. Additionally, bank deposits serve as a function of making payments, essentially functioning as money. Bank deposits are now the most common form of payment in developed countries. The vast majority of people who deposit their cash in banks have a need for their money to be easily available, indicating a preference for liquidity. At the same time, many people who take out bank loans desire the option of a long repayment period (Norges Bank, 2022).

Overall, bank deposits have been proven to be a relatively stable source of funding (Abakaeva & Glisovic-Mezieres, 2009). Through statistical calculations, banks predict how much they can typically have available for payout to depositors. Banks also have deposit and borrowing access with the central bank, which helps them manage fluctuations in customer deposits. Nevertheless, situations of uncertainty about a bank's stability can arise, leading many depositors to withdraw their funds simultaneously, which is known as a bank run. To prevent this, a depositor guarantee scheme has been implemented to safeguard small depositor's funds even if the bank encounters problems. The Norwegian guarantee scheme provides coverage for deposits up to two million NOK per depositor per bank, with higher coverage in certain cases, such as recent deposits related to events that are infrequent (Norges Bank, 2022).[1]

[1] Infrequent events can be such as insurance payments and real estate transactions (Norges Bank, 2023).

Diamond and Dybvig (1983) highlight that maturity transformation exposes banks to liquidity risk. This is because banks are typically unable to liquidate their long-term assets quickly without incurring significant losses. As a result, if a large number of depositors demand their funds back at the same time, a bank may be unable to meet its obligations. If depositors believe that a bank is likely to fail, they may be more likely to withdraw their funds. This can lead to a cascade of withdrawals, even if the bank is fundamentally solvent.

Further, Diamond and Dybvig (1983) propose that banks could structure their liabilities in a manner that allows for the orderly withdrawal of funds over time. This could help to mitigate the risks associated with sudden and destabilizing runs. For example, banks could offer depositors the option to withdraw their funds on a staggered basis, rather than allowing them to withdraw all their funds at once.

Maturity transformation has one main implication for LCR management. The LCR is a regulatory requirement that requires banks to hold a certain amount of HQLA in relation to net cash outflows for the next 30 calendar days. The purpose of the LCR is to ensure that banks are able to meet their obligations during a 30-day period of stress. Maturity transformation allows banks to earn higher returns on their investments, but it also exposes them to liquidity risk. This is because banks may not be able to meet their obligations to depositors if they experience a sudden withdrawal of funds. Consequently, to satisfy the demands of depositors withdrawing funds, banks have to maintain a sufficient amount of HQLA.

Maturity transformation is a fundamental aspect of banking that provides several economic benefits. However, maturity transformation also exposes banks to liquidity risk. Banks can mitigate this risk by carefully managing their LCR and by exploring optimal balance structures.

2.2 Balance Sheet Structure

This section will start by providing a definition of balance sheet management, clarifying its purpose, and discussing the related risks. In addition, we will analyze the composition of the balance sheet for Norwegian banks and explore the asset classes in relation to the LCR. Finally, a discussion of the most relevant risks will be undertaken.

2.2.1 Balance Sheet Management

The balance sheet of a bank consists of two main components: assets and liabilities. The assets on the balance sheet include a range of financial instruments, including loans, investments, and reserves. Conversely, the liability side consists of deposits, market funding, and equity. The structure of a bank's balance sheet is essentially crucial in determining its ability to generate revenue and effectively mitigate risk, such as default risk.

Balance sheet management involves strategically allocating resources to optimize profitability and maintain financial stability. Banks must strike a balance between assets that generate income, like loans and investments, and the liabilities used to fund those assets, such as deposits and borrowings.

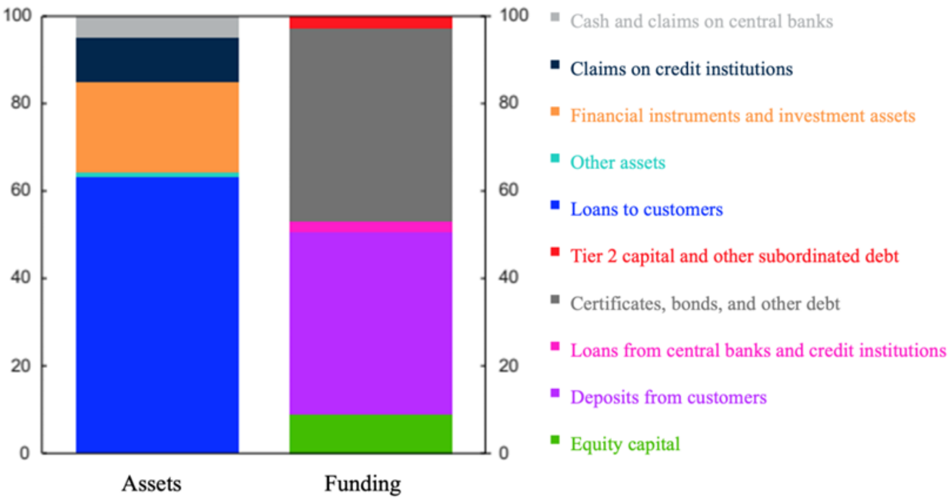
Effective balance sheet management requires careful consideration of factors such as interest rate risk, credit risk, and liquidity risk. It also involves making decisions regarding the maturity and liquidity of assets and liabilities to ensure a healthy interest rate spread while safeguarding against potential risks (Fernando, 2023).

2.2.2 Norwegian Banks Balance Sheet Structure

In Figure 2.1, loans to customers emerge as a significant component within the assets of Norwegian banks. One of the primary reasons for banks to maintain liquid assets is the necessity to hold readily convertible funds that can be quickly liquidated in response to heightened withdrawal demands from depositors or unexpected difficulties in renewing market funding. (Norges Bank, 2022).

The primary sources of funding for Norwegian banks are deposits and bonds, as illustrated in figure 2.1. Equity represents approximately 7%, while loans from central banks and credit institutions, as well as certificates, bonds, and other debt, constitute 45%. Customer deposits account for approximately 40%. The latter two sources of financing are typically assumed to be stable, aligning with LCR principles. Financial institutions that hold reliable sources of funding are more adept at sustaining periods of uncertainty. It is worth highlighting that smaller savings banks rely more heavily on customer deposits compared to their larger counterparts. On the other hand, large banks extensively utilize short-term market financing through the issuance of certificates in foreign currencies. In addition to deposits and loans, banks are also funded by equity. In the event of financial losses within banking institutions, equity serves as the primary mechanism for bearing such losses (Norges Bank, 2022).

Figure 2.1 Assets and Funding for Norwegian banks and covered bonds-credit institutions in percentage as of December 31, 2022



Note. The figure represents the sum of all banks and specialized credit institutions, excluding branches and subsidiary banks of foreign banks in Norway. From Norges Bank, *Det norske finansielle systemet (2023).*

How Norwegian banks gather and use funds is carefully structured. It concentrates around the right balance between staying financially stable, being adaptable, and following the rules of LCR. In this section, we will take a closer look at how Norwegian banks manage their funds. We will see how they decide where to get their funds and how they use them while making sure they meet the LCR guidelines.

The funding structure of Norwegian banks provide a glimpse into their financial stability, particularly when analyzed within the framework of LCR requirements. The subsequent breakdown of figure 2.2 reveals key allocations and their implications.

With about 7% commitment to equity capital, Norwegian banks establish a robust financial cushion capable of absorbing potential losses. The sizable equity base signifies a valuable resource that can be tapped during times of crisis. By having a strong equity base, banks are more resilient to potential losses, which in turn, supports their ability to hold enough liquid assets. If a bank has a robust financial cushion from its equity capital, it can withstand losses without jeopardizing its liquid assets. This means the bank can continue to meet its short-term obligations without selling off assets at a loss, ensuring that it remains compliant with the LCR standards that are designed to promote stability and reduce the risk of liquidity shortfalls.

LCR management emphasizes diversifying, a pivotal strategy for maintaining liquidity during periods of need. This diversification significantly bolsters the overall liquidity position, further enhancing their adherence to LCR guidelines. Seen in figure 2.2, certificates and other bonds[2] which accounts for about 13% play a pivotal role in bank funding as it reduces liquidity risk. These instruments can also serve as a significant component of their HQLA. Loans from central banks and credit institutions account for about 3%, this category underscores the strategy of ensuring some liquidity that remains readily accessible.

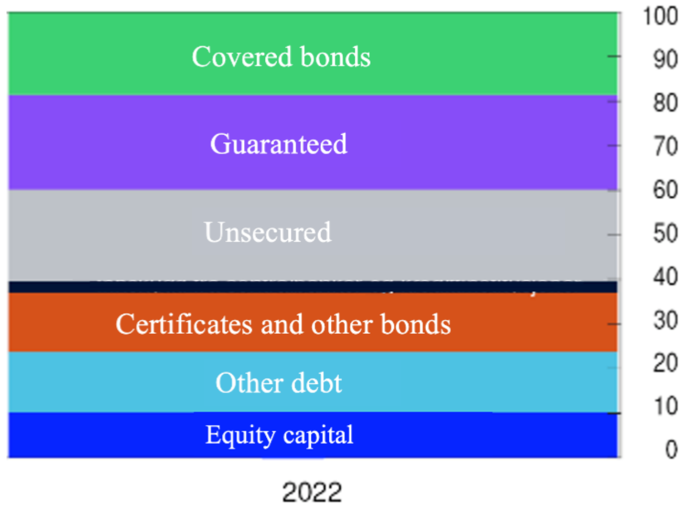
Both unsecured and guaranteed deposits are prominent at 20% each within the funding mix. These sources are integral to the overall funding strategy. While guaranteed deposits offer heightened security, unsecured deposits are perceived as less stable. Nonetheless, both deposits contribute to funding and liquidity, facilitating compliance with LCR requirements.

Covered bonds represent a substantial portion of the funding structure. Often backed by secured residential mortgages that are considered as high-quality collateral. The 20% allocation to covered bonds holds particular significance in LCR-management. These assets are known for high liquidity and ease of conversion during periods of stress.

In summary, the funding structure of Norwegian banks is aligned with the principles of LCR-management. It reflects a diversity of funding sources that are pivotal for liquidity and financial resilience. The banks maintain a robust presence of equity capital, a significant allocation to covered bonds, and a well-balanced distribution of deposits (both guaranteed and unsecured). These components collectively provide a strong assurance of possessing HQLA assets to meet LCR requirements, particularly during stressful scenarios.

[2] A bond is an interest-bearing security with a remaining maturity of over one year. Certificates have a remaining maturity of less than one year (Pedersen, 2023).

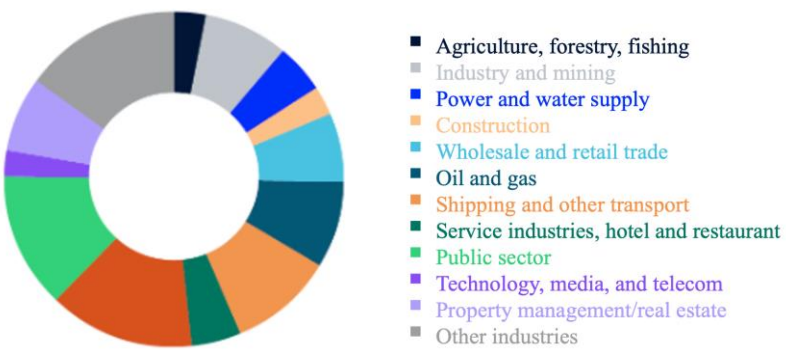
Figure 2.2 Norwegian banks funding structure, in percentage



Note. The black area represents loans from central banks and credit institutions. From Norges Bank, *Finansiell stabilitet 2023 - 1. halvår* (2023).

According to the Norges Bank (2023), approximately 90% of retail deposits and 30% of corporate deposits in Norwegian banks are covered by the deposit guarantee scheme, accounting for about half of all customer deposits. Corporate deposits are typically short-term and can be withdrawn at any time. The diversification of corporate deposits across industries, as shown in figure 2.3, helps to mitigate the risk associated with potential sector-specific shocks.

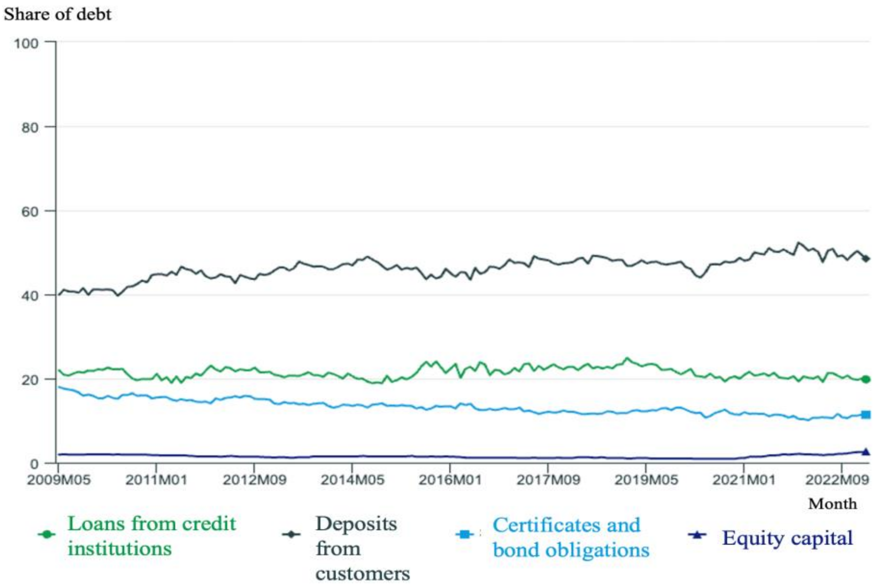
Figure 2.3 Corporate deposits in Norwegian banks across industries



Note. From Norges Bank, *Finansiell stabilitet 2023 – 1. halvår* (2023).

The chart presented in figure 2.4 illustrate the financing structure for Norwegian banks from 2009 to February 2023. Following the occurrence of the financial crisis, there has been a steady increase in customer deposits into Norwegian banks, with the percentage rising from 41,2% in 2009 to 48,5% as of February 2023. In contrast, loans from credit institutions have shown a rather stable trend, maintaining a consistent level of roughly 20% over the specific period. Furthermore, there has been a little decline in the allocation of funds through certificates and bonds. According to the data provided by Statistical research at Statistics Norway (2023), the bank financing composition as of February 2023 indicates that certificates and bonds accounted for 11,4%, while subordinated debt represented 2,7% of the total certificate and bond funding (Nordbakken & Pålsson, 2023).

Figure 2.4 Development in Norwegian banks' financing

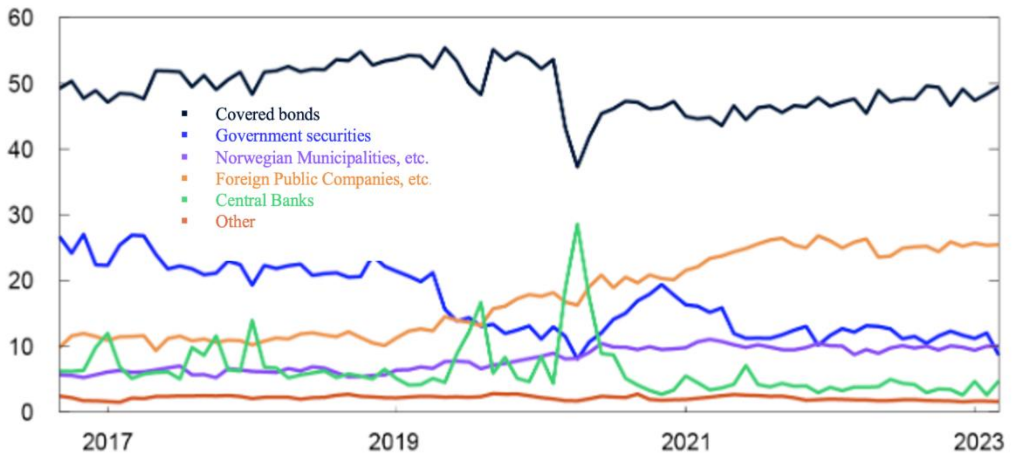


Note. From Statistical research at Statistics Norway, *Stabil finansiering for bankene* (2023).

The structure of Norwegian banks liquidity reserves in Norwegian kroner has seen some changes in recent years. As seen in figure 2.5, the proportion of covered bonds in the liquidity reserve has experienced a decline, decreasing from around 55% to slightly below 50%. Further, the Norges Bank (2023) states that the aforementioned transition has been followed by a growth in the proportion of securities denominated in Norwegian krone issued by multilateral development banks, foreign public companies, and foreign municipalities.

Furthermore, it is evident that the liquidity reserves were significantly affected by the COVID-19 pandemic. This resulted in a substantial decline in the proportion of covered bonds and an increase in deposits in central banks. The observed phenomenon is commonly referred to as "flight to quality” and is a notable characteristic of HQLA.

Figure 2.5 Various types of securities as a share of Norwegian banks liquidity reserve



Note. From Norges Bank, *Finansiell stabilitet 2023 – 1. halvår* (2023).

2.3 Risk Management

Risk management plays a crucial role in ensuring the secure and stable operations of financial institutions. Credit- and liquidity risk are two major risks that banks encounter, both of which are closely related to the structure of their balance sheets.

Credit risk refers to the risk that borrowers may default on their loan obligations, leading to potential losses for the bank. Effective credit risk management involves assessing the creditworthiness of borrowers, setting appropriate lending standards, and monitoring loan portfolios to mitigate potential losses. Liquidity risk is the risk that a bank may not have sufficient liquid assets or access to funding sources to meet its short-term financial obligations. This risk arises due to the maturity transformation discussed earlier. Banks must maintain adequate liquidity buffers address liquidity shortfalls during periods of stress (Munichiello, 2022).

During the recent extended period of historically low and stable interest rates, there have been instances of certain financial institutions in some countries who appeared to take liquidity and balance sheet management for granted. However, as interest rates began to rise and uncertainty loomed, a number of these institutions encountered difficulties in maintaining adequate liquidity and achieving the desired balance sheet structure. This was primarily due to deposit run-offs and mismatches in the duration of their portfolios. The problem of liquidity risk became even more pronounced as the value of assets deteriorated in response to tightening monetary policies. The inadequate balance sheet management led to bank failures and raised a heightened awareness of liquidity risk (SAS Institute, NA).

Furthermore, SAS Institute (NA) explains how liquidity risk management encompasses a range of processes and strategies that banks employ to address several key objectives. This includes ensuring that the balance sheet generates the desired net interest margin without exposing the institution to excessive risks. Such risks can be interest rate fluctuations, credit risks, prepayment dynamics, and deposit run-offs. Furthermore, banks strategically plan and structure the balance sheet, ensuring an optimal mix of assets and liabilities to enhance the institution's risk-return profile in the future.

Additionally, banks evaluate their capacity to meet cash flow and collateral requirements, both under normal operating conditions and in highly stressed scenarios, such as those outlined in liquidity assessments like the LCR and the Net Stable Funding Ratio (NSFR). These assessments should not negatively impact day-to-day operations, the overall financial standing, or public sentiment. Banks also implement risk mitigation strategies. This includes taking appropriate actions to guarantee the availability of necessary funds when needed (SAS Institute, NA).

Credit risk in the banking sector is the potential challenge banks face in recovering the funds they have loaned to borrowers. This risk can emerge from factors such as changes in a borrower's income, shifts in market conditions, loans extended without a thorough assessment of the borrower's creditworthiness, or sudden increases in interest rates. While credit risk is a natural part of lending, its impact can be minimized through effective evaluation and control measures.

Banks encounter various types of credit risk. Default risk occurs when a borrower fails to adhere to the terms of a loan, often due to a lack of credit repayment capacity or external factors, like changes in the market. Concentration risk arises when banks heavily invest in a single industry, geographic area, or borrower, making them vulnerable to adverse developments in those specific areas. Counterparty risk relates to transactions where parties fail to fulfill their commitments, such as in derivatives contracts. Sovereign risk occurs when banks invest in government bonds or have exposure to foreign governments that may default on their debt obligations due to political or economic instability.

To mitigate credit risk, banks should diversify their lending practices and establish robust credit assessment and monitoring processes. Several factors can lead to higher credit risk for banks. These include credit concentration, issues in credit assessment processes, subjective decision-making, inadequate monitoring, and the cyclical performance of industries. Credit risk management will continue to be a critical aspect of the banking sector as long as banks remain involved in lending, issuing credit cards, and engage in activities related to credit functions.

3. Regulation of Banks

Chapter threes' objective is to discuss the background for the need of bank regulation in recent time and provide a thorough clarification about the liquidity requirements LCR and NSFR. We will start by explaining the financial crisis of 2008 and point out how the crisis and its following consequences have affected European nations, mainly concentrating on Norway. Additionally, we will go through the history of the Basel Committee on Banking Supervision and following reforms they have put together over the years. Finally, we will specify requirements for valuation and composition of liquid assets that are HQLA eligible.

3.1 Necessity of Bank Regulation

The primary aim of bank regulation is to maintain financial stability by facilitating solidity and liquidity in the banking sector. A significant portion of the regulatory framework has been shaped because of financial crises and various historical and political occurrences. A wide range of people with various opinions, intentions, and experiences have shaped the current supervisory structure. As a consequence, bank regulation has evolved to serve numerous goals, goals which have changed over time (Spong, 2000).

3.1.1 The Financial Crisis of 2008 and its Consequences

The rise of the financial crisis in 2008 emerged from a subprime crisis through the US mortgage market, subsequently escalating into a crisis within the banking sector and ultimately culminating in a worldwide financial crisis. The period leading up to the crisis was marked by a notable expansion of credit, particularly in the real estate sector, and a significant increase in leverage within the financial system. These developments were facilitated by historically low interest rates, extensive liquidity, minimal volatility in financial markets, a rise in risk-taking behavior, and relaxed credit standards (Financial Stability Board, 2008). Under these circumstances, there was a spike in the demand for housing and housing investment, leading to a significant boom and a continuing rise in real estate prices. Robert Shiller (2005) constructed a comprehensive dataset spanning from 1895, revealing that real estate prices remained relatively stable for a century leading up to 1995. By the years from 2002 to 2006, there was a significant increase of around 31,6% in real estate prices (Baker, 2008). The housing bubble saw a subsequent collapse in 2008, resulting in the rapid spread of a crisis across the banking sector and the global economy (Svilenova, 2011). The aftermath of the crisis resulted in a decrease in mutual trust between financial institutions and their customers.

From the late 1990s through 2006, the US economy experienced a substantial increase in credit. Levetin and Wachter (2010) posit a new explanation for the occurrence of the housing bubble. The authors illustrate that the housing bubble essentially originated from the supply-side, as the crisis was triggered by the mispricing of mortgage loans. However, financial institutions failed to acknowledge the additional risk associated with the introduction of new credit instruments from 2003 to 2004, when the market transitioned from utilizing regulated securitization for financing mortgages to applying unregulated securitization (Levitin & Wachter, 2010).

When examining demand-side theories, it is assumed that the housing bubble was driven by an increase in consumer demand for housing, resulting in a surge in home prices (Levitin & Wachter, 2010). According to Shiller (2005), the housing bubble was fueled by consumers' confidence in the continuous appreciation of real estate prices, which subsequently increased the demand for housing finance. Levitin and Wachter (2010) agree that there is consensus regarding the presence of irrational consumer expectations and behaviors. However, it is important to consider how consumer belief alone could have played a significant role in fueling the home price bubble observed in 2006. The consumers required financial resources to sustain the upward trajectory of real estate prices. Therefore, according to Levitin and Wachter (2010), Shiller's argument that the housing bubble can be attributed solely to irrational consumer behavior is an insufficient explanation for the bubbles' emergence without mentioning the role of credit institutions.

Shifting our focus to the supply-side, we will analyze the crucial role of financial intermediaries and regulators in the events leading up to the crisis. According to John B. Taylor (2009), a prominent macroeconomist known for developing the Taylor Rule to direct monetary policy, the housing bubble can be attributed to the mismanagement of monetary policy. Taylor suggests that in the period following 2000, "the Federal Reserve held interest rates too low for too long" (Levitin & Wachter, 2010, p. 1222). The setting of low interest rates resulted in the creation of mortgage credit that was unnaturally cheap, hence stimulating an excessive level of demand for mortgages (Taylor, 2009). Given that mortgages are the most common form of leverage for consumers, Levitin and Wachter (2010) states that "housing was the asset class in which a bubble was most likely to form." (p. 1222).

It is clear that monetary policy had an impact on the housing bubble. Nonetheless, Taylor's analysis of this event appears incomplete for various reasons. Initially, it is important to note that the federal funds rate[3] applies to short-term interest rates. In the context of a housing market primarily characterized by fixed mortgages, the influence of short-term rates on house prices are relatively limited, as highlighted by Negro and Otrok (2007). Therefore, it exists a distinction between the federal-funds rate and the long-term rate applied to mortgages. Prior to the housing bubble in 2006, there were historical occurrences in which a reduction in the federal-funds rate did not result in any formation of a housing market bubble. For instance, during the early 1990s, the effective rate experienced a decrease from approximately 8% to 3%. Thus, previous drops in the federal funds rate itself have not resulted in any formation of housing bubbles (Levitin and Wachter 2010).

Additionally, it should be highlighted that there is a correlation between long-term interest rates and home prices. However, as Glaeser et al. (2010) pointed out, it is crucial to keep in mind that the decline in long-term rates is not the only factor responsible for the entirety of the housing bubble. Through their research, it was discovered that a decrease of 1% in long-term interest rates corresponds to an approximate increase of 8% in house prices.

As the gap between housing prices and fundamental values continued to widen, the banking sector implemented increasingly advanced financial instruments to sustain its expansion. A key component was the large increase in the use of subprime mortgage-backed securities (MBS).[4] Subprime mortgages refer to loans that were granted to individuals with poor credit records. Individuals who obtained subprime mortgages were commonly characterized by inconsistent job histories or a prior history of loan defaults.[5] The interest rates related to subprime loans were commonly two to four percentage points higher in comparison to the current interest rates offered on prime loans granted to individuals possessing a good credit

[3] Federal-funds rate is the target interest set by the Federal Open Market Commitee (FOMC). This is the overnight rate at which commercial banks borrow and lend each other their excess reserves (Chen, 2023).

[4] Mortgage-backed securities (MBS) are similar to bonds. MBS are bundles of house loans and other real estate debt purchased by issuing banks. Like bond coupons, MBS investors receive periodic payments (Kagan, 2023).

[5] Many people with strong credit records were intentionally given subprime mortgages at this time. Bank lending has historically discriminated against African Americans and Hispanics, occasionally resulting in higher interest rates or denial of credit (Baker, 2008).

background. During this period, there was significant growth in the subprime market, from under 9% of the market in 2002 to a substantial 25% by 2005 (Baker, 2008).

Furthermore, according to Baker (2008), a significant set of improper incentives were present in the securitization process within the secondary market. The importance of this procedure lies in the fact that the presence of a secondary market provided mortgage issuers with motivation to approve mortgages, even when they were aware that the borrower would not be able to fully meet the mortgage requirements. The issuers often encountered less risk once the mortgage was transferred to the secondary market, hence motivating them to maximize the issuance of mortgages.

Following that, the banks proceeded to acquire and bundle the loans, subsequently packaging them into MBSs. These financial institutions generated revenue through the fees related to this procedure. Consequently, the securitizers were motivated to prioritize the expansion of loan volume without properly assessing the quality of the loans being bundled or the underlying quality of the MBS being issued. The acceleration of this process was enabled by the extensive use of innovative and more sophisticated financial instruments. For example, financial institutions initiated the issuance of collateralized debt obligations (CDO)[6], incorporating MBS combined with other assets. Due to the novelty of these instruments, the credit rating agencies had limited historical data to base their judgments on. Consequently, credit rating agencies frequently assigned significantly greater investment ratings to CDOs primarily comprised of assets that, in turn, were backed by mortgages characterized by high levels of risk (Baker, 2008).

Underlying the logic of this whole set of developments was an incentive structure, coupled with a weak regulatory system, that placed an enormous premium on short-term profits, often at the expense of longer-term profits or even longer-term corporate survival. The biggest income flowed from generating large fees, even if there would be losses from the assets being sold (Baker, 2008).

[6] A collateralized debt obligation (CDO) is a structured finance derivative that is offered to institutional investors. It is backed by a pool of loans and other assets, which will be used as collateral if the underlying loans goes into default (Tardi, 2023).

Following the occurrence of the financial crisis, significant changes have been learned within the banking industry's framework. In response to the crisis, regulators have implemented measures with the goal of reorganizing the global prudential framework and strengthening supervision. The primary objectives of these reforms have been to enhance the robustness of banks by increasing their capital and liquidity buffers (Buch & Dages, 2018). These reforms will be examined in greater detail in Chapter 3.2.

3.1.2 The Financial Crisis Impact on Europe and Norway

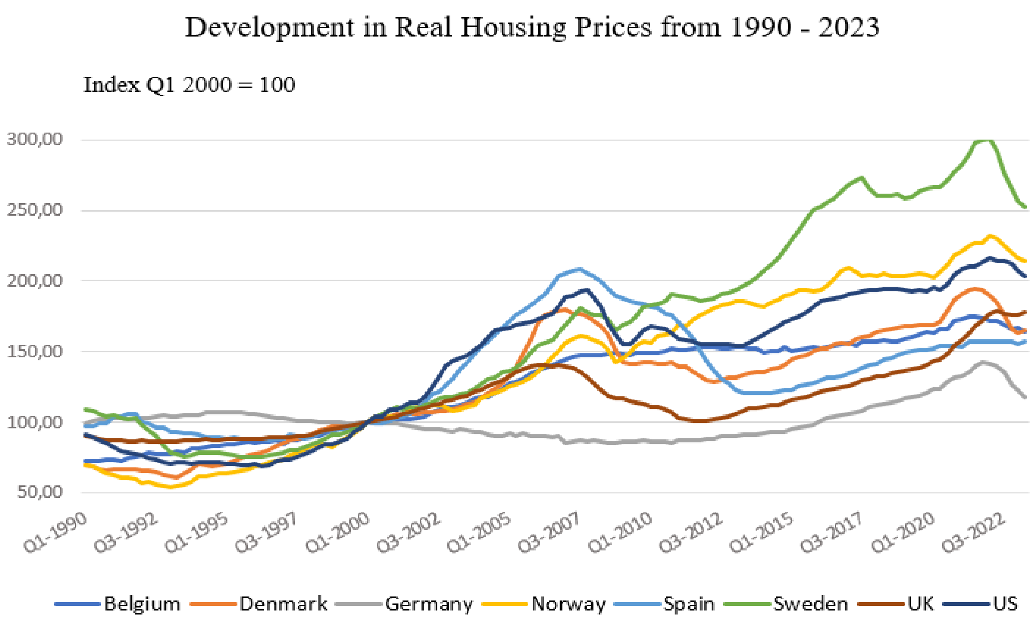
We are now shifting our focus over to see how the crisis originated from US affected Europe and Norway. This section will include a brief discussion about the crisis consequences for European countries and banks, and further delve into the crisis impact on the Norwegian economy before we discuss the consequences on the Norwegian banking sector in chapter 3.1.2.1.

Primarily the United Kingdom, Spain, Denmark, and Belgium experienced a surge in the housing market during the same period as the boom in US housing market. Banks in Belgium, Switzerland, Germany, and Netherlands were exposed to these markets and consequently experienced a banking crisis as well. The primary factor influencing the involvement of European nations in the crisis was their investment in and issuance of US mortgage bonds. Moreover, European financial institutions increased the leverage of their equity by investing in US private debt with dollars borrowed from the American banks (McCauley, 2018). Furthermore, several significant European banks experienced failure, causing market panic. This was followed by a collapse in inter-bank markets, and even financially solid banks drained their liquidity reserves (Grytten, 2011).

Prior to the crisis, Norwegian housing prices experienced great growth. In fact, from 1993 - 2007, the growth in the Norwegian housing market was about twice as much than the US housing market. Further, Grytten (2011) points out that there has been recorded a decrease of approximately 40% in housing prices in US, Spain, Ireland, and Denmark, as well as greater decline in the Baltics. Norway only experienced a fall in real house prices at approximately 18%, 14% in nominal terms, from mid 2007 to the end of 2008.

Figure 3.1 compares the housing prices in Norway, US, UK, Belgium, Denmark, Germany, Spain, and Sweden from 1990 to 2023 with quarterly intervals. From the figure, it is evident that housing prices in Norway had a notable and rapid recovery subsequent to the crisis. Furthermore, the housing market has seen a remarkable and significant increase since 2009.

Figure 3.1 Development in real housing prices in selected countries from 1990 – 2023



Note. The chart presents the development of real housing prices for selected countries from 1990 to 2023, with index = 100 in first quarter year 2000. Own calculations with data collected from the Organization for Economic Cooperation and Development (2023).

Although Norway was not as severely affected by the crisis as the aforementioned nations, it was strongly influenced in the stock market. Norway experienced a collapse greater than many other countries with a decline in the stock market of 64% over a six-month period, from late May to late November in 2008. Nonetheless, the effect on total output in the second quarter of 2009 over the preceding four quarters was comparatively small, considering Norway's open and small economy, as well as in comparison to Sweden, Denmark, and Finland (Grytten, 2011). The small effect on total output and the rapid recovery implies a smaller effect on Norway's real economy compared to other nations.

In conclusion, what originated as a liquidity crisis in several countries ended up in a solvency crisis. This was not the case for Norway as government measures prevented a rapid spread of the crisis to solvency and the real economy by financial stimulation, e.g., providing loan agreements and injecting capital into banks (Gjedrem, 2009). As we further will discuss, the crisis led to several changes to strengthen the financial system in Norway and the world.

3.1.2.1 Consequences on Banking Regulation

In this chapter we are going to look at how the new regulations that were formed as a consequence to the financial crisis affected Norwegian banking regulation. Moreover, we will specify which regulations Norwegian banks must follow, and further compare the effects of implementation with Norway and European nations.[7]

Norwegian banks are required to adhere to European Union (EU) banking regulation, including any national adaptations they allow for, as a result of Norway's participation in the European Economic Area (EEA). Furthermore, the EU is obligated to adhere to the international regulations established by the Basel Committee. Implicitly, it may be inferred that Norwegian banking regulation is significantly influenced by international standards (Lund & Nordal, 2017). In subsequent sections, we will explore in further details the extent to which Norwegian banks are obligated to meet these standards, as well as the ways in which the Norwegian banking system differs from other central nations.

In accordance with the previous paragraph's elucidation, the primary principle governing Norwegian banking regulation requires adherence to the regulations established by the Basel Committee. Due to the relatively moderate impact of the financial crisis on the Norwegian economy compared to other major economies, Norwegian banks advanced the implementation of the Basel III capital requirements faster than the required timeline. Additionally, since 2016, the Norwegian Financial Supervisory Authority has played a significant role in tightening capital requirements related to Pillar II for Norwegian banks compared to other nations (Lund & Nordal, 2017).

Countries obliged to implement the new regulations have been affected in different ways. A main component for the adaption is the respond to the requirement for capital adequacy ratio

[7] See chapter 3.2 “Basel Framework” for more details on the establishment of the Basel Commiitee and specific requirements they provided as a consequence to the Financial Crisis.

(CAR).[8] Banks have the option of raising their common equity tier 1 (CET1) capital and tier 2 capital or reduce their allocation of risk-weighted assets to increase their CAR. For instance, Norway and Sweden have demonstrated good results throughout their transitional phase primarily through the increase of their CET1 capital. Additionally, Norwegian banks have witnessed a notable rise in the use of their own models for the purpose of determining risk-weights when evaluating their risk-weighted assets (RWA) (the denominator). As a result, there has been a decrease in the average risk-weights applied when determining their RWA, hence resulting in an increased CAR. This presents a distinct difference in comparison to other European countries, whereas weak economic growth has led to mediocre results and lower return on equity for banks. Furthermore, the primary emphasis of their efforts has been directed at reducing the exposure related to the risk-weighted assets, and, to some extent, increased their issuance of new capital (Lund & Nordal, 2017).

Another distinction between Norway and other countries required to follow the Basel Committee regulation is the approach in valuation of liquid assets in relation to the numerator within the LCR.[9] Government securities play a significant role as a source of liquid assets for calculating the LCR. The Basel Committee proposed that nations with limited access to government securities markets should be permitted to utilize other financial instruments to achieve a sufficient LCR. Norway, along with several other nations in EEA, was considered as a potential candidate for receiving special treatment. Nonetheless, Norway was the only country granted special treatment. Consequently, Norway was allowed to use HQLA with foreign currency to achieve a satisfactory LCR. Additionally, the Basel Committee allowed for a creation of an own loan agreement with the central bank of Norway (Lund & Nordal, 2017).

Throughout this discussion we have made it clear that Norwegian banks are obliged to follow regulation from EU, and hence the Basel committee, as a result of their involment in EEA. Due to the special features of Norway's small and open economy, it is apparent that Norwegian banking sector have had specific regulations that deviates from other central nations in Europe when adhering to new capital requirements. Consequently, this has made it easier for the banks

[8] See chapter 3.2.5 for further elaboration of the CAR.

[9] See chapter 3.3.3 for more detailed explanation of the valuation of HQLA.

to fulfill the requirements. Finally, it is worth highlighting the significance of the Norwegian Financial Supervisory Authority’s involvement in the implementation of increased capital requirements to strengthen Norwegian banking sector.

3.2 Basel Framework

The Basel Committee introduced the Basel framework in early 1980s, with the implementation of Basel I as a response to the Latin American debt crisis and the ever rise of risks associated to the globalization of economies. Moreover, the Basel Committee has had an important saying in controlling global banking regulation. Hence, we find it meaningful to give an elaboration of the relevant implementations the Basel Committee has recently undergone, specifically Basel II and Basel III.

3.2.1 Basel II

Furthermore, the Bank for International Settlements (2018) writes that in June 1999, the Committee proposed a fresh capital adequacy framework to replace the 1988 Accord. In June 2004, the revised framework, known as "Basel II," introduced three key pillars:

1. <u>Minimum Capital Requirements:</u> Pillar 1 sets the minimum capital requirements for banks. These requirements are designed to ensure that banks have sufficient capital to absorb losses and avoid insolvency.
2. <u>Supervisory Review:</u> Pillar 2, Supervisors, i.e., the Financial Supervisory Authority of Norway, have authority to impose additional capital requirements on banks to address risks that are not captured in Pillar 1.
3. <u>Marketing Discipline:</u> Pillar 3 encourages effective disclosure and transparency by making it easier for investors and other stakeholders to assess the banks risk.

Basel II aimed to create more accurate regulatory capital requirements and address recent financial innovations. It sought to reward improvements in risk measurement and control. Adoption of new standards was complicated by the need for approvals for risk measuring methods across jurisdictions. In 2006, the Committee issued information-sharing instructions as well as advice on supervisory collaboration and allocation methods, notably for advanced measuring methodologies for operational risk (Bank for International Settlements, 2018).

3.2.2 Basel III

The inception of the Basel III framework stems from the aftermath of the global financial crisis of 2008, which exposed weaknesses in banking regulations. The primary objective of these newly implemented rules is to foster a more stable and resilient banking and financial sector, capable of weathering economic challenges, regardless of their origins. This is to prevent the spread of financial market disturbances into the real economy, as observed during the financial crisis of 2008. Basel III essentially constitutes a package of reforms built upon the insights gained from the financial crisis. These reforms aim to improve risk management, transparency, and governance in banks, along with bolstering the oversight of banks deemed systemically significant (Bank for International Settlements, 2011).

Furthermore, the Bank for International Settlements (2011) explains that Basel III extends its foundation from the three pillars established in the Basel II framework, amplifying the quality and quantity of minimum capital prerequisites. The first pillar sets out the minimum capital coverage requirements, while the second pillar delves into banks' internal capital assessments and regulatory supervision. The third pillar encompasses the public disclosure and communication of vital factors such as capital, risk exposure, organizational structure, and capital demands. In the subsequent parts, we will examine the new liquidity- and capital requirements implemented in Basel III.

1. **Liquidity Requirements**

Basel III introduces new liquidity regulations to address the issue of insufficient liquid assets that banks maintained during the global financial crisis. Banks were unable to meet their obligations, necessitating government intervention to provide liquidity support. The two new liquidity requirements are the following ratios:

<u>Liquidity Coverage Ratio:</u> The LCR enhances banks' resilience to short-term liquidity shortages, ensuring they hold sufficient liquid reserves to cover net cash outflows over a 30-day period. This prepares banks to withstand stress scenarios lasting one month.

Assets that are eligible for the liquidity portfolio are clearly outlined in Chapter 3.3.2.

Net Stable Funding Ratio: The NSFR incentivizes banks to improve the longer-term structural funding of their balance sheets, including off-balance sheet exposures and capital markets activities.

Banks are now obligated to consolidate, calculate, test, and report their liquidity positions to regulators regularly, often at frequent intervals. These challenges involve producing timely reports in standardized regulatory formats, performing stress testing, data gathering, and auditing. Integrating liquidity risk management across various bank functions, including treasury-, balance sheet-, and risk management, remains another key challenge for banks (Moody's Analytics, 2011).

2. Capital Requirements

The new capital requirements followed by Basel III were a response to solvency issues faced by banks during the financial crisis. Consequently, the new capital requirements focus on robustness against loan defaults, higher equity requirements for prominent banks, and dynamic adaptation in response to economic cycles. Furter, we will discuss these implementations in detail.

Systemic risk buffer

The primary objective of the systemic risk buffer is to enhance the robustness of financial institutions against potential loan defaults and other disturbances that may arise due to structural vulnerabilities in the economy and ongoing systemic risks. The Ministry of Finance is evaluating the situation and has the authority to determine the level of systematic risk buffer every two years. The systematic risk buffer rate for Norwegian exposures was raised from 3% before 2020 to 4,5% after 2020, and it have remained on that level (Lovdata, 2014). As seen in figure 3.2, the recent rise in the systematic risk buffer is a consequence of the rising risks in the global economy, high interest rates, and geopolitical tension. Specific for Norway, it is notable that households are significantly leveraged, housing prices have had great growth rate after 2009, and banks are substantially exposed to commercial real estate (Norges Bank, 2023b).

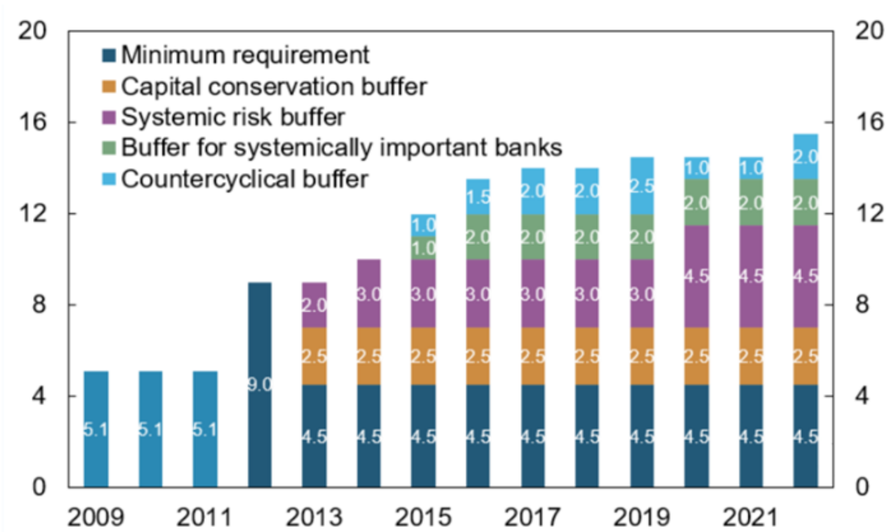
Buffer for systemically important institutions

Systemically important institutions are subject to a higher CET1 capital requirement due to their systemic importance and significant impact on both the financial system and the real economy. This measure aims to decrease the likelihood of these institutions encountering financial difficulties, which could potentially have significant adverse effects on both the financial system and the real economy. Consequently, the Ministry of Finance shall decide which institutions that are designated as systemically important in Norway, and thus are subject to an increased capital buffer of one to two percentage points (Lovdata, 2014).

<u>Countercyclical capital buffer</u>

The intention of the countercyclical capital buffer (CCB) is to enhance the robustness of financial institutions in periods with great credit expansion in financial markets. Additionally, it aims to minimize the likelihood of these institutions extending a potential economic decline by limiting their lending activities. Norges Bank determines the CCB rate quarterly and it is decided that the CCB rate shall span between 0% to 2,5%. The CCB rate applicable to Norwegian exposures is currently set at 2,5% (Lovdata, 2021).

Figure 3.2 Pillar 1 requirements for Norwegian banks from 2009 - 2022, in percentage



Note. The updated requirement for countercyclical capital buffer is 2,5%, as of 14 of August 2023 (The Financial Supervisory Authority of Norway, 2023). The chart is collected from Norges Bank staff memo: *Optimal capital adequacy ratio for Norwegian banks* (Andersen & Juelsrud, 2022).

3.3 Liquidity Coverage Ratio

This chapter aims to offer a comprehensive description of the LCR, following up on Chapter 3.1's examination of the necessity for regulation of bank liquidity. The discussion will include an exploration of its complexity and clarify the way banks use the LCR as a tool for effectively managing their liquidity risk. Additionally, our objective is to provide an overview of the characteristics and required haircuts appropriate for different asset classes.

3.3.1 Introduction and Background

The LCR represents a significant change implemented by the Basel Committee on Banking Supervision with the objective of enhancing the resilience within the banking industry. The primary aim of the LCR is to strengthen the "short-term resilience of a bank's liquidity risk profile by ensuring that it has sufficient HQLA to survive a significant stress scenario lasting for one month" (Bank for International Settlements, 2013, p. 7). Further, the liquidity reserve is valued at market value and is reduced by a factor (haircut) that reflects the estimated loss of value in the event of financial stress (Norges Bank, 2023). The LCR, as defined by the Bank for International Settlements (2013), is a ratio that consists of the numerator, which represents unencumbered[10] HQLA, and the denominator, which represents the total net cash outflows expected to occur during the next 30 calendar days.

$$LCR = \frac{Stock\ of\ High-Quality\ Liquid\ Assets\ (HQLA)}{Total\ net\ cash\ outflows\ over\ the\ next\ 30\ calendar\ days} \geq 100\%$$

The LCR is expected to improve the banking industry's capacity to withstand and mitigate the impact of financial and economic disturbances, regardless of their origin. Consequently, this measure is anticipated to decrease the likelihood of adverse effects spreading from the

[10] The term "unmencumbered" refers to the state of being without any legal, regulatory, contractual, or other limitations that might limit the bank's ability to liquidate, sell, transfer, or assign the asset (Bank for International Settlements, 2013).

financial sector to the real economy. The crisis underlined the significance of liquidity in facilitating the effective operation of financial markets and the banking industry. Prior to the crisis, asset markets indicated a positive and optimistic trend, while the accessibility of capital was available at a relatively low cost. The sudden shift in market conditions demonstrated the quick drain of liquidity, displaying the potential for extended periods of illiquidity. The banking sector experienced significant stress, triggering the need for involvement by central banks to ensure the proper operation of money markets and, in certain instances, to provide support to specific institutions (Bank for International Settlements, 2013).

In recognition of the limits of the LCR as a standalone measurement for assessing a bank's liquidity profile, the Committee has devised an additional set of monitoring tools, e.g., the framework of Sound Principles and the NSFR. These measures aim to enhance and foster global standardization in the supervision of liquidity risk (The Financial Supervisory Authority of Norway, 2022). According to the Bank for International Settlements (2013), these instruments serve as supplements to the LCR and are intended for the continuous monitoring of banks' liquidity risk exposures. For example, in Norway, it is mandatory for commercial banks and credit institutions to quarterly disclose their LCR-calculations, as per the requirements for “Disclosure of financial information” outlined by The Financial Supervisory Authority of Norway (2018). To access the LCR-calculation related to Norwegian banks and credit institutions, one can simply refer to the “Investor Relations Pillar 3” documentation.

The implementation of the LCR requirement commenced on January 1, 2015. This strategy was used to ensure that the introduction of the liquid capital requirement did not disrupt the regular financing of economic activities. The progressive implementation process can be seen in the table presented below.

Table 3.1 Gradually implementation of LCR requirement

	1 January 2015	1 January 2016	1 January 2017	1 January 2018	1 January 2019
Minimum LCR	60%	70%	80%	90%	100%

3.3.2 Characteristics of High-Quality Liquid Assets

The stock of HQLA consists of the liquidity portfolio for financial institutions and constitutes the numerator of the LCR. This chapter will outline the defining qualities of assets and the operational standards that must be met for them to be included in a bank's liquidity portfolio.

Assets must possess liquidity in markets during periods of stress, and, ideally, be central bank eligible to be classified as HQLA (Bank for International Settlements, 2013).[11] Liquidity refer to assets ability to be easily and quickly converted into cash with minimal or no depreciation in value. The liquidity of an asset is conditional upon several factors, including the specific stress scenario affecting it, the magnitude of the volume that may be converted into cash, and the duration of time under consideration (Bank for International Settlements, 2013). In the subsequent sections, we will explore the fundamental and market-related characteristics associated with HQLA.

The Basel Committee on Banking Supervision (2013, p. 13) states four fundamental characteristics for HQLA:

1. Low risk: Assets with lower risk levels tend to have greater liquidity. Low risk is enhanced by several factors, e.g., low credit- and liquidty risk.

2. Ease and certainty of valuation: The pricing method for HQLA should be straightforward and not rely on significant assumptions. Also, the pricing formula and its inputs must be publicly available. In general, the liquidity of an asset improves when there is greater agreement among market participants on the asset's valuation.

3. Low correlation with risky assets: Risky assets tends to be more illiquid. In order for an asset to be more liquid, it should have low correlation with risky assets. Assets issued

[11] Eligible assets for central banks refer to assets that can be utilized by central banks as collateral for their operational activities. These assets are commonly characterized by their high liquidity and ease of valuation, hence considered as safe and secure. The specific assets eligible for central banks vary for different countries, but they typically include government bonds, treasury bills and bank deposits. Eligible assets are important for central banks because they allow them to carry out their functions effectively. They also help to ensure that the financial system is stable and resilient (Bank for International Settlements, 2015). However, it should be noted that "central bank eligibility does not by itself constitute the basis for the categorisation of an asset as HQLA" (Bank for International Settlements, 2013, p. 14).

by financial institutions, for instance, are more vulnerable to turning illiquid during periods of liquidity stress in the banking sector.

4. Listed on a developed and recognized exchange: Beeing included on an exchange enhances the level of transparency associated with an asset.

Furthermore, the Basel Committee on Banking Supervision (2013, p. 14) provide three market-related characteristics HQLA need to obtain:

1. Active and sizeable market: An active and sizeable market can be illustrated by low bid-ask spread, substantial trading volumes, robust market infrastructure, and a diverse range of market participants. The latter helps to reduce market concentration, and hence, improving the certainty of market liquidity.

2. Low volatility: Assets with steady pricing and less volatility are less prone to fire sales to fulfill immediate liquidity needs. The standard deviation of traded prices and spreads are indicators of market volatility. Additionally, historical evidence should demonstrate a sense of stability in relation to market conditions and trading volumes during stressful periods.

3. Flight to quality: Historically, during periods of systemic crises, the market has shown a tendency for reallocating investments into these specific categories of assets.

As defined by the mentioned characteristics, a prevalent criterion is whether or not "high quality" assets are liquid. The liquid-generating capacity of these assets should remain unaffected during a period of market stress. Conversely, lower quality assets generally fall short of satisfying that criterion, thus leading to reduced valuations in stress scenarios. In conclusion, the purpose of these requirements is to guarantee that the bank's liquidity portfolio is effectively managed. This enables immediate conversion of the stock of HQLA assets into cash, to cover funding deficits between cash inflows and outflows at any moment throughout the 30-day stress period (Bank for International Settlements, 2013).

3.3.3 Valuation of High-Quality Liquid Assets

In the previous chapter, we defined assets that are eligible to be a part of the HQLA portfolio. Further, the assets are divided into three categories, namely Level 1, Level 2A, and Level 2B assets. Each category aims to reflect the different levels of liquidity and quality of the assets. The most liquid and highest quality assets are assigned the highest level of HQLA (Level 1), while the least liquid and lowest quality assets are assigned the lowest levels of HQLA (Level 2B). In this section, we aim to provide an overview of the assets belonging to each of the levels and their appropriate haircuts in table 3.2, and further delve into the requirements for portfolio diversification.

Note that these definitions are simplified with the aim of making it less complicated.

Table 3.2 Valuation of HQLA with haircuts and portfolio constraints

Valuation of High-Quality Liquid Assets

Level	Asset	Haircut	Portfolio Constraints	
	Coins and banknotes	0 %		
	Exposure to central banks	0 %		
	Government securities	0 %		
	Assets guaranteed by central or regional governements, local authorities, or public sector entities, treated as exposure to central government	0 %	> 30%	
1	Assets issued by credit intitutions	0 %		> 60%
	Shares or units in CIUs, ex. extremely high-quality covered bonds	5 %		
	Extremely high-quality covered bonds (EEA), credit quality step 1, > NOK 6 bn	7 %		
	Shares or units in CIUs for extremely high-quality covered bonds	12 %		
	Securities issued by regional governments, local authorities or public sector entities	15 %		
	High-quality covered bonds (EEA), credit quality step 2, > NOK 3 bn	15 %		
2A	High-quality covered bonds (third country), credit quality step 1	15 %		
	Corporate debt securities, max 10 years time to maturity, credit quality step 1, > NOK 3 bn	15 %		
	Exposure to third countries	15 %		
	Shares or units in CIUs, level 2A assets	20 %		
	Asset Backed Securities, NOK 800 m	25% / 30%		
	Corporate debt securities, max 10 years time to maturity, credit quality step 3, > NOK 3 bn	50 %		
	Shares, part of a major stock index	50 %		
2B	High-quality covered bonds, underlying assets 35% or lower risk weight, > NOK 3 bn	30 %	< 15%	
	Shares or units in CIUs			
	- Mortgage and auto loans	30 %		
	- Level 2B covered bonds	35 %		
	- Consumer and corporate loans	40 %		
	- Level 2B corporate debt securities and shares	55 %		

Note. The table provides assets that are HQLA eligible, with following portfolio constraints, and haircuts applied. The information is collected from Lovdata (2014), documents provided by Sparebank 1, and Commission Delegated Regulation (EU) 2015/61 (2015).

3.3.4 Composition of Liquidity Portfolio by Asset Level

The purpose of these regulations is to establish measures to ensure that banks maintain a diversified portfolio of HQLA. Diversification is of essential importance due to its ability to mitigate liquidity risk. If a bank concentrates all of its HQLA into a single asset class, such as government bonds, it becomes highly vulnerable to any shocks occurring within the specific asset class, e.g., a rise in interest rates. Consequently, this will reduce the value of the bonds, and thus reduce the banks liquidity.

The following requirements need to be met after appropriate haircuts have been applied:

a) A minimum of 60% of the HQLA shall be composed of level 1 assets.

b) A minimum of 30% of the HQLA shall be composed of level 1 assets, excluding extremely high-quality covered bonds, as referred to in point f) under level 1 assets.

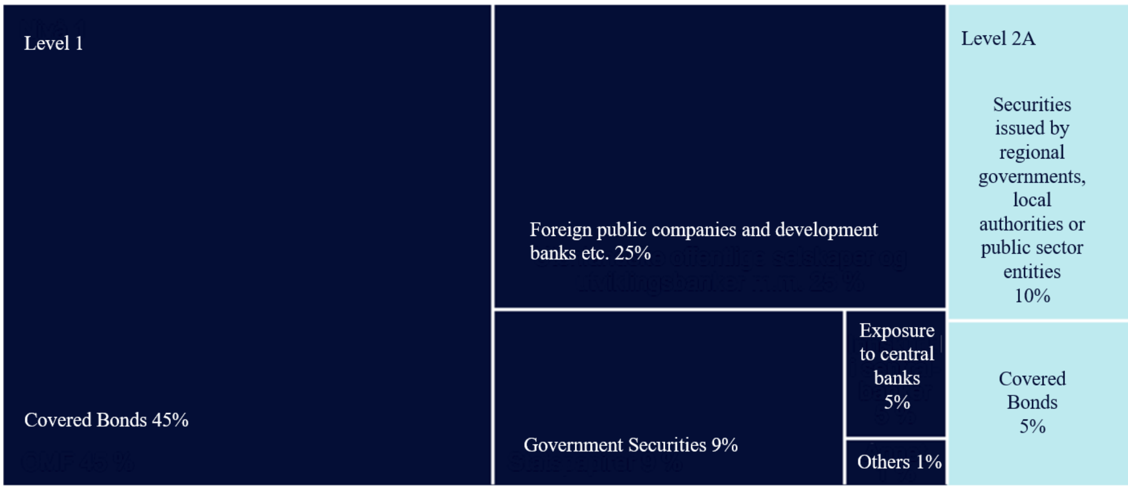
c) With respect to point a), there is an implicit requirement of a 40% cap of the HQLA being composed of level 2 assets.

d) A maximum of 15% of the HQLA may be composed of level 2B assets.

Norwegian banks adopt a strategic approach to manage their liquidity reserves, primarily denominated in Norwegian kroner. A substantial portion of these reserves comprises covered bonds alongside government or government-guaranteed securities, as visually elucidated in figure 3.3, which displays our reference portfolio. These assets function as a vital safety net, ensuring that banks have prompt access to liquidity when the need arises. Their valuation is contingent on market assessments, reflecting their current market value.

In the context of Norwegian banks, a substantial portion of their liquidity reserves is comprised of assets with relatively short maturities, many of which become available within three years (Norges Bank, 2023). Having these assets with shorter maturities means they are less sensitive to changes in interest rates, i.e., duration risk. Further, these assets are highly liquid, making them easy to sell, and they are often accepted by other banks as collateral, enhancing security. Additionally, level 2B is rarely included in banks liquidity portfolio due to their high haircuts.

Figure 3.3 The composition of liquidity portfolio for Norwegian banks in NOK, per 31.03.2023.



Note. The figure represents the average composition of the liquidity portfolio for Norwegian banks in NOK, per 31.03.2023. The data is collected from the Financial Supervisory Authority of Norway, from Norges Bank report, Financial Stability 2023 - 1st semester (2023).

3.3.5 Total Net Cash Outflows

The term "total net cash outflows"[12] is defined as the result of subtracting total expected cash inflows from total expected cash outflows in a specific stress scenario for the upcoming 30 calendar days. To calculate total expected cash outflows, we multiply the current balances of different liability categories and off-balance sheet commitments by the associated run-off rate. Total expected cash inflows, on the other hand, are determined by multiplying the current balances of various contractual receivables by the appropriate flow in rate, up to a maximum limit of 75% of the total expected cash outflows (Bank for International Settlements, 2023).

[12] When relevant, the calculation of cash inflows and outflows should take into account any expected interest to be received and paid within the 30-day period.

The calculation of total net cash outflows is shown below:

$$Total\ net\ cash\ outflows\ over\ the\ next\ 30\ days$$

$$= Total\ expected\ cash\ outflows - min(Total\ expected\ cash\ inflows, 75\%\ of\ total\ expected\ cash\ outflows)$$

The outflows, as described in chapter 2 of the commission delegated regulation (2015), include expected payments based on a company's obligations, multiplied by a run-off rate. This rate reflects the expected reduction in a stress situation and is adjusted based on the nature of the obligation. It also varies depending on whether the counterparty can include corresponding assets in their liquidity buffer. The run-off rates are specified for different types of obligations (The financial supervisory authority of Norway, 2015). Table 3.3 provides a clarification for the obligations and following run-off rates.

Table 3.3 Different types of outflows and following run-off rates for outflows

Valuation Outflows	
Non-operational deposits	
Correspondant banking and provisions of prime brokerage deposits	100 %
Deposists by financial customers	100 %
Deposits by other customers	
Covered by the DGS	20 %
Not covered by the DGS	40 %
Additional outflows	
Collateral other than Level 1 assets collateral posted for derivatives	20 %
Level 1 EHQ covered bonds assets collateral posted for derivatives	10 %
Material outflows due to deterioration of own credit quality	100 %
Impact of an adverse market scenario on derivatives transactions	100 %
Outflows from derivatives	100 %
Committed facilities	
Credit facilities	
To retail customers	5 %
To non-financial customers other than retail customers	10 %
To credit institutions	
For funding promotional loans of retail customers	5 %
For funding promotional loans of non-financial customers	10 %
Other	40 %
To regulated financial institutions other than credit institutions	40 %
Within IPS or cooperative network if treated as liquid asset by the depositing institution	75 %
To other financial customers	100 %

Note. DGS stands for deposit guarantee scheme. The source used to assemble this table is gathered through emails with the Financial Supervisory Authority of Norway, providing us with *Annex 24* and *LCR Calculation Tool.*

Inflows, as described in articles 31 to 34 of the commission delegated regulation (2015), include expected liquidity inputs from exposures that are not in arrears. Expected payments from central banks and financial customers have an input factor of 100%, while payments from non-financial customers typically have an input factor of 50% (The financial supervisory authority of Norway, 2015). As seen below, table 3.4 provides specific input factors for given inflows.

Table 3.4 Different types of inflows and belonging input factor

Valuation Inflows

Inflows	**Input Factor**
Inflows from unsecured transactions/deposits	
Monies due from non-financial customers (except for central banks) not corresponding to principal repayment	100 %
Monies due from retail customers	50 %
Monies due from non-financial corporates	50 %
Monies due from sovereigns, multilateral development banks and public sector entities	50 %
Monies due from other legal entities	50 %
Monies due from central banks	100 %
Monies due from financial customers	100 %
Monies due from trade financing transactions	100 %
Monies due from securities maturing within 30 days	100 %
Loans with an undefined contractual end date	20 %
Monies due from positions in major index equity instruments provided that there is no double counting with liquid assets	100 %
Inflows from the release of balances held in segregated accounts in accordance with regulatory requirements for the protection of customer trading assets	100 %
Inflows from derivatives	100 %
Other inflows	100 %
Inflows from secured lending and capital market-driven transactions	
Level 1 collateral, EHQ covered bonds	7 %
Level 2A collateral	15 %
Level 2B ABS (residential or auto) collateral	25 %
Level 2B high quality covered bonds collateral	30 %
Level 2B ABS (commericial or individuals) collateral	35 %
Other Level 2B assets	50 %

Note. The source used to assemble this table is gathered through emails with the Financial Supervisory Authority of Norway, providing us with *Annex 24* and *LCR Calculation Tool.*

We will not delve further into the details outlined above, as the primary focus of our task lies in the management of assets in the numerator of the LCR. The details about outflows and inflows, as discussed, provide context to the broader regulatory framework, but our primary emphasis remains on understanding and addressing the challenges related to asset management in the context of LCR.

3.4 Net Stable Funding Ratio

The Net Stable Funding Ratio (NSFR) is another crucial component of the post-crisis reforms. It ensures that banks finance less liquid assets, such as loans, with stable funding, reducing their vulnerability to frequent refinancing needs. Stable funding, in this context, includes equity, bond debt with a remaining maturity of over one-year, guaranteed deposits, and deposits from small and medium-sized businesses. The NSFR restricts banks' capacity to finance less liquid assets with volatile deposits and short-term loans (Norges Bank, 2023).

The NSFR is expressed as a ratio that should be at or above 100%. This ratio relates a bank's available stable funding to its required stable funding, and its calculation involves various factors reflecting supervisory assumptions about the liquidity characteristics of different funding sources and exposures.

In the absence of regulatory standards, banks may not always have strong incentives to avoid excessive reliance on volatile, short-term funding for their core assets. During periods of financial stability, banks can be inclined to expand their balance sheets rapidly, relying on short-term, cost-effective, and readily available wholesale funding. The NSFR seeks to address this issue by ensuring that banks maintain a stable funding structure over the long term (Bank for International Settlements, 2018).

Mutual trust between institutions and consumers in the banking sector serves as the cornerstone of a secure deposit base. Instances where trust erodes, resulting in substantial and rapid withdrawals of deposits, were influential factors in the challenges faced by Silicon Valley Bank, Signature Bank, Credit Suisse, and First Republic Bank. In Norway, robustly capitalized, cost-efficient, and profitable banks mitigate the risk of such occurrences. This, in turn, instills trust in the banking system, bolstered by stringent regulation and vigilant oversight (Norges Bank, 2023).

Banks also shoulder the responsibility of implementing effective risk management practices. Furthermore, banks are obliged to disclose information that empowers market participants to gauge risk profiles, capital adequacy, governance, and control (aligned with Pillar 3 requirements). This disclosure mechanism fosters market discipline and streamlines investor evaluations of banking sector risk. In contrast, the reporting of deposits lacks a standardized framework. Ultimately, transparency regarding a bank's governance, risk profile, and financial standing plays a pivotal role in nurturing trust in the banking sector, which, in turn, upholds the stability of deposits (Norges Bank, 2023).

4. Liquidity Portfolio Management

In this chapter we delve into the liquidity portfolio management in Norwegian banks. Specifically, this section starts by exploring the use of capital and its following costs in respect to pillar 1 and 2 for Norwegian banks. Lastly, an introduction for the MPT and the MVP will be given, in context of our analysis.

4.1 Equity Use in LCR Management

The increase in banks' equity capital improves their capacity to absorb losses, thereby reducing the risk of banking crises. However, this comes with a trade-off as higher equity can lead to increased funding costs. If these costs are transferred to loan customers, it could result in higher interest rates, potentially slowing economic activity.

The credit margin is the difference between the interest rate that a bank charges on its loans and the interest rate that a bank pays on its deposits. To cover equity costs, a bank must have a credit margin that is high enough to generate enough return on equity. The return on equity is a measure of how much return a bank must achieve to compensate its shareholders for the risk they take.

The Basel Committee's 2021 analysis using the NEMO model to assess the impact of Basel III on the Norwegian economy, finding that increased capital requirements can reduce crisis probability by adjusting banks' funding costs and lending margins.[13] Moreover, higher capital adequacy requirements can help reduce crisis costs significantly, as a given loss affects a smaller percentage reduction in the equity ratio when banks have more equity.

4.1.1 Pillar 1 and Pillar 2 costs

Pillar 1 costs are calculated based on the bank's RWAs. RWAs are a measure of the riskiness of a bank's portfolio. The RWAs for a particular asset are based on several factors, including the creditworthiness of the borrower, the type of asset, and the maturity of the asset. The

[13] NEMO is founded on the idea that Norway, with its own currency, can control its own level of inflation over time. As a result, the model requires that monetary policy estimates inflation expectations and directs inflation back to the target. The model posits that while making decisions concerning consumption, investments, wages, and prices, economic agents consider monetary policy and plan ahead (Norges Bank, 2019).

minimum capital requirement is a percentage of RWAs that banks must hold to meet regulatory requirements (Andersen & Juelsrud, 2022).

The Pillar 2 costs are calculated based on the Financial Supervisory Authority of Norway assessment of the bank's risk profile. The supervisory authority may require banks to have higher capital levels than the Pillar 1 requirement if they deem the bank to be a higher risk.

The calculation of Pillar 1 and Pillar 2 costs is a complex process that considers a number of factors. Banks must carefully consider their risk profiles and internal risk management practices to ensure that they are meeting their regulatory capital requirements.

4.1.2 Capital Adequacy and the Required Rate of Return

Capital adequacy ratio (CAR) plays a crucial role in the banking sector, balancing financial stability with the costs of lending. Norwegian banks are recommended to maintain a Common Equity Tier 1 (CET1) ratio between 12% and 19%, with current ratios around 18%. This aligns with international studies, although estimates can vary with changing assumptions (Andersen & Juelsrud, 2022).

The numerator in the CAR consists of capital of various quality. The authorities establish capital adequacy standards, which are based on CET1 capital, tier 1 capital, and subordinated capital, commonly known as tier 2 capital. The prevailing practice in computing and disclosing capital ratios is to mainly utilize CET1 capital, which refers to equity that has been adjusted for specific deductions.[14] The CET1 capital is the initial capital that bears responsibility for absorbing any incurred losses (Andersen & Juelsrud, 2022).

The denominator in the CAR is the RWAs which are calculated by risk-weighting banks' exposure. The relationship between the risk of losses on an exposure and the corresponding risk weight is such that when the chance of losses increases, the risk weight should also increase. Consequently, the bank is required to retain a greater amount of capital for its exposure. The Financial Supervisory Authority of Norway has granted authorization to the major Norwegian banks to employ their own models, known as the internal rating based (IRB)

[14] CET1 denotes the core capital of the bank. The components included within this category consist of common shares, retained earnings, stock surpluses resulting from the issuance of common shares, common shares issued by subsidiaries and held by third parties, and accumulated other comprehensive income (Grant, 2023).

approach, for calculating risk weights. In contrast, smaller banks are required to utilize more standardized and general risk weights, known as the standardized approach (Andersen & Juelsrud, 2022).

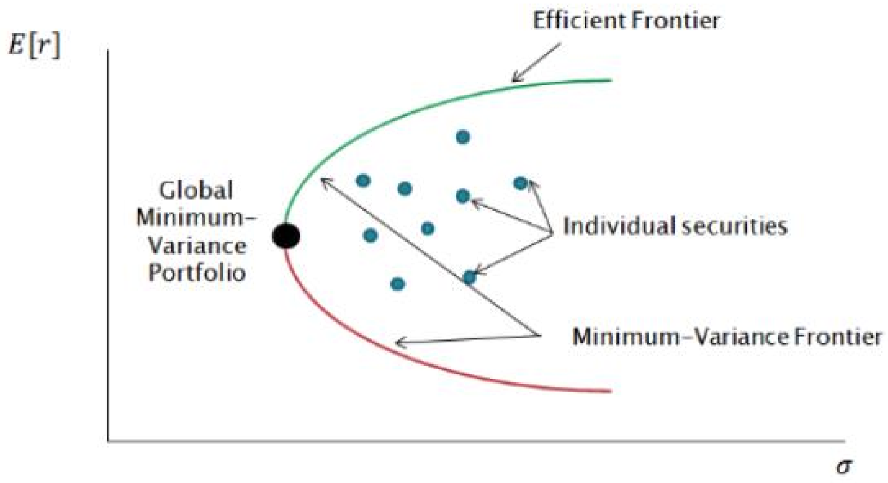
4.2 Modern Portfolio Theory

In financial management, Mean-Variance Analysis (MVA) is a part of Modern Portfolio Theory (MPT), which has fundamentally shaped the way investors approach portfolio construction and risk management. While MPT offers a broad framework for portfolio optimization, mean variance analysis provides the tools necessary for executing this strategy within the constraints of risk and return.

MPT, introduced by Harry Markowitz, revolutionizes investment thinking by advocating for diversification as a method to maximize returns within an optimal risk framework. This theory differentiates between systematic and unsystematic risks. Systematic risk, encompassing market-wide factors such as interest rate fluctuations and recessions, is inherent and inescapable. Unsystematic risk, however, is specific to individual stocks and can be mitigated through a well-diversified portfolio. This diversification not only reduces the overall risk but also shifts the focus from individual stock performance to the collective dynamics of the portfolio (Clarine, 2023).

The efficient frontier is a key concept in MPT, representing portfolios that offer the maximum expected return for each level of risk (Santos, 2022b). This concept underscores the importance of a balanced risk-return trade-off, a central concept within our optimization model. By utilizing mean-variance analysis, we analyze this balance by evaluating the variance against their expected gains. Such an analysis is crucial to our methodology, which seeks to construct portfolios that are optimized within the given constraints of risk and return.

Figure 4.1 Illustration of the efficient frontier



Note. Illustration from Santos (2022b). The efficient frontier, represented in the image as a curve that delineates the set of portfolios that yield the highest return for a given risk level (standard deviation, σ) or the lowest risk for a specific return (expected return, E[r]). The image illustrates this concept through a boundary line above which lie all the optimal combinations of risk and return.

MVA, as an integral part of MPT, focuses on balancing the pursuit of gains with tolerance for risk. It uses variance to measure the spread of potential investment returns, contrasting this with the expected return. This analysis helps investors in two fundamental scenarios: preferring lower variance when expected returns are equal, and favoring higher returns when variance levels are similar. This methodical approach guides investors to select a mix of securities with varying levels of variance and expected returns, thus diversifying the investment risk (Chen & Li, 2021).

MPT and MVA together form a comprehensive approach to investment strategy. They emphasize a balanced view of risk and return, encouraging diversification as a key to achieving efficient portfolios. By employing these strategies, investors can navigate the uncertainties of investing, aiming for optimal returns while managing risk effectively. The theoretical underpinnings of MPT and MVA, as detailed here, will be foundational in understanding the choices and constraints within our optimization model for liquidity portfolios in chapter 7.

5. Methodology and Data

Building upon the concepts presented in chapters three and four, we will now examine our dataset by focusing on essential parts that are central to liquidity portfolio management. The dataset is compiled by Sparebank 1 and includes credit margins acquired from Nordic Bond Pricing. We will start by examining various assumptions and computations employed in the dataset. Additionally, we will provide a concise overview of the primary elements in the dataset using descriptive statistics before getting into the analysis in chapter six and seven.

In the development of this master thesis, we have had the privilege of collaborating closely with two highly respected experts in the finance sector, Roar Snippen and Kristian Semmen. Their expertise and contributions in data selection have been crucial in ensuring that our analysis is relevant and valuable for the actual management of liquidity portfolios in Norwegian savings banks.

Roar Snippen, Chief Financial Officer at Sparebank 1 Sør-Øst Norge, brings over 30 years of experience in various key roles within the finance industry. He holds a degree in economics from the University of Oslo and has also completed auditing education at the University College of Southeast Norway. Snippen has previously worked at Storebrand as the Director of Strategic Risk Management and Investment Strategy, and he served as the Managing Bank Director at Holla and Lunde Savings Bank. Additionally, he has played a significant role as a board member in both Eika Asset Management and Skagerak Maturo Seed AS.

Kristian Semmen is the Head of Fixed Income at SpareBank 1 Markets, with a career spanning 28 years in financial markets. He has formerly served as the Investment Director at Orkla Finans and Storebrand, and as a Fixed Income Manager at the Norges Bank Investment Management. He is also recognized for his academic prowess, notably as a lecturer in Fixed Income at the Norwegian School of Economics (NHH). Semmen has been instrumental in defining the concepts of return and risk for this study, and he has also quality-checked the application of these concepts in our analysis.

In summary, both Snippen and Semmen have shown a deep interest in the Liquidity Coverage Ratio. They have for many years investigated relevant data for Norwegian HQLA. Furthermore, after a discussion with our advisor, it was a natural step to contact these two experts to establish a collaboration. In conclusion, they can be considered some of the leading practitioners and academics in liquidity portfolio management in Norway.

5.1 Description of Dataset

The dataset included in our analysis encompasses the period from October 2016 to October 2023. It consists of weekly observations on credit margins for four distinct asset classes. The selected assets are believed to constitute a well-diversified liquidity portfolio, consisting of the most prevalent assets in relation to the reference portfolio, as indicated in figure 3.4. The dataset comprises level 1 and level 2A assets, with level 2B assets excluded from our analysis. Level 1 assets are categorized into two groups: assets with a 0% haircut, hence "0-weight", and covered bonds. On the other hand, level 2A assets are separated into covered bonds and securities issued by municipality.

Further, our raw data consists of credit margins for four different maturities, namely one, two, three, and five years. These are the given maturities reported by Nordic Bond Pricing. In order to come up with credit margins for maturities of four years, we use linear interpolation, i.e., using three- and five-year data to achieve four-year data. By doing so, we obtain weekly credit margins for one-to-five-year maturities. However, we do not utilize the two- and four-year maturities in our analysis. This approach is solely used so we can calculate the realized excess return for three- and five-year maturities, illustrated in chapter 5.2.2.

LCR portfolios, which primarily consist of nearly credit risk-free bonds, it is crucial to understand that "credit margin" predominantly represents liquidity premiums rather than credit risk. These liquidity premiums have shown strong mean reverting characteristics, meaning that over time they tend to return to a historical average, which is examined in chapter 6.5. This feature minimizes the need for adjustment for expected losses when estimating the realized excess return of these bonds. This understanding is critical for evaluating the performance and risk of LCR bonds, as it affects our interpretation of the credit margins and their impact on the portfolio’s return profile.

According to Semmen, a consistently rising term structure of liquidity premiums is observed. This is a significant difference from the interest rate markets, where implicit rates are often derived from zero-coupon structures. In credit markets, this methodology becomes less relevant, as the term structure is dominated by liquidity premiums rather than expectations of future market developments. Therefore, realized excess return must include a roll down-effect, reflecting a reduction in the expected return over time as the maturity of the bonds shortens. Managers of high-quality bonds, with AA rating or higher, regard credit margins, including the roll down-effect, as the best estimate of realized excess return. Given these characteristics, the credit margin is the natural choice for estimating expected return, which also reflects current market practice.

The different maturities are an important addition in our dataset to see how different maturities are affected by historical events, e.g., under financial stress. Additionally, it is interesting to observe the effect maturities have on the liquidity portfolio, for example if shorter or longer maturities are preferred at the expense of others. As observed in reality, and pointed out earlier, Norwegian banks prefer shorter maturities rather than longer, usually maturing in less than three years, hence they are less exposed for interest rate risk etc. (Norges Bank, 2023). Part two in our analysis will question mark this phenomenon and delve into the optimum portfolio based on our data.

5.2 Descriptive Statistics

Table 5.1 and 5.2 provide various statistical measures on credit margins and realized excess return for all the asset classes and maturities. Credit margins are denoted in basis points (bps), where a change of one basis point equals 0,01%-point change. Realized excess return is denoted in percentages.

5.2.1 Credit Margins

The assets display a diverse range of mean values over different time periods, with higher mean values observed for assets that are less liquid. The increase in both the mean and median credit margins for assets with lower liquidity demonstrates a larger risk premium that compensates investors for the assets' reduced liquidity and increased risk. Moreover, the increase in credit margins for longer durations serves as compensation for investors to account for the potential impact of macroeconomic factors, such as inflation and fluctuations in interest rates. Additionally, the disparity between the mean and median values implies that the credit margins do not follow a normal distribution, indicating the presence of skewness in the data.

To summarize, there is a consistent pattern of rising credit margins as the maturity of assets increases. This is accompanied by higher levels of standard deviation, indicating more volatility and risk for longer time periods.

Table 5.1 Descriptive statistics on credit margins, denoted in basis points

Asset	Maturity	Mean	Median	Std.dev	Min	Max
0-weight	1	-8,43	-8,50	0,07 %	-19,00	8,00
	2	-3,52	-5,30	0,07 %	-13,25	11,00
	3	1,28	-1,50	0,07 %	-8,20	15,80
	4	5,21	2,48	0,08 %	-5,95	20,80
	5	9,14	5,98	0,08 %	-3,70	25,80
LCR 1 Covered	1	2,06	0,69	0,06 %	-7,00	38,54
Bonds	2	11,74	9,22	0,08 %	1,80	50,85
	3	20,33	17,57	0,10 %	6,90	59,58
	4	27,40	24,73	0,11 %	10,55	65,80
	5	34,46	31,76	0,13 %	14,20	72,02
LCR 2A Covered	1	6,64	5,45	0,07 %	-2,50	44,11
Bonds	2	16,72	13,95	0,09 %	4,80	55,73
	3	25,96	23,36	0,10 %	10,70	66,26
	4	33,52	31,05	0,12 %	14,99	72,11
	5	41,07	38,76	0,14 %	19,10	77,96
LCR 2A	1	16,63	14,75	0,13 %	-1,60	73,16
Municipality	2	24,60	20,75	0,14 %	8,40	80,92
	3	32,13	29,18	0,14 %	14,30	86,18
	4	39,05	35,95	0,14 %	19,29	90,94
	5	45,96	43,37	0,14 %	23,99	95,69

5.2.2 Realized Excess Return

We have segmented the realized excess return into maturities of one, three, and five years. The rationale for considering these maturities is twofold. Firstly, the four-year credit margins are a function of the three-year and five-year periods. Therefore, it was deemed unnecessary to analyze the results for that specific period. Secondly, two-year maturities were excluded to ensure that the duration between maturities is consistent across all periods. By doing so, we have accumulated sufficient data to analyze returns for both short-term and longer-term durations that are relevant for managing the liquidity portfolio.

The annual realized excess return is calculated using the credit margins, adding the 3 monthly NIBOR and adjusting for the risk-free rate. We apply the Norwegian policy rate as the risk-free rate, as this represents the interest received on overnight deposits in Norges Bank. The formula for realized excess return for one year maturity can be written as follows:

$$3month\ NIBOR + \frac{Credit\ Margin}{100} - rf$$

In order to calculate realized excess return for three- and five-year maturities, we adjust the formula in respect to change in credit margin over time and weight the change by its maturity *d - 1*. Thus, the general realized excess return formula for d maturity can be expressed as follows:

$$3month\ NIBOR + \frac{Credit\ Margin_{\ d}}{100} + \frac{Credit\ Margin_{\ d} - Credit\ Margin_{\ d-1}}{100} * (d-1) - rf$$

Table 5.2 shows a consistent trend across various assets and maturities. As the level of risk and maturity increases, the realized excess return also tends to increase. As a result of this increase in return, there is a corresponding increase in standard deviation, indicating that the volatility or risk associated with these assets is larger. This concept is highly recognized in finance and is referred to as the risk-return tradeoff. However, it is noteworthy to mention that the 2A covered bonds have a greater standard deviation than the 2A municipality for a five-year maturity period. Despite the increased standard deviation of 2A covered bonds, one would anticipate a higher expected excess return for the 2A covered bond compared to 2A municipality. However, this is not observed. This is the only instance within our dataset where the principle of risk-return tradeoff does not hold.

Table 5.2 Descriptive statistics on realized excess return

Asset	Maturity	Mean Annual Return	Median Annual Return	Std.dev	Min	Max
NIBOR 3month		1,44 %	1,10 %	1,13 %	0,19 %	4,77 %
Risk-free rate		0,95 %	0,50 %	1,02 %	0,00 %	4,25 %
		Realized Excess Return				
0-weight	1	0,41 %	0,37 %	0,23 %	-0,03 %	1,18 %
	3	0,60 %	0,55 %	0,25 %	0,12 %	1,38 %
	5	0,74 %	0,68 %	0,27 %	0,26 %	1,54 %
LCR 1 Covered Bonds	1	0,51 %	0,46 %	0,24 %	0,12 %	1,34 %
	3	0,87 %	0,80 %	0,30 %	0,38 %	1,81 %
	5	1,12 %	1,03 %	0,35 %	0,54 %	2,16 %
LCR 2A Covered Bonds	1	0,56 %	0,52 %	0,24 %	0,16 %	1,39 %
	3	0,94 %	0,87 %	0,31 %	0,44 %	1,87 %
	5	1,21 %	1,13 %	0,36 %	0,62 %	2,24 %
LCR 2A Municipality	1	0,66 %	0,57 %	0,29 %	0,24 %	1,65 %
	3	0,97 %	0,88 %	0,32 %	0,47 %	2,00 %
	5	1,23 %	1,18 %	0,32 %	0,66 %	2,11 %

5.2.3 Clarification on credit margin and realized excess return

The distinction between credit margin and realized excess return is a subtle yet vital component of our analysis. The measure of excess return, as depicted in the formula under chapter 5.2.2, is more comprehensive than merely considering the credit margin. It factors in the 3-month NIBOR, which, contrary to being a risk-free rate, is a benchmark lending rate that includes credit risk. The risk-free rate is represented by the central bank's policy rate. In the formula, the risk-free rate has been subtracted to isolate the component of return attributable to taking on additional risk.

Additionally, the formula encapsulates a 'roll-down effect' observable in longer maturities, such as three year and five-year assets. This effect arises from the passage of time as the security 'rolls down' the yield curve. The roll-down effect assumes that the term structure for liquidity premiums is constant and upward-sloping throughout the holding period. For HQLA, this assumption holds according to Semmen, as the term structure in credit markets are dominated by liquidity premiums and not by future market expectations. Consequently, the formula for realized excess return accounts for this effect.

Snippen states that in the context of liquidity portfolio management for banks, it is common practice in Norway for banks to use NIBOR plus credit margin as a benchmark for both funding and investment. It is crucial to incorporate NIBOR into the realized excess return measure to accurately represent the complete compensation investors require for bearing credit risk. This adjustment accounts for the risk-free rate, duration, and the roll-down impact.

5.2.4 Volatility on change in credit margin

In this section, we commence by presenting our formula for measuring an asset's volatility, focusing on changes in credit margins over a 26-week period and adjusting for the asset's duration. The subsequent sections detail our methodical approach in chapters 6 and 7, where we analyze short-term and long-term market dynamics and their impact on the risk profile of HQLA portfolios.

Furthermore, we address the rationale behind our choice of risk measure, exploring why we prioritize standard deviation on changes in credit margin over the standard deviation on realized excess returns. This discussion will shed light on the complexities of risk assessment in portfolio management, specifically highlighting the challenges in accurately capturing the risk associated with varying asset maturities and the practical methodologies employed by portfolio managers.

Volatility for an asset is measured using the following formula:

$$(Standard\ deviation\ of\ n\ week\ change\ in\ credit\ margins\ for\ 26\ weeks * \sqrt{52/n}\ ) * d$$

Here, n represents the number of weeks for change in credit margins and d the duration of the asset.

The choice of a 26-week period is strategic, as it provides sufficient data for a robust calculation of the standard deviation. With 26 observations, we achieve a balance where we have enough data points for an accurate measurement of volatility, while also avoiding the overpowering impact of the rolling effect – the phenomenon where earlier data progressively falls out of the calculation.

In chapter 6, we analyze volatility by applying a 26-week rolling window for 1-week changes in credit margins. The rationale for investigating 1-week changes in credit margins is to obtain an accurate presentation of the development throughout our time series. This approach offers insights into short-term volatility and reflects short-term market dynamics.

In chapter 7, where we analyze optimum solutions for HQLA-portfolio, we use two different periods of change: 12-week and 52-week changes, both over a 26-week window. This allows us to compare the volatility and its impact on portfolio management from a quarterly perspective versus an annual perspective. By using a 26-week window for both these periods of change, we can effectively evaluate how different investment horizons affect the risk profile of the portfolio, while maintaining consistency in our methodological approach.

Choice of Risk Measure

A key question is why we do not use the standard deviation of realized excess return as the measure of risk in our analysis. Firstly, the issue lies in the fact that the realized excess return assumes a consistent yield curve. By applying the mentioned approach, we would underestimate the potential risk associated with longer maturities. Failure to include the appropriate risk parameter results in quite a similar risk for both shorter and longer durations. This will impact our optimal analysis by favoring longer maturities due to their greater realized excess return, leading to a skewed representation of its actual performance.

Secondly, according to Semmen, the most relevant way to account for the risk associated with LCR assets is by examining the volatility on change in credit margin. Moreover, this approach requires an adjustment for the modified duration corresponding to each asset. This is to take into account that pricing of longer duration assets fluctuates more than shorter duration assets. Therefore, our focus in assessing risk is based on volatility in credit margin changes adjusted for modified duration.

Lastly, Semmen further elaborates that in practical scenarios, most portfolio managers prefer to ignore the roll-down effect and focus exclusively on the volatility observed in credit margin fluctuations. Therefore, we exclude the roll-down effect from our risk measurement, thus sticking to accepted market practices.

5.3 Periods applied in our analysis

In our analysis, we will present three distinct periods. While mostly applicable to chapter 7, this information will also enhance the understanding of chapter 6.

Periode 1: 2018 - 2023.

Periode 2: 2020.

Periode 3: 2021 - 2023.

6. Inspection of Dataset

The initial phase of our study analyzes credit margins and realized excess return across various asset classes and maturities in LCR portfolios. Guided by the hypothesis questioning whether credit margins increase with risk and duration, we utilize graphical representations to explore this relationship across one-, three-, and five-year durations. Further, we investigate realized excess return to determine if it increases with risk and duration, uncovering a distinct pattern where excess returns escalate with extended maturity. Additionally, the chapter offers an examination of volatility on change in credit margin and its impact on different asset classes, as well as an analysis of the explanatory variables for the increase in realized excess return using regression analysis. Finally, the Variance Ratio test provides insights into whether credit margins indicate random walk or mean reversion, illuminating key aspects of liquidity portfolio management. This chapter offers comprehensive understanding of the complex dynamics for Norwegian LCR assets, emphasizing the importance of detailed analysis in decision-making processes for portfolio management.

6.1 Credit Margins

In the exploration of credit margins across various asset classes and maturities, our guiding hypothesis is: Do credit margins increase with risk and duration? The graphs for one-, three-, and five-year duration assets provide a visual representation to address this question.

Observing the graphs 6.1, 6.2, and 6.3, a clear pattern emerges across the different maturities for all asset classes. Credit margins exhibit cyclical fluctuations over time, with pronounced highs and lows. A significant surge in credit margins for all asset classes and durations is notably observed around 2020, which can be attributed to the economic impact of the COVID-19 pandemic - a period characterized by heightened market volatility and perceived liquidity risk.

Across the board, the trend is consistent with our hypothesis, as the duration of the assets increases, so do the credit margins. This trend is observed from the one-year assets to the five year assets, indicating that the market compensates for the increased risk associated with longer-term investments. Moreover, this pattern is consistent for different asset classes as well, displayed by higher credit margins for less liquid securities in the LCR hierarchy. This supports our hypothesis for a consistent correlation between duration, risk, and credit margins.

Figure 6.1 Credit margin on 1-year duration assets, in basis points

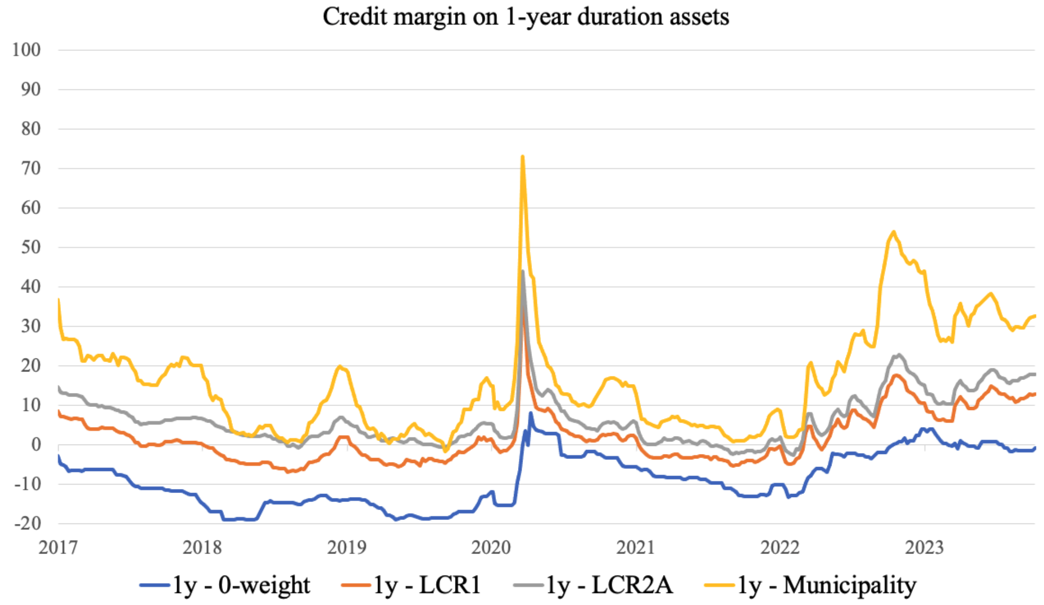


Figure 6.2 Credit margin on 3-year duration assets, in basis points

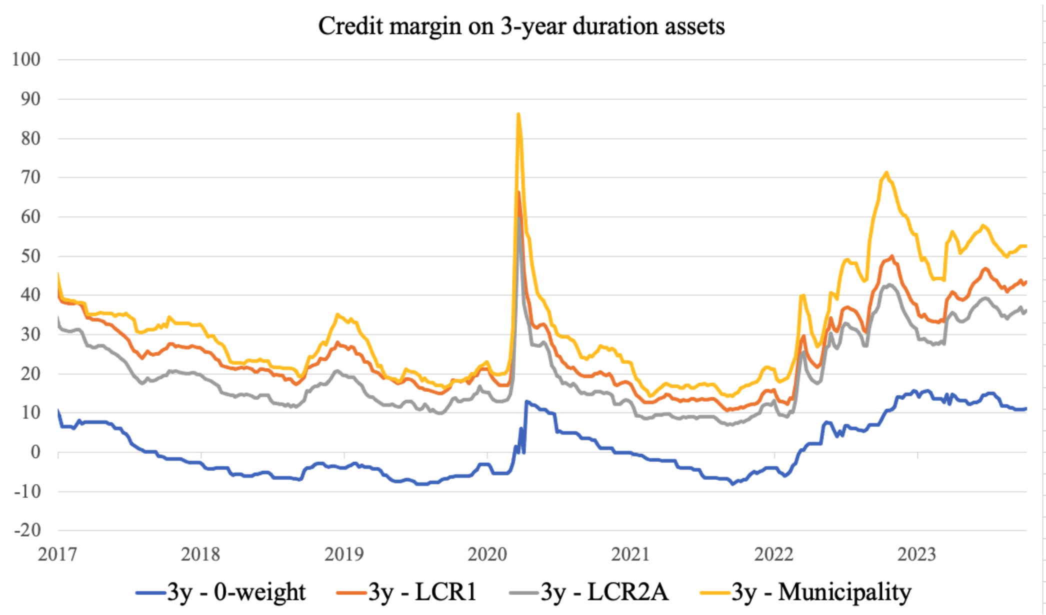
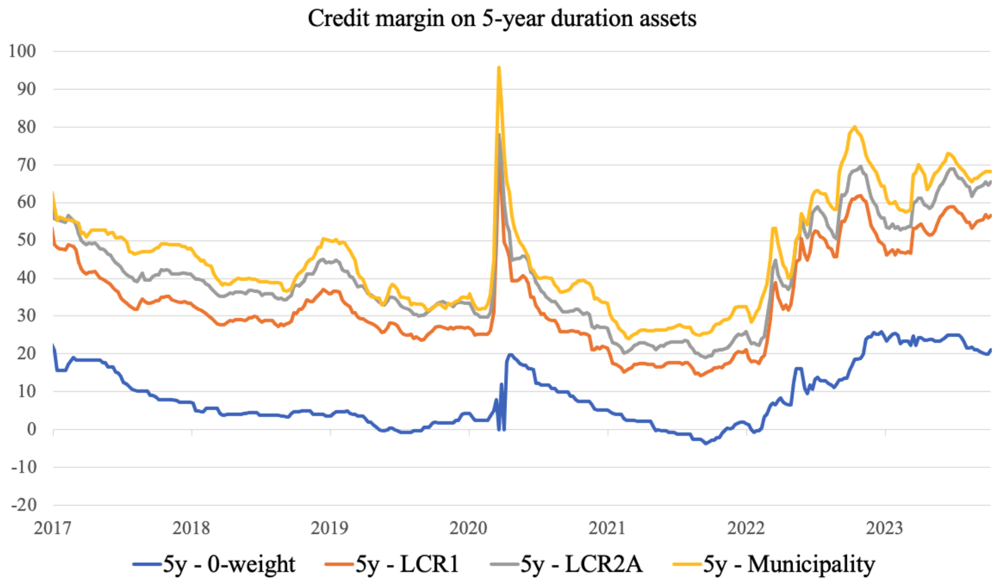


Figure 6.3 Credit margin on 5-year duration assets, in basis points

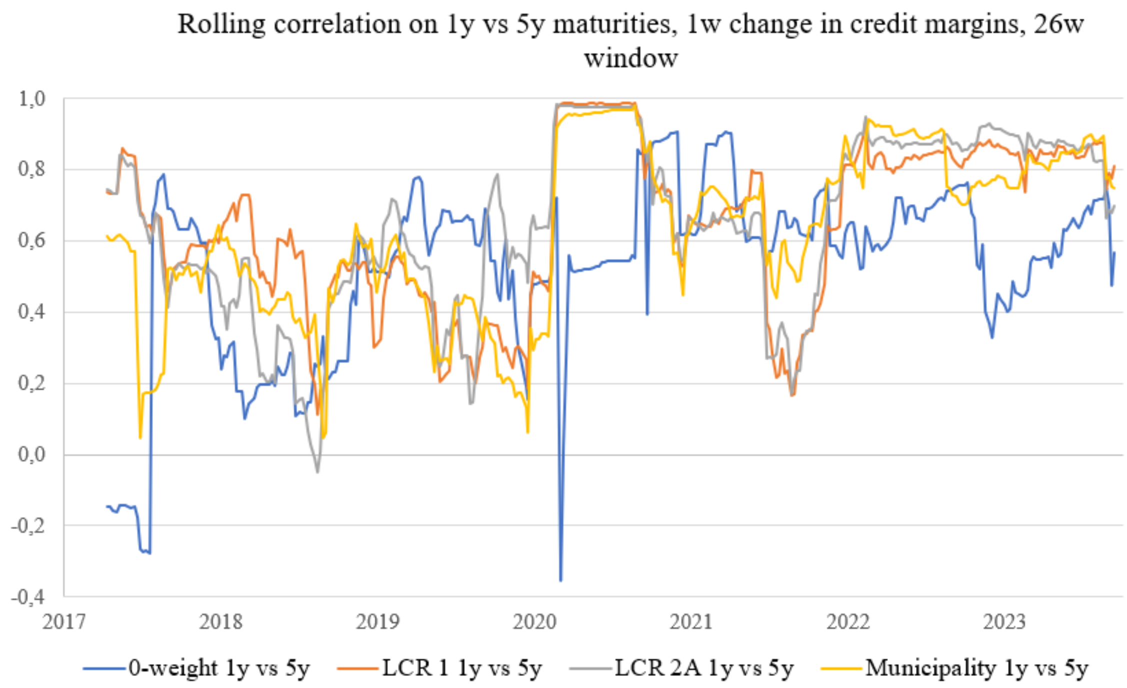


In conclusion, the analysis of the graphs supports the hypothesis that credit margins are positively correlated with both risk and duration. This correlation is essential for liquidity portfolio management, as it indicates that longer-duration assets and higher risk assets demand a higher risk premium. These insights are valuable for portfolio managers in constructing a portfolio that appropriately compensates for the risk profile of the assets.

Figure 6.4 provides a dynamic view of how short-term and long-term credit margin correlations are related over time for 0-weight, LCR 1, LCR 2A, and municipality assets. From the graph, we can observe that the correlations are volatile over the period from 2017 to 2023, with certain years showing higher fluctuations. The period around 2020 stands out, reflecting market reactions to the COVID-19 pandemic and its impact on risk perceptions.

There is a distinct difference for 0-weight and LCR 1, LCR 2A and municipality bonds. Moreover, from the beginning of our time series we observe that 0-weight one-year and five-years have negative correlation. However, due to a rapid increase, all assets follow a reasonable similar trend until 2020, when COVID-19 hits. The pandemic can be said to be a financial stress test for banks in reality, with liquidity risk at its peak. Norges Bank had to inject money into the financial market to maintain liquidity under control. The heightening period is displayed through the rapid drop, followed by a rapid increase, in correlation for one and five year 0-weight assets. On the other hand, LCR 1, LCR 2A and municipality bonds express an opposite trend, where their correlations spike close to one. As market stress diminishes, we observe a decline in correlations for LCR 1, LCR 2A, and municipal bonds, while correlation for 0-weight assets increase. Moreover, the correlation between one-year and five-year maturities for all assets has increased in the past two years, in contrast to the levels recorded between 2017 and 2020.

Figure 6.4 Rolling correlation on 1- and 5-year weekly change in credit margins, 26-week window



The year 2020 stands out markedly for 0-weight assets, which see a precipitous decline in correlation compared to other asset types. This pronounced shift may reflect the market's perception of 0-weight assets as less risky or more liquid during the pandemic's uncertainty, contrasting with the maintained correlation levels in LCR1, LCR2A, and Municipality assets. Such a divergence is indicative of 0-weight assets responding differently to the crisis, possibly due to their safe-haven status, which could attract investors seeking stability amidst the turmoil.

6.2 Realized Excess Return

In this analysis, we address the hypothesis: Does realized excess return increase with risk and duration? We examine this by observing the patterns of excess returns across all asset classes and maturities in the LCR-portfolio as depicted in the graphs.

Figure 6.5, 6.6, and 6.7 shows that there is a distinct trend indicating that excess returns escalate with the extension of maturity. This pattern can partly be attributed to the fact that longer maturities carry higher interest rate risk, for which investors demand compensation in the form of increased returns. Simultaneously, the graphs indicate that during periods of economic turbulence, such as the financial market volatility experienced in 2020, all asset classes have undergone significant fluctuations in excess returns, reflecting the inherent risk and the resulting pricing of this risk in the market. Furthermore, the analysis of the graphs shows that LCR managers receive higher realized excess returns when they extend the duration of their portfolios or when they maximize holdings in the less liquid parts of the LCR hierarchy.

Figure 6.5 Realized excess return on 1-year duration assets, in percentage

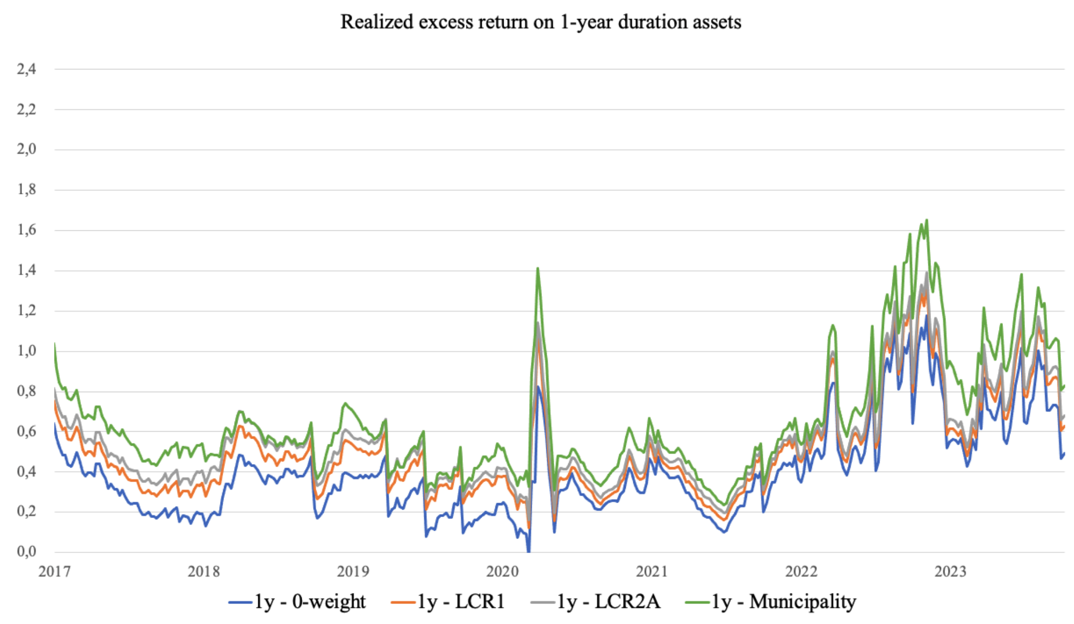


Figure 6.6 Realized excess return on 3-year duration assets, in percentage

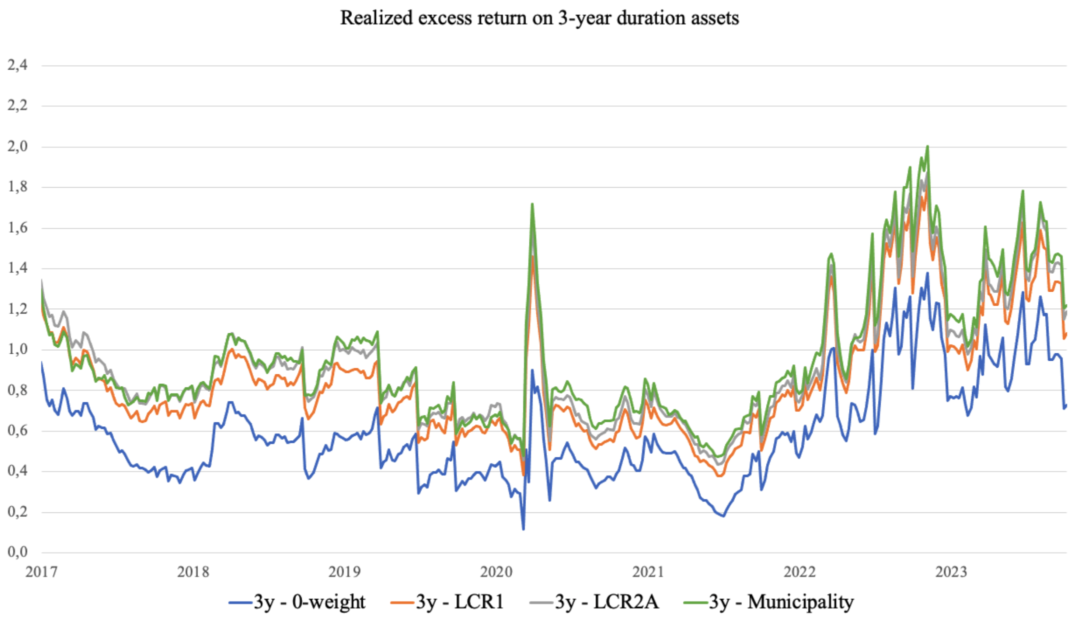
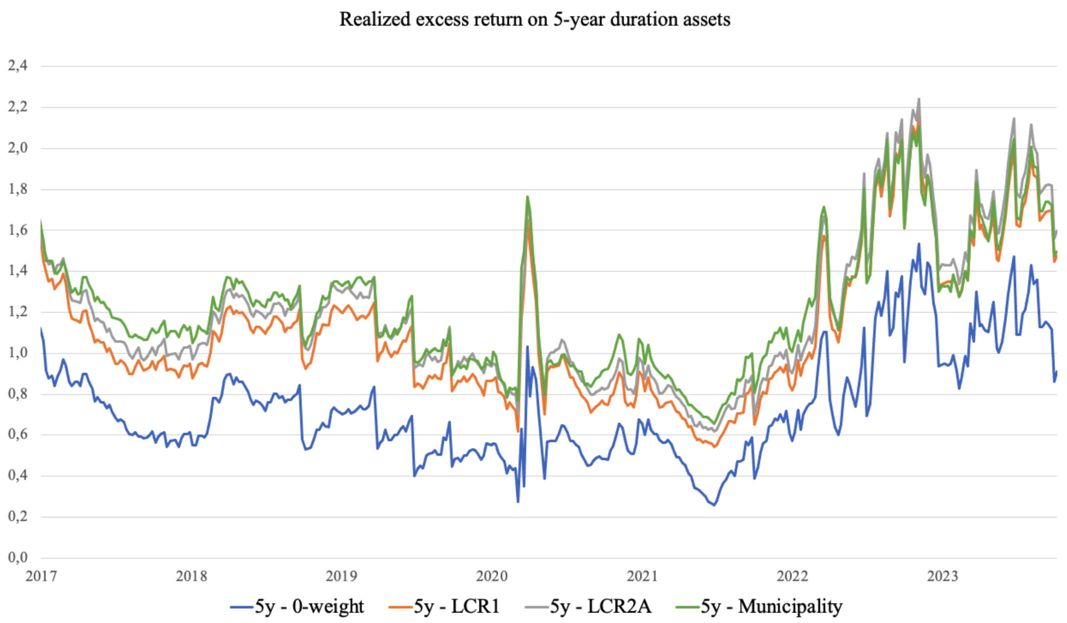


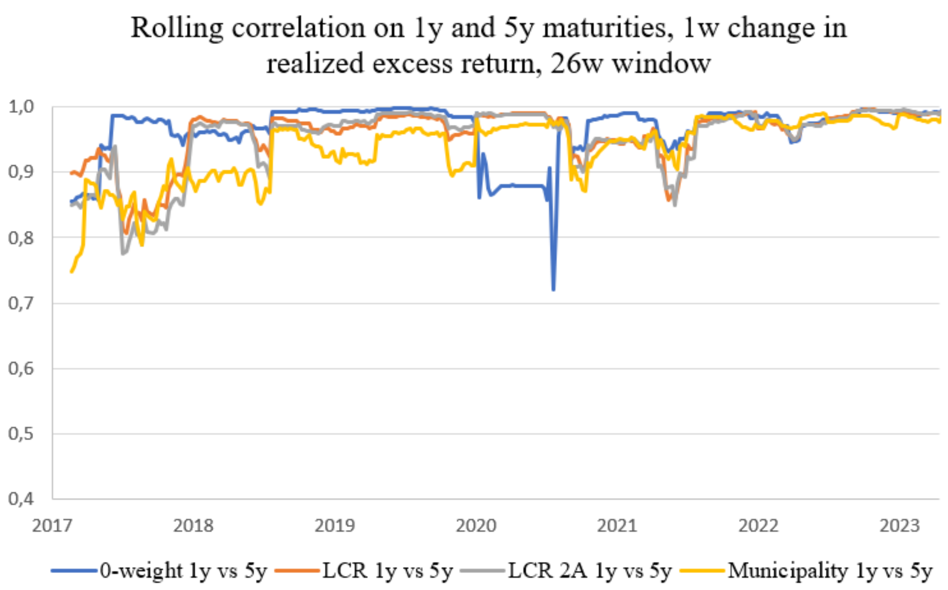
Figure 6.7 Realized excess return on 5-year duration assets, in percentage



Collectively, these observations support the hypothesis and suggest that an increase in both duration and risk profile can lead to higher realized excess returns. This provides valuable insights for the management of liquidity portfolios, where balancing risk and return is crucial to achieve optimal portfolio construction.

Figure 6.8 illustrates the rolling correlation for one year and five-year maturities for all asset classes. The figure shows a significant shift during the 2020 market disturbance. Prior and subsequent to this period, there is a strong and consistent correlation across all asset types, suggesting that short-term and long-term returns typically move in tandem. However, during 2020, the 0-weight assets experienced a strong drop in correlation, diverging from the otherwise stable relationship seen in LCR1, LCR2A, and Municipality assets.

Figure 6.8 Rolling correlation on 1- and 5-year weekly change in realized excess return, 52-week window



The anomaly in 0-weight assets indicate a unique reaction to the financial stress of the pandemic, possibly due to their nature as safer and more liquid characteristics. In contrast, the other asset classes maintain their correlation, which highlights their different risk profiles and investor perceptions during times of economic uncertainty. These insights are crucial for understanding the behavior of various asset classes during market fluctuations and for strategic liquidity portfolio management.

6.3 Volatility on change in credit margin

In this section, we illustrate the development of volatility in credit margin for the LCR assets. We are guided by the question: As we progress through asset classes and maturities, does volatility on change in credit margin amplify accordingly? The volatility is quantified as the annualized standard deviation of weekly change in credit margin using a 26-week rolling window, expressed in basis points.

As shown in figure 6.9, the volatility on change in credit margin does indeed escalate with the extension of asset maturity, confirming the widely accepted belief that longer duration assets carry greater risk. This is visually represented by higher levels of standard deviation in the five-year duration assets across all classes compared to their one year and three-year counterparts.

Figure 6.9 Volatility on change in credit margin for 0-weight assets, denoted in BPS

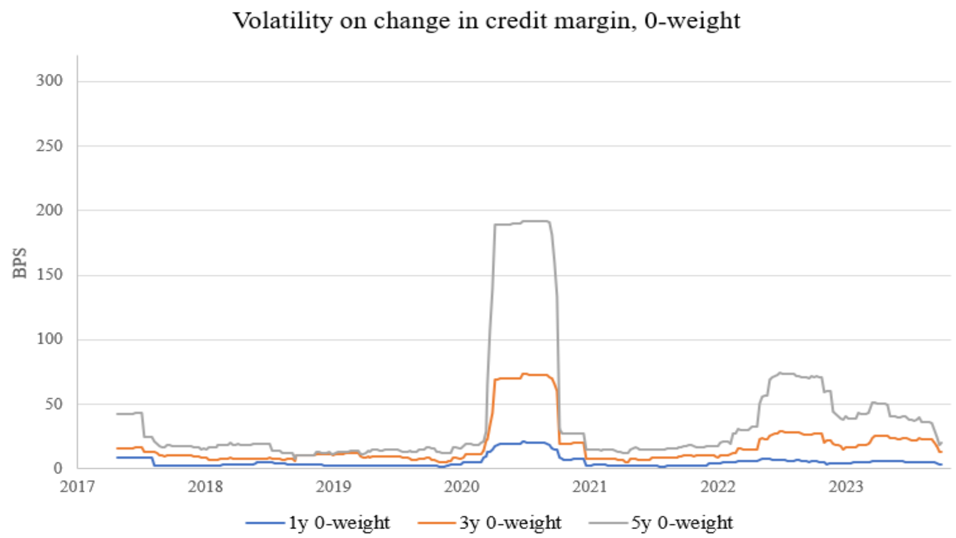
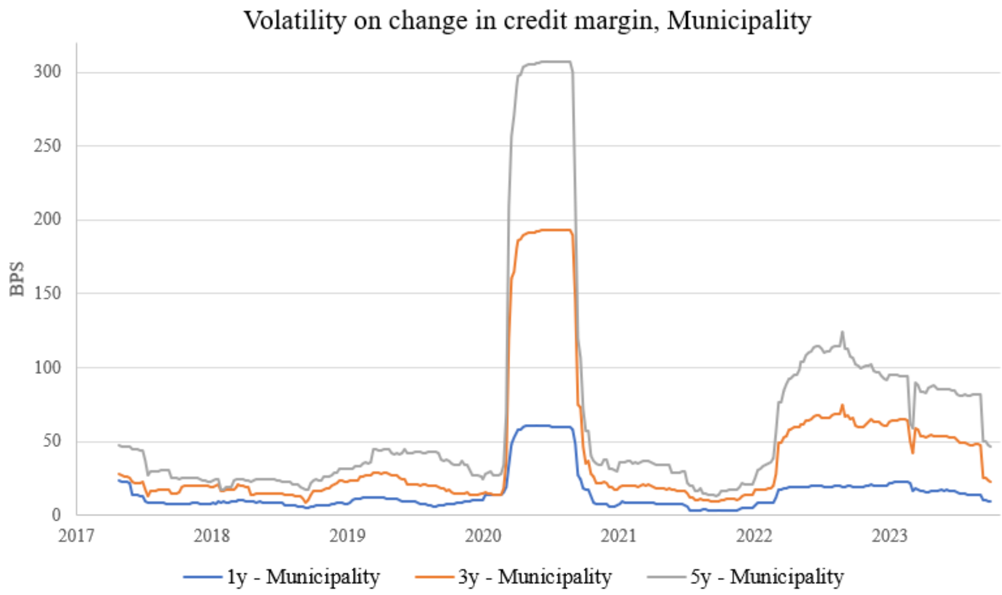


Figure 6.10 illustrates the volatility for municipality assets. It is clear that municipality assets hold greater volatility than 0-weight assets, explained by higher liquidity risk. Additionally, we have chosen to leave out the similar figures for LCR 1 and LCR 2A assets, as they do not bring any new information to the table. The standard deviation for those assets lays between the 0-weight and the municipality assets, with a maximum standard deviation in the COVID-19 period at approximately 150 basis points for three-year maturity and 250 basis points for five-year maturity.

Figure 6.10 Volatility on change in credit margin for municipality assets, denoted in BPS



In conclusion, the correlation between volatility, duration, and asset class is evident and behaves as anticipated. Portfolio managers must navigate the inherent trade-off between expected returns and risk, tailoring their strategies to the dynamic risk profiles of assets as they mature. The pronounced variations in volatility on change in credit margin underscore the necessity for careful period selection in portfolio optimization, as different time series can reveal great distinctions for optimum solutions.

6.4 Variance Ratio-test

In this section, we will investigate our dataset by performing a variance ratio-test (VR-test). This test is performed on time series 1, to explore if the credit margins indicate observations of random walk or mean reversion. In turn, the findings will provide our research with valuable insight regarding managing liquidity portfolios. Further, we will provide a brief description for the VR-test before we describe the statistics used in the test. Lastly, we will present our findings and come up with a conclusion and following consequences for the analysis in chapter seven.

The VR-test is based on the framework elaborated by Amélie Charles and Olivier Darné (2009) for the individual VR-test. They state that the idea behind the test is to observe uncorrelated returns over time. The test evaluates the variance of periodic returns for longer intervals and the variance of corresponding shorter intervals. If the variances observed over longer intervals are smaller than the variances observed over shorter intervals, it might suggest presence of mean reversion in the time series. The rationale for this interpretation is that time series that revert to the mean will gradually decrease deviations from the average, thereby reducing long-term variance. To sum up, if returns are positively autocorrelated, the VR should be > 1. On the other hand, the time series is said to be mean reverting if VR is significantly < 1. Additionally, if the VR is equal to one, it suggests that the time series is a random walk. Based on this elaboration, we will explore the tendencies for our periods by observing if the VR-test is higher, lower, or equal to one.

For this inspection, we define longer intervals to be the annual variance of yearly change in credit margins, with a 26-week window. For short term intervals, we apply the annual variance of 12 week change in credit margins, with a 26-week window.

After calculating all fractions, we have reported the findings for all assets and maturities in table 6.1. Due to large outliers in our findings, we have chosen to report the median numbers we obtained. The findings from the VR-test indicate a strong tendency for mean reversion over longer time periods in our time series. This tendency is especially strong for covered bonds with one year maturity, represented by low fractions.

Table 6.1 Variance ratio-test

Asset	Maturity	Variance Ratio
0-weight	1	0,42
	3	0,42
	5	0,47
LCR 1 Covered Bonds	1	0,14
	3	0,18
	5	0,30
LCR 2A Covered Bonds	1	0,11
	3	0,21
	5	0,29
LCR 2A Municipality	1	0,13
	3	0,21
	5	0,23

Our variance ratio-test on credit margin time series indicates a strong tendency towards mean reversion. This suggests that over longer periods, credit margins generally revert to their average levels, implying predictability in their movements. These findings are crucial for liquidity portfolio management, as they offer a basis for more informed asset allocation and risk assessment decisions, particularly for assets exhibiting mean-reverting behavior. This mean reversion is consistent with the risk identified for the analyzed periods in chapter 7, providing a cohesive understanding of risk dynamics across different time frames.

7. Optimization of Liquidity Portfolios

The second part of our analysis is to use the information extracted in part one to find optimal portfolio solutions for HQLA across several time series. Further, we will compare our findings to the reference portfolio introduced in chapter 3.3.4 and look for similarities and differences in respect to the optimum portfolios.

7.1 Data used in Optimization Model

The optimization model is constructed in Excel, using solver to maximize and minimize different values, i.e., maximum sharpe ratio, maximum excess return, and minimize standard deviation for the portfolios. We are basing our model on annual realized excess return and annual volatility on change in credit margin for each asset. Additionally, we apply the periods introduced in chapter 5.3 to examine whether different horizons reveal various results. Further, we will elaborate on the return and risk used in our model in this chapter.

7.1.1 Realized Excess Return

The annual realized excess return is calculated as stated in chapter 5.2.2. The realized excess return for each asset in each time series is calculated as the average realized excess return for the specific time series, based on weekly observations in credit margins. Consequently, the realized excess return is a constant variable in each time series, meaning it does not change throughout the time series.

7.1.2 Volatility in credit margin

Shifting our focus over to risk, we use volatility on change in credit margin as the risk indicator in our optimization model. The calculation for volatility on change in credit margin was presented in chapter 5.2.3.

We apply two different periods of change in our volatility calculations, namely 12 weeks and 52 weeks. The rationale for the chosen periods is to see if different maturities represent more volatility, and how the optimum solutions differ from one another. Additionally, Norwegian banks are obliged to report LCR-numbers quarterly. Moreover, we will analyze the impact of a short-term volatility measure against a longer-term volatility measure on the optimum portfolios. Our hypothesis is that short-term volatility will provide more risk-averse portfolios due to higher sensitivity against short-term market fluctuations, i.e. the assets will have higher standard deviations for the calculations based on 12-week changes.

We use a covariance matrix for rolling volatility on 12- and 52. week change in credit margin to determine the standard deviation for the portfolios we will simulate. This computation is completed for all three periods, as well as the 12- and 52-week changes. As a result, we derive an average estimate of the standard deviation for each asset's 12- and 52-week changes in each time series.

Further, we use the MMULT-function in Excel for matrix multiplication. The formula essentially calculates the standard deviation of a portfolio based on the weighted covariances between assets. The weights represent the allocation of funds to each asset, and the covariance matrix accounts for how the returns of the assets move together. The use of the transpose function ensures proper alignment for matrix multiplication, a fundamental operation in portfolio risk analysis. The final result is the standard deviation of the portfolio, providing a measure of the total risk associated with the chosen set of weights for assets in the portfolio.

Simulation modeling benefits greatly from its ability to describe complicated systems using mathematical equations, with the objective of identifying the optimal input values for achieving a desired outcome. The key components used in our model is described as follow:

<u>Decision variables:</u> The decision variables are the variables in the model that can be adjusted to optimize the objective function. In this analysis, the decision variables is the weight for each asset, which should equal 100% in total.

<u>Objective function:</u> The objective function is the cell that represents the value one would maximize, minimize, or set equal to. We have based this analysis on three different objective functions, namely maximizing the sharpe ratio of the portfolio and the realized excess return of the portfolio, and minimizing the standard deviation of the portfolio.

<u>Constraints:</u> These are limitations or restrictions placed in the decision variables. Constraints in a simulation model are essential for reflecting relevant limitations in our analysis. We have made use of several constraints to observe how the optimal weights change as the constraints

change. The constraints used in our analysis is; i) No constraints, ii) 10% in 0-weight, iii) 30% in 0-weight, and iv) Full constraints, suggesting that the portfolio constraints is equal to today's regulation, that is, 30% in 0-weight and 60% in 0-weight + LCR 1 assets. Additionally, we implement the constraint for all portfolios that the total weight must equal 100%.

7.2 Optimum Results

7.2.1 Period 1: 2018 - 2023

This period is a representation for the whole dataset we have available for our analysis. Although we have data available from October 2016, we decided to set January 2018 as the first observation. The reasoning is intuitive since we are using 52 week change to calculate the annualized volatility on change in credit margin in our first optimum model, meaning that the first observation is in October 2017. Further, for statistical reasons, we find it reasonable to have at least 10 observations when calculating the standard deviation.

The annual realized excess return and volatility on change in credit margin for both 12- and 52 week change is presented in table 7.1 below. The table shows that as the maturity increases, generally, the realized excess returns and volatility also increase. The annualized standard deviation for 52-week changes is consistently lower than that for 12-week changes, suggesting less volatility over the longer term. This indicates more stability in credit margins over an extended period.

Table 7.1 Realized excess return and volatility on change in credit margin for assets in period 1

Asset	Realized Excess Return	Annualized Std.dev 12w change	Annualized Std.dev 52w change
1y 0-weight	0,42 %	0,05 %	0,02 %
3y 0-weight	0,60 %	0,14 %	0,06 %
5y 0-weight	0,73 %	0,25 %	0,11 %
1y - LCR1	0,52 %	0,07 %	0,03 %
3y - LCR1	0,86 %	0,27 %	0,12 %
5y - LCR1	1,12 %	0,46 %	0,20 %
1y - LCR2A	0,57 %	0,08 %	0,04 %
3y - LCR2A	0,93 %	0,29 %	0,13 %
5y - LCR2A	1,20 %	0,48 %	0,20 %
1y - Municipality	0,66 %	0,13 %	0,06 %
3y - Municipality	0,97 %	0,43 %	0,20 %
5y - Municipality	1,22 %	0,66 %	0,30 %

Further, we present our optimum portfolios in table 7.2, for 52 week change calculations of volatility in credit margins, while table 7.3 present the volatility for 12 week change in credit margins. The tables are grouped into three different portfolios, with the aim of comparing across several objectives. Additionally, we illustrate the reference portfolio in all tables to show how the reference portfolio responds to the varying volatility connected to each time series.

Table 7.2 presents the optimum weights for the portfolio where volatility is based on 52 week changes in credit margins. For the portfolios that maximizes sharp ratio, all solutions are identical, meaning that the constraints do not affect the optimum solution. Not surprisingly, the portfolios for maximizing excess return invest in longer duration assets due to higher realized excess return. On the other hand, the portfolios for minimizing standard deviation invest all in one year 0-weight assets.

Table 7.2 Optimum portfolio weights for period 1, 52-week change

	Max Sharpe ratio				Max excess return				Min standard deviation				Reference Portfolio		
Asset	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	Small	Middle	Large
1y 0-weight	79,73 %	79,73 %	79,73 %	79,73 %	-	-	-	-	100,00 %	100,00 %	100,00 %	100,00 %	-	-	-
3y 0-weight	-	-	-	-	-	-	-	-	-	-	-	-	43,15 %	41,09 %	40,47 %
5y 0-weight	-	-	-	-	-	10,00 %	30,00 %	30,00 %	-	-	-	-	-	-	-
1y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	44,70 %	41,19 %	36,71 %
5y - LCR1	-	-	-	-	-	-	-	30,00 %	-	-	-	-	-	-	-
1y - LCR2A	20,27 %	20,27 %	20,27 %	20,27 %	-	-	-	-	-	-	-	-	-	-	-
3y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	3,65 %	8,67 %	6,44 %
5y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	8,50 %	9,05 %	16,38 %
5y - Municipality	-	-	-	-	100,00 %	90,00 %	70,00 %	40,00 %	-	-	-	-	-	-	-
Weight	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %
Excess return	0,45 %	0,45 %	0,45 %	0,45 %	1,22 %	1,17 %	1,07 %	1,04 %	0,42 %	0,42 %	0,42 %	0,42 %	0,76 %	0,77 %	0,78 %
Std.dev	0,03 %	0,03 %	0,03 %	0,03 %	0,30 %	0,28 %	0,24 %	0,21 %	0,02 %	0,02 %	0,02 %	0,02 %	0,10 %	0,10 %	0,11 %
Sharpe ratio	17,58	17,58	17,58	17,58	4,01	4,15	4,49	5,07	17,39	17,39	17,39	17,39	7,78	7,72	7,38

Table 7.3 illustrates the optimum weights for volatility based on 12 week changes in credit margins. As anticipated, it displays a more risk averse allocation of assets by investing over 97% in one year 0-weight and the remaining in one-year LCR 1 for maximum sharpe ratio portfolios. The two other portfolios display a similar result and interpretation as for table 7.2

Table 7.3 Optimum portfolio weights for period 1, 12-week change

	Max Sharpe ratio				Max excess return				Min standard deviation				Reference Portfolio		
Asset	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	Small	Middle	Large
1y 0-weight	97,38 %	97,38 %	97,38 %	97,38 %	-	-	-	-	100,00 %	100,00 %	100,00 %	100,00 %	-	-	-
3y 0-weight	-	-	-	-	-	-	-	-	-	-	-	-	43,15 %	41,09 %	40,47 %
5y 0-weight	-	-	-	-	-	10,00 %	30,00 %	30,00 %	-	-	-	-	-	-	-
1y - LCR1	2,62 %	2,62 %	2,62 %	2,62 %	-	-	-	-	-	-	-	-	-	-	-
3y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	44,70 %	41,19 %	36,71 %
5y - LCR1	-	-	-	-	-	-	-	30,00 %	-	-	-	-	-	-	-
1y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	3,65 %	8,67 %	6,44 %
5y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	8,50 %	9,05 %	16,38 %
5y - Municipality	-	-	-	-	100,00 %	90,00 %	70,00 %	40,00 %	-	-	-	-	-	-	-
Weight	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %
Excess return	0,47 %	0,47 %	0,47 %	0,47 %	1,22 %	1,17 %	1,07 %	1,04 %	0,42 %	0,42 %	0,42 %	0,42 %	0,76 %	0,77 %	0,78 %
Std.dev	0,06 %	0,06 %	0,06 %	0,06 %	0,66 %	0,61 %	0,53 %	0,46 %	0,05 %	0,05 %	0,05 %	0,05 %	0,22 %	0,23 %	0,24 %
Sharpe ratio	8,29	8,29	8,29	8,29	1,85	1,91	2,04	2,24	8,58	8,58	8,58	8,58	3,42	3,39	3,25

7.2.2 Period 2: 2020

The data from 2020, displayed in table 7.4, provides a detailed look into the yearly realized excess returns and the volatility on change in credit margin for LCR assets during a year characterized by financial stress.

Period 2 is characterized by lower realized excess return and higher standard deviations for all assets, in comparison to time series 1. Further, we observe an increase in the difference between short- and long-term volatility. This difference is notably higher for longer maturities, suggesting that volatility for 12 week changes in credit margins capture a larger extent of the fluctuations in the market during this period.

Table 7.4 presents the annual realized excess return and volatility based on credit margin changes for a range of assets during period 2. The same pattern illustrated in table 7.1 is also found in table 7.4. The table reveals a general trend: as maturity increases, both the realized excess return and volatility tend to increase, as well as with the annualized standard deviation for the 52-week period lower than for the 12-week period across all asset classes.

Table 7.4 Yearly realized excess return and volatility in credit margin for assets in period 2

Asset	Realized Excess Return	Annualized Std.dev 12w change	Annualized Std.dev 52w change
1y 0-weight	0,30 %	0,07 %	0,03 %
3y 0-weight	0,44 %	0,21 %	0,08 %
5y 0-weight	0,56 %	0,35 %	0,13 %
1y - LCR1	0,39 %	0,10 %	0,04 %
3y - LCR1	0,68 %	0,38 %	0,16 %
5y - LCR1	0,89 %	0,65 %	0,25 %
1y - LCR2A	0,43 %	0,10 %	0,04 %
3y - LCR2A	0,73 %	0,40 %	0,17 %
5y - LCR2A	0,96 %	0,67 %	0,26 %
1y - Municipality	0,53 %	0,17 %	0,08 %
3y - Municipality	0,79 %	0,61 %	0,26 %
5y - Municipality	1,00 %	0,95 %	0,41 %

An interesting observation in table 7.5 is the presence of the constraints changing the optimum solution for maximum sharpe ratio portfolios. It is clear that the optimum solution is chasing more excess return in period 2 compared to period 1. In turn, this is a result of the high increase in volatility for all assets. However, the gain from the risk-return tradeoff illustrates a more risk-seeking behavior in period 2.

Table 7.5 Optimum portfolio weights for period 2, 52-week change

	Max Sharpe ratio				**Max excess return**				**Min standard deviation**				**Reference Portfolio**		
Asset	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	Small	Middle	Large
1y 0-weight	36,83 %	36,83 %	36,83 %	40,07 %	-	-	-	-	100,00 %	100,00 %	100,00 %	100,00 %	-	-	-
3y 0-weight	-	-	-	-	-	-	-	-	-	-	-	-	43,15 %	41,09 %	40,47 %
5y 0-weight	-	-	-	-	-	10,00 %	30,00 %	30,00 %	-	-	-	-	-	-	-
1y - LCR1	-	-	-	19,93 %	-	-	-	-	-	-	-	-	-	-	-
3y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	44,70 %	41,19 %	36,71 %
5y - LCR1	-	-	-	-	-	-	-	30,00 %	-	-	-	-	-	-	-
1y - LCR2A	63,17 %	63,17 %	63,17 %	40,00 %	-	-	-	-	-	-	-	-	-	-	-
3y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	3,65 %	8,67 %	6,44 %
5y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	8,50 %	9,05 %	16,38 %
5y - Municipality	-	-	-	-	100,00 %	90,00 %	70,00 %	40,00 %	-	-	-	-	-	-	-
Weight	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %
Excess return	0,38 %	0,38 %	0,38 %	0,37 %	1,00 %	0,95 %	0,87 %	0,83 %	0,30 %	0,30 %	0,30 %	0,30 %	0,59 %	0,60 %	0,60 %
Std.dev	0,04 %	0,04 %	0,04 %	0,04 %	0,41 %	0,38 %	0,32 %	0,27 %	0,03 %	0,03 %	0,03 %	0,03 %	0,13 %	0,13 %	0,14 %
Sharpe ratio	9,70	9,70	9,70	9,69	2,44	2,52	2,72	3,08	9,25	9,25	9,25	9,25	4,58	4,54	4,34

Table 7.6 presents the optimal weights for the portfolio where volatility is based on 12-week changes in credit margins. In the portfolios maximizing the sharpe ratio, all solutions are identical, indicating that the imposed constraints do not alter the optimal solution. Compared to table 7.3, the solution in table 7.6 appears more risk-seeking because it shifts holdings from one-year LCR1 to one-year LCR2A. Unsurprisingly, the portfolios focusing on maximizing excess return are invested in longer-duration assets due to their higher realized excess returns. Conversely, the portfolios aimed at minimizing standard deviation invest entirely in one year 0-weight assets, reflecting a preference for stability.

Table 7.6 Optimum portfolio weights for period 2, 12-week change

Asset	Max Sharpe ratio				Max excess return				Min standard deviation				Reference Portfolio		
	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	Small	Middle	Large
1y 0-weight	63,87 %	63,87 %	63,87 %	63,87 %	-	-	-	-	100,00 %	100,00 %	100,00 %	100,00 %	-	-	-
3y 0-weight	-	-	-	-	-	-	-	-	-	-	-	-	43,15 %	41,09 %	40,47 %
5y 0-weight	-	-	-	-	-	10,00 %	30,00 %	30,00 %	-	-	-	-	-	-	-
1y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	44,70 %	41,19 %	36,71 %
5y - LCR1	-	-	-	-	-	-	-	30,00 %	-	-	-	-	-	-	-
1y - LCR2A	36,13 %	36,13 %	36,13 %	36,13 %	-	-	-	-	-	-	-	-	-	-	-
3y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	3,65 %	8,67 %	6,44 %
5y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	8,50 %	9,05 %	16,38 %
5y - Municipality	-	-	-	-	100,00 %	90,00 %	70,00 %	40,00 %	-	-	-	-	-	-	-
Weight	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %
Excess return	0,35 %	0,35 %	0,35 %	0,35 %	1,00 %	0,95 %	0,87 %	0,83 %	0,30 %	0,30 %	0,30 %	0,30 %	0,59 %	0,60 %	0,60 %
Std.dev	0,08 %	0,08 %	0,08 %	0,08 %	0,95 %	0,88 %	0,76 %	0,67 %	0,07 %	0,07 %	0,07 %	0,07 %	0,32 %	0,32 %	0,34 %
Sharpe ratio	4,28	4,28	4,28	4,28	1,05	1,08	1,14	1,25	4,22	4,22	4,22	4,22	1,85	1,84	1,77

7.2.3 Period 3: 2021 - 2023

Period 3 captures a post-pandemic market environment where assets have been subject to shifting economic conditions and regulatory changes, such as recovery from the pandemic and interest rate fluctuations. The statistics provided in table 7.7 illustrate the performance of short-term to long-term assets, with the annualized standard deviation for 12-week and 52-week changes offering insights into their respective volatilities. This period is crucial for understanding the evolving dynamics for HQLA as markets stabilize and adapt to a new normal post-2020.

Comparing period 2 and 3, we observe that while the realized excess returns have indeed increased from period 2 to 3, the annualized volatility in credit margin has remarkably decreased for all assets. This suggests that during the period from 2021 to 2023, the assets offered higher excess returns without a corresponding increase in volatility, implying an improved risk-return profile. Such a trend could indicate a stabilization in market conditions and a recovery phase where investors are potentially receiving higher returns for less risk compared to the more turbulent period of 2020.

Table 7.7 displays the yearly realized excess return and volatility in credit margin changes for LCR assets in period 3. The table reveals the same trend as in table 7.4 and 7.1, as maturity increases, both the realized excess return and volatility tend to increase. The annualized standard deviation for the 52-week period is also consistently lower than for the 12-week period across all categories, except for one year 0-weight asset where the volatility seems to be identical.

Table 7.7 Yearly realized excess return and volatility in credit margin for assets in period 3

Asset	Realized Excess Return	Annualized Std.dev 12w change	Annualized Std.dev 52w change
1y 0-weight	0,56 %	0,02 %	0,02 %
3y 0-weight	0,73 %	0,07 %	0,05 %
5y 0-weight	0,85 %	0,18 %	0,08 %
1y - LCR1	0,65 %	0,04 %	0,03 %
3y - LCR1	1,00 %	0,17 %	0,09 %
5y - LCR1	1,25 %	0,30 %	0,14 %
1y - LCR2A	0,68 %	0,04 %	0,03 %
3y - LCR2A	1,06 %	0,19 %	0,10 %
5y - LCR2A	1,34 %	0,32 %	0,16 %
1y - Municipality	0,81 %	0,09 %	0,05 %
3y - Municipality	1,12 %	0,26 %	0,15 %
5y - Municipality	1,33 %	0,35 %	0,24 %

Table 7.8 presents the optimal weights for the portfolio where volatility is based on 52-week changes in credit margins. In the portfolios maximizing the Sharpe ratio, all solutions are yet again identical, indicating that the imposed constraints do not alter the optimal solution. Compared to all the previous tables we observe that when excess return is maximized in table 7.8, the portfolios have shifted from mainly investing in five-year municipality to five year LCR2A. Conversely, the portfolios aimed at minimizing standard deviation invest entirely in one year 0-weight assets, reflecting a preference for stability.

Table 7.8 Optimum portfolio weights for period 3, 52-week change

	Max Sharpe ratio				Max excess return				Min standard deviation				Reference Portfolio		
Asset	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	Small	Middle	Large
1y 0-weight	79,39 %	79,39 %	79,39 %	79,39 %	-	-	-	-	100,00 %	100,00 %	100,00 %	100,00 %	-	-	-
3y 0-weight	-	-	-	-	-	-	-	-	-	-	-	-	43,15 %	41,09 %	40,47 %
5y 0-weight	-	-	-	-	-	10,00 %	30,00 %	30,00 %	-	-	-	-	-	-	-
1y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	44,70 %	41,19 %	36,71 %
5y - LCR1	-	-	-	-	-	-	-	30,00 %	-	-	-	-	-	-	-
1y - LCR2A	20,61 %	20,61 %	20,61 %	20,61 %	-	-	-	-	-	-	-	-	-	-	-
3y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	3,65 %	8,67 %	6,44 %
5y - LCR2A	-	-	-	-	100,00 %	90,00 %	70,00 %	40,00 %	-	-	-	-	-	-	-
1y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	8,50 %	9,05 %	16,38 %
5y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weight	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %
Excess return	0,58 %	0,58 %	0,58 %	0,58 %	1,34 %	1,29 %	1,19 %	1,17 %	0,56 %	0,56 %	0,56 %	0,56 %	0,89 %	0,90 %	0,91 %
Std.dev	0,02 %	0,02 %	0,02 %	0,02 %	0,16 %	0,15 %	0,13 %	0,12 %	0,02 %	0,02 %	0,02 %	0,02 %	0,07 %	0,07 %	0,08 %
Sharpe ratio	26,28	26,28	26,28	26,28	8,64	8,85	9,33	9,37	25,92	25,92	25,92	25,92	12,26	12,10	11,56

Table 7.9 presents the optimal weights for the portfolio where volatility is based on 12-week changes in credit margins. In the portfolios maximizing the sharpe ratio, all solutions are yet again identical, indicating that the imposed constraints do not alter the optimal solution. We observe a similar pattern as in table 7.3 where a smaller portion is invested in one-year LCR 1. The portfolios for maximizing excess returns show similar character as illustrated in table 7.9, where five-year LCR 2A is most favored. On the other hand, the portfolios for minimizing standard deviation invest all in one year 0-weight assets. Conversely, in table 7.9 all solutions are yet identical for portfolios aiming to minimize standard deviation and has the exact same allocation as when sharpe ratio is maximized. Minimizing standard deviation still shows a new discovery, there is no longer 100% invested in one year 0-weight, but a small portion of 5,11% is invested in one-year LCR 1.

Table 7.9 Optimum portfolio weights for period 3, 12-week change

Asset	Max Sharpe ratio				Max excess return				Min standard deviation				Reference Portfolio		
	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	No constraints	Min 10% 0-weight	Min 30% 0-weight	Full constraints	Small	Middle	Large
1y 0-weight	94,89 %	94,89 %	94,89 %	94,89 %	-	-	-	-	94,89 %	94,89 %	94,89 %	94,89 %	-	-	-
3y 0-weight	-	-	-	-	-	-	-	-	-	-	-	-	43,15 %	41,09 %	40,47 %
5y 0-weight	-	-	-	-	-	10,00 %	30,00 %	30,00 %	-	-	-	-	-	-	-
1y - LCR1	5,11 %	5,11 %	5,11 %	5,11 %	-	-	-	-	5,11 %	5,11 %	5,11 %	5,11 %	-	-	-
3y - LCR1	-	-	-	-	-	-	-	-	-	-	-	-	44,70 %	41,19 %	36,71 %
5y - LCR1	-	-	-	-	-	-	-	30,00 %	-	-	-	-	-	-	-
1y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - LCR2A	-	-	-	-	-	-	-	-	-	-	-	-	3,65 %	8,67 %	6,44 %
5y - LCR2A	-	-	-	-	100,00 %	90,00 %	70,00 %	40,00 %	-	-	-	-	-	-	-
1y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	8,50 %	9,05 %	16,38 %
5y - Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weight	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %	100,00 %
Excess return	0,56 %	0,56 %	0,56 %	0,56 %	1,34 %	1,29 %	1,19 %	1,17 %	0,56 %	0,56 %	0,56 %	0,56 %	0,89 %	0,90 %	0,91 %
Std.dev	0,02 %	0,02 %	0,02 %	0,02 %	0,32 %	0,30 %	0,27 %	0,27 %	0,02 %	0,02 %	0,02 %	0,02 %	0,13 %	0,13 %	0,14 %
Sharpe ratio	35,18	35,18	35,18	35,18	4,24	4,31	4,44	4,40	35,18	35,18	35,18	35,18	6,95	6,84	6,61

7.3 Summary

While period 1 provides a broad basis for our understanding of LCR portfolios, period 2 sheds light on the extraordinary market conditions of 2020 and how various asset classes and maturities responded to this volatility. Additionally, period 3 is included in our analysis to demonstrate the development in HQLA and portfolio composition in the aftermath of a financial stress test.

Our findings demonstrate distinct optimum solutions for the portfolios in respect to short-term volatility and longer-term volatility. In line with our stated hypothesis, it is clear that short-term volatility accounts for more fluctuations in the assets, hence demonstrating more risk-averse portfolios for the sharpe ratio solutions. This is illustrated with higher weights allocated in one year 0-weight and lower allocation in one-year LCR 1 assets. In contrast, the long-term volatility portfolios take on more risk by allocating more of their investments in one-year LCR 2A. To sum up, the standard deviations for the longer-term volatility measure is lower for all assets, and the realized excess return is similar for both volatility measures. Hence, the simulation model we apply in this analysis allows the optimum weights in longer-term portfolios to allocate more in assets characterized with higher risk, without minimizing the sharpe ratio.

Another interesting finding is that long-term volatility portfolios achieve a higher sharpe ratio in periods 1 and 2. However, this is not the case in period 3, where the short-term portfolio achieves a higher sharpe ratio than the long-term portfolio. This is most likely due to the fact that the excess return and standard deviation for long-term and short-term portfolios is quite similar, and it comes down to small fractions affecting the outcome for the sharpe ratio. This illustrates that, in the aftermath of financial stress, the short-term volatility captures an optimum composition between one year 0-weight asset and one-year LCR 1 that decreases the standard deviation for the portfolio, while increasing its excess return. However, this diversification attribute is not captured to the same extent for the long-term volatility portfolio.

In regard to our reference portfolios for small, middle, and large banks, their allocations remain constant throughout all periods. As an assumption stated earlier, the reference portfolios are all invested in three-year maturities since this is the approximate average duration for liquidity portfolios in Norway. It is evident that the reference portfolios take a more neutral position, compared to the simulated optimum portfolios we have obtained. I.e., that the reference portfolios neither solely focuses on volatility (maximizes sharpe ratio and minimize standard deviations solutions), nor maximizing excess return. With this interpretation, it is clear that Norwegian liquidity portfolios miss out on potential gain, suggesting that they manage their liquidity portfolios in respect to other purposes. This leads up to a discussion which we cover in the subsequent chapter, where we make up our conclusion.

8. Conclusion

Our analysis reveals that the reference portfolios of banks significantly differ from the optimum portfolios we have simulated. This disparity can be partly attributed to mean-variance optimization often resulting in corner solutions, where portfolios are heavily concentrated in specific assets. An intriguing observation is that if banks implement similar optimization techniques, they can potentially achieve better outcomes than their current performances, in terms of both return and risk. Further, we aim to discuss several qualitative reasons for our distinctive results regarding the reference portfolios.

One possible explanation for this difference could be that banks place greater emphasis on their sources of funding and the duration of their funding. The reason for this important consideration is that, in liquidity portfolio management, banks usually aim to match their duration on assets with their duration on liabilities. This usually results in liquidity portfolios with three-year duration, as observed for Norwegian banks.

Furthermore, a critical element might be the diverse capital requirements that influence the choice of securities held by banks. For instance, if banks predominantly hold papers with a certain capital requirement, this could affect the composition of their portfolios. Moreover, the composition of a bank's liquidity portfolio is not solely determined by market considerations or investment preferences but is also influenced by regulatory factors like capital requirements.

As noted in section 6.4, quarterly variance is twice as volatile as annual variance. The verification of mean reversion for LCR assets has major implications for liquidity portfolio management and LCR regulatory compliance. Mean reversion is crucial to our analysis as it implies that credit margins tend to revert to their long-term average over time. While mean reversion is beneficial for long-term investment stability, this attribute can be challenging to achieve quarterly. If credit margins do not revert to the mean within this quarterly period, banks may not meet LCR requirements. This could be one of the main reasons why the reference portfolios do not show preferences for maximizing excess return.

In practice, many portfolio managers overlook the asset's strong mean-reverting nature when managing liquidity portfolios, according to Snippen and Semmen. However, our findings suggest a paradigm shift in liquidity portfolio management. Understanding the tendency of assets to revert to their mean can serve as a catalyst for developing innovative strategies for managing liquidity portfolios.

In conclusion, our findings suggest that Norwegian banks can improve their management for liquidity portfolios. This is evident throughout our research, where we find strong tendencies for mean reversion in our time series, and optimum solutions for portfolio allocation that deviates from our reference portfolios. However, it's important to recognize that liquidity portfolio management does not constitute the primary function of banks' overall activities, potentially causing them to prioritize other aspects in their banking operations. Nonetheless, the potential benefits of implementing advanced optimization strategies for liquidity portfolios cannot be overstated. Moreover, although there is clear potential for enhancement in LCR management, it is crucial to adopt a comprehensive approach that considers the wider goals of the LCR requirements. Effective liquidity portfolio management involves not only optimizing returns but also adhering to regulatory requirements and maintaining stability across various market conditions.

For further studies, it is clear that a vital factor to consider is to understand the magnitude of potential losses that banks can endure over a three-month period. Exploring data analysis in depth and optimizing portfolios according to the risk tolerance of banks would be of great benefit. This investigation has the potential to offer a more profound understanding of risk tolerance levels and facilitate the creation of stronger strategies for managing liquidity portfolios. Such an exploration can provide deeper insights into risk tolerance levels and help develop more robust strategies for liquidity portfolio management, aligning with regulatory compliance while maximizing potential returns.

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