Master Thesis

Cand.merc.(mat)

The impact of FRTB´s market risk framework on the Danish Covered Bond Market Liquidity

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Resume

Dette speciale har til formål at give læsen en forståelse af, hvilke faktorer som har indflydse på likviditeten i det danske realkredit marked, samt hvordan likviditeten bliver påvirket af skærpede kapital krav til bankerne gennem FRTB regelsættet. Afhandling besvarer problemformuleringen ved at give læseren en præsentation af det danske obligationsmarked, markedets forskellige aktører og en gennemgribende introduktion til de kommende FRTB kapitalkrav. På bagrund af en række udregninger af de danske realkreditobligationers kapitalkrav under det nye FRTB regelsæt kombineret med en teoretisk model og empirisk data til at tjekke modellens forklaring af det danske marked, kan det konkluderes at danske banker som i dag benytter bankens balance til at agere market maker og spekulant i markedet, må forvente et øget kapitalkrav. Ligeledes må bankerne forvente, at de øgende kapitalkrav har en direkte effekt på likvidteten af markedet, da det bliver dyrere for bankerne at agere market maker. Fra den teoretiske model kan det konkluderes at likviditeten i markedet forsvinder, når market maker og spekulanter har sværere ved at skaffe tilstrækkelig billig funding. Da bankerne som idag agerer market maker er afhæning af funding via deres kapitalkrav ville likviditeten alt andet lige blive påvirket negativt via højrere kapitalkrav.

Contents

1 Introductory

1.1 Introduction

Denmark has one of the largest markets in the world for covered bond, and the market plays a central role in the Danish economy. Danish covered bonds are very popular among investors because of the safety collateral behind the mortgage bonds, the safety margin is mainly because of the legislation on the market and because of the unique system, which the markets are built upon. Danish covered bonds are an interesting asset class for various reasons. The bonds are issued under a strong mortgage act and have strong 220-years history with a strong track record, with no mortgage series never defaulted.

Throughout the last couple of years, the financial markets have been hit by a row of proposal for new regulation, such that the supervisory market participants are better able to mimic the risk for a new financial crisis as the one in the financial world experienced in 2008 and 2009. The Basel committee have been the father for global regulation, while the EU commission are the regulatory body that needs to secure the implementation of the Basel proposal into European legislation. As part of developing the Basel III framework, the Basel Committee on Banking Supervision initiated the Fundamental Review of the Trading Book (FRTB). Several years later, the outcome is a new set of global standards for calculating minimum capital requirements for market risk in the trading book. The EU plans to implement the standards for European credit institutions in the Capital Requirements Regulation/Directive (CRR/CRD) in the coming years. As the time of writing this thesis, Danish and European banks are required to report the minimum capital requirements under the standardised approach by the end of 1st of January 2020, if the bank has a notional of the trading higher than 500m EUR or if the trading book comprises more than 10 percent of the banks total asset[1].

As a consequence of the higher capital requirements that Danish commercial banks are expected hold, lowers their covered bond holdings even further, and the Danish covered bond market will come under severe pressure if the market liquidity vanish. It is expected that the market will become more of a broker style model, where market makers are expected to reduce their bond inventory and instead add an extra search cost, when trading covered bonds. A lower market liquidity will also have a consequence for the individual Danish homeowners if the Danish mortgage institutions are not able to issue the required amount of bonds in the primary market, and this will make it more expensive for each individual homeowner to finance and refinance their mortgages.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0876&from=BG – Article 325a.

1.2 Motivation

The purpose of this thesis is to provide the reader with a broad and specific knowledge of the Danish mortgage model, the different market participants and how the market liquidity of Danish covered bonds are affected by higher capital requirements opposed by the Danish commercial banks of the Standardised Approach in the FRTB market risk framework. As mentioned in the introduction, the financial markets have seen a long list of new regulation since the financial crisis in 2008. The intention is to provide the reader with a comprehensive overview of the FRTB market risk framework, which is the heaviest capital requirements which are expected to have large consequence for Danish covered bonds in the primary and secondary market, respectively. It is of interest to the broader Danish economy and the Danish covered bond market participants to assess the implications of higher capital requirements opposed to the market makers of Danish covered bonds. The Danish financial sector was strike with joy, when the Basel committee accepted to include Danish covered bonds in the LCR measure as high quality liquid assets, however more market participants have since told serval supervisory institutions that the overall market liquidity are declining. It is therefore of high interest to assess if the market makers can absorb liquidity shocks in the future and help balance out supply demands shocks with their balance sheet, or if we would expected the Danish market to turn into a broker style model.

1.3 Research Questions

To better help achieve the overall motivation of the thesis and create the best possible structure, the below research question has been constructed. The research question will also be the primary focus of the thesis and will be answered throughout the thesis with a finale conclusion and discussion in the end.

RQ: How will the implementation of the current FRTB market risk framework from January 2019 effect the liquidity of the Danish covered bond market.

To help answer the main research question, the below sub research questions have been setup. The sub-research questions will be answered throughout the thesis in different sections. The sub research questions will then be combined into a discussion and conclusion which should help answer the main research question of the thesis.

1.3.1 Sub Research Questions

- How does the current Danish covered bond market look like?
- How are covered bond treated to the FRTB regulation?
- How will the capital requirements effect single bond holdings?
- How are liquidity described in a theoretical model framework and can the model describe the Danish covered bond market?

To provide a complete and comprehensive answer to my research questions, I have chosen to construct my thesis into 2 overall parts followed by row of relevant sections and sub-sections.

1.4 Delimitations and Research Method

To retain the focus on the primary research question of the thesis, which is to see how the current FRTB market risk framework from January 2019 will affect the market liquidity of Danish covered bonds and because of the pre-determined delimitation of a thesis, a set of additional delimitations have been setup. The delimitations are the following:

- The thesis will only discuss the Danish covered bonds. Danish government bonds will not be analyzed but will however be mentioned as a reference in the thesis.
- The empirical calculation of the capital requirement for Danish covered bonds will only focus on RTL and FRN, this is to keep the setup as simple as possible and to focus on the implication of the capital requirements. The calculation for fixed rate callable bonds is very cumbersome and will change the focus of the thesis.
- The empirical calculation on Danish covered bond will not be calculated by myself but will build on calculation already constructed by banks or other researchers. This is because of the high complexity of calculating covered bond sensitivities. Calculating and collecting the right data would shift the focus away from the research question. Therefore, most data and calculation are collected from Scanrate Financial System A/S, which is very trusted source for covered bond calculation in the Danish market.
- A theoretical model will be presented and will be backed by empirical data. The empirical data in the thesis will be constructed by using secondary empirical results, this is done because the Danish covered bond market are very fragmented and it is not easy to collect raw data that individual researcher are able to conduct very deep analysis upon. Therefore, to provide the best overview of the market and the different factors influencing the market

liquidity, the thesis is presenting and using data and calculation based on other market research.

- The data used in this thesis are collected and first presented in research done by Jens Dick-Nielsen et. al and the Danish Central bank (Danmarks Nationalbank)
- The methodology used to accomplish and focus on the motivation and the main objectives are a combination of a theorical and empirical analysis study.

1.5 Structure

The thesis is split into two overall parts. The first part contains an introduction to the Danish covered bond market, the main market participants and how the mortgage market is designed. In addition, the first part also contains the necessary theory surrounding Danish covered bonds, liquidity theory, and a comprehensive presentation of the minimum capital requirements for market risk which will be referred to as the FRTB market risk framework throughout the thesis. The second part of the thesis contains the theoretical and empirical analysis together with a discussion and conclusion of the results and models presented in part 2.

Part 1: Market and Regulation

Section 2: Declaration of the Danish mortgage market model
Section 3: Declaration of Commercial Banks and Danish regulation
Section 4: Declaration of The Basel framework
Section 5: Declaration of the Liquidity theory

Part 2: Analysis

Section 6: Analysis of the effects of FRTB on single bond holdings
Section 7: Analysis of the liquidity drivers, theoretically and empirically
Section 8: Conclusion and discussion
Section 9: Further research

Part 1 and the following sections are intended to give the reader an understanding of the Danish mortgage market model, and how the current regulation have formed the market since its origination. Part 1 will also provide the reader with a comprehensive overview of the FRTB ruleset such that the reader has the right understanding of rules before part 2 begins. Part 2 are the analysis part of the thesis; the reader will obtain a better understanding of how the capital requirements are calculated and how much a market maker can expect his capital requirements to increase compared with the

current legislation. After the reader have been introduced to the capital requirement calculation, the thesis introduces a theoretical model that gives at better understanding of the main drivers of market liquidity. Finally, before the conclusion and discussion, the theoretical model will be backed up by a wide range of market data provided in reports and market papers from the Danish national bank, Danmarks Nationalbank.

Part 1: Bond Market and Regulation

2 The Danish Mortgage Market Model

This section and its sub section are to define the fundamental structure of the Danish covered bond market and the main participants in the market. The reader will be introduced to the background of the Danish covered bond market, its design, and the uniqueness of the market. The reader will also be introduced to the different types of bonds that are issued and traded in the market.

Denmark has one of the largest markets in the world for covered bond, the Danish covered bonds are very popular among investor because of the high safety behind the mortgage bonds. The high safety margin is mainly because of the legislation on the market and because of the unique system which the markets is built upon. In the coming section, the Danish mortgage market, will be presented, the background on the market, bond issues in the market and the opportunity for early exercise. There will also be a description of the different types of bonds and cash loan and lately the different covered bonds will be described. The intention is to provide the reader with a solid and through understanding of the market and the different securities the thesis will examine more in depth in Part 2.

2.1 Background

Danish covered bonds are an interesting asset class for various reasons. The bonds are issued under a strong mortgage act and have strong 220-year history with a strong track record. Even when the Danish economy have experienced a significantly stress, the level of defaults among homeowners have been very low, and the market have never seen a mortgage institutions default. The Danish Mortgage bond market is alongside the German market Europe´s oldest[2]. The Danish Mortgage market was created back in 1795 after a large fire in Copenhagen, which resulted in a quarter of Copenhagen was destroyed. The rebuilding required a lot of capital, which at the time was a scarcity. A group of the wealthy citizens in Copenhagen at the time, created on the backbone of the fire a mortgage union, which issued loans with a guaranty in the properties. Hereafter the first Danish mortgage institution “Kreditkassen for husejere I Kjøbenhavn” was created.

The cornerstone of the Danish mortgage market has not changed in the last 200 years, that is, then a borrower wishes to take a loan to buy a property, the mortgage institution issues and sells the

[2] Nykredit Markets Covered Bonds Handbook, May 2019

mortgage bonds on behalf of the borrower, the mortgage institution is secured with a guarantee in the borrowers property[3]. The investor buys the bonds in the public market and the mortgage institution can now lend the money to the borrower so they can buy the desired property.

In the broader Danish economy, the Danish mortgage institutions has a central role when it comes to financing real estate in Denmark, and they are critically in creating financial stability in the general Danish society. Throughout economic expansions and downturns of the Danish economy, the Danish mortgage market have proved to be efficient and stable. The design and stability have over the years resulted in recognition in research by very prominent financial persons, both in (George Soros, 2008) and in (Paulson, 2009). Some of the words of praise to the Danish system, are the unique access to very cheap financing and the transparency of the market. The Danish mortgage models is based on a one-to-one relationship between loans and bonds issues. This is referred to as the balance principle/Match Funding, which will be described in further details in the coming sub sections.

2.2 Danish Covered bond market

The Mortgage institutions issues bonds, which are tradable on the Danish Stock Exchange, NASDAQ OMX. As the day of writing Denmark are the world largest marked for covered bonds, both in terms of absolute numbers and compared to the size of the Danish economy, bonds used as financing in mortgage loans stands for 78% of the circulated bond issues on NASDAQ OMX[4]. The mortgage institutions issuing in the Danish market tries to issue bonds in large series, to keep the bond series as liquid as possible, this statement will be analyzed through in part 2.

Danish covered bonds can be issued either by specialized Danish banks, under the so-called balance principle, or by a Danish universal bank. Issuance under the balance principle is by far the most prevalent, and volumes far exceed issuance from Danish universal bank that to date has issued covered bonds[5]. Danish covered bonds are issued by a comparatively small number of mortgage banks. Furthermore, market concentrations are high, with the two largest issuer accounting for over 68% of the market, the market split are illustrated in the below Table 1.

[3] Realkreditforeningen.dk
[4] Realkreditforeningen.dk
[5] Nykredit Markets, Covered Bonds Handbook, 2020

Mortgage Institution	Share (%)	Volume outstanding in DKK, bn
Nykredit Realkredit	42%	1.263,00
Realkredit Danmark	26,20%	783,00
Nordea Kredit	14%	440,70
Jyske Realkredit	11,50%	338,70
DLR Kredit	5,40%	164,50

Table 1 - Own creation, with numbers from Nykredit Markets. Volumes and market share of Danish mortgage banks

Under the balance principle, Danish mortgage banks match fund all types of lending – even lending that is refinanced during the term of the loan. When loans are refinanced, loan rates are reset to match the interest rates at which new funding is issued. Thereby Danish mortgage banks transfer market risk in connection with refinancing directly to the individual borrower.

We can classify securities from the Danish covered bond market into three major categories based on each bonds specification: callable bonds, fixed-rate bullets, and floaters bonds (with and without caps). From figure 1 below which illustrates the outstanding amount in DKK of each issued bond segment, Callable bonds and fixed-rate bullets comprise the greater part of the market. EUR-denominated bonds make up about 3% of the Danish covered bond market, with the highest volume in the fixed-rate bullet segment Nykredit Markets (2020).

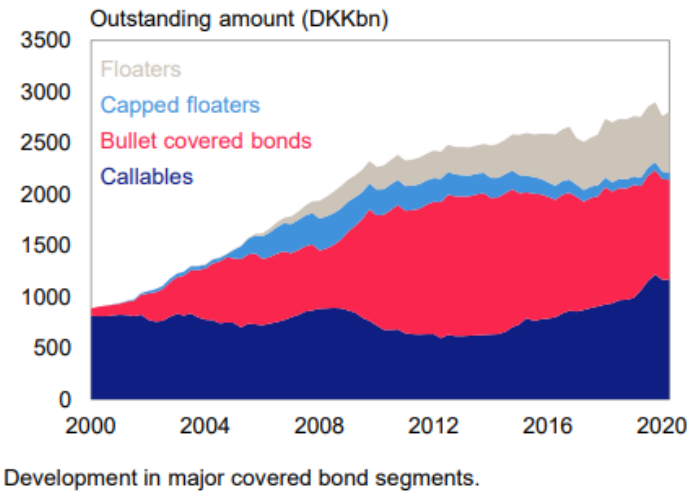

Figure 1 - Source Nykredit Markets.

Danish covered bonds are generally issued either on tap or by refinancing auction. Tap issues satisfy day-to-day funding needs, and issuers thus avoid having to sell large amounts in the market in one single day. As nearly all lending is based on pass-through, higher funding cost do not affect issuers but are passed directly onto borrowers. Due to the match funding, the range of loan products is determined by the development in the funding market Nykredit Markets (2020)

Long-term callable bonds and long-term capped floaters typically have an opening period of three years with tap issuance on a day-to-day basis. The relatively long opening period enables issuers to build sizeable bond series.

Adjustable-Rate Mortgages (ARMs) funded by short-term fixed-rate bullets are refinanced through auctions held about one month before the existing funding matures (1st of January, 1st of April, 1st of July, 1st of October). The auctions give rise to major issuance of mainly 1-year, 3-year, and 5-year fixed rate bullets.

The origination, structuring, issuance, and servicing of Danish mortgage bonds take place in a fully integrated system. The process is illustrated below. First the mortgage bank grants a loan to the borrower based on collateral in the property. It then issues a bond to fund the loan. Following this the mortgage bank acts as the mortgage servicer, assuming the responsibility for collecting payments form borrowers and redistributing them to bond investors.

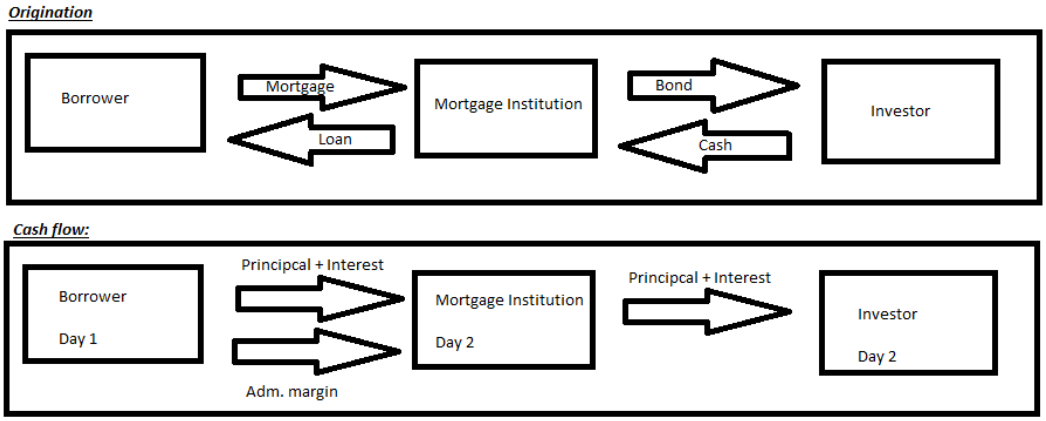

Figure 2- Source – Own creation with inspiration from Nordea Markets Danish Mortgage market origination model.

The bond is a balance sheet liability of the mortgage credit institution, backed by the firm's own funds. The below figure provides an illustrative purpose of a mortgage institutions balance sheet, and shows the effect of the balance fund principal

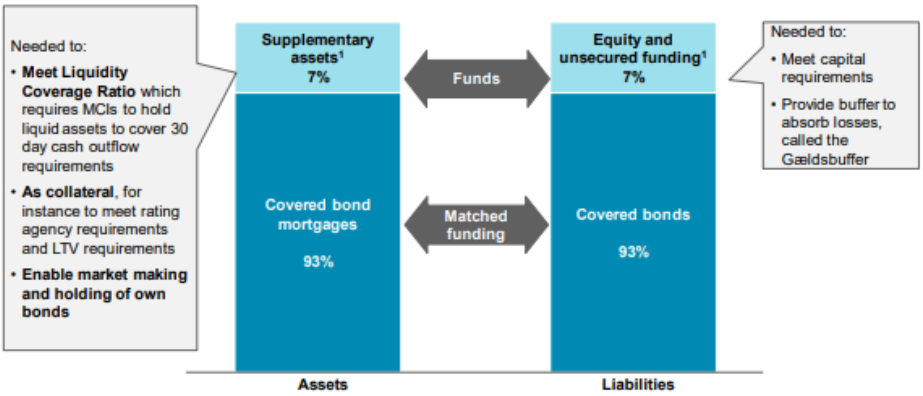

Figure 3 - Source Oliver Wyman analysis. Stylised Balanace sheet of Danish Mortage insitutions

Bonds are issued on tab by the mortgage bank in individual "series" backed by a specific pool of loans. Loans to all types of borrowers serve as collateral for all bond issues, for example a standard 30-year callable bond is open for issuance for up to three years. Each bond series increases in size as loans are granted and matching tap issuance of bonds take place, the result of this process, is some very large and tradable bond issues.

The individual mortgage banks view themselves as jointly responsible for creating and maintaining a well-functioning secondary market for Danish mortgage bonds. To achieve this objective, they entered into several agreements covering market-making and the dissemination of common information of the characteristics of underlying mortgages of individual bonds and on prepayment speed statistics by bond issue.

2.3 The balance principle

In this section, we go into detail with the description of the balance/match funding- principle as implemented in the Danish mortgage system. We contrast the Danish mortgage system design to that used in the US and Germany. Both the US system and the German system had illiquidity concerns during the crisis, whereas the Danish market remained highly liquid as we shall see evidence of in part two.

The strict match funding principle requires mortgage banks to fund their lending activity by issuing covered bonds with cash flows that fully match those of the underlying mortgage loans until maturity on a loan-by-loan basis. The mortgage loans stay on the books of the covered bond issuer, unlike in the originate-to-distribute securitization model used in the US system. In case of a default on a mortgage loan, the issuer will replenish the loan without a loss to investors (unless the mortgage issuer

also defaults). The pass-through funding thus forces the interest period on the bonds to exactly match the interest period for the homeowner.

Bond issuance in the Danish covered bond market is completely dominated by specialized private institutions or independent subsidiaries of major banks. The market has shifted slowly from being completely dominated by fixed-rate mortgages (FRMs) to having a sizable share of adjustable-rate mortgages (ARMs). These two main types of contracts are also the most used globally. The dominating fixed rate contracts is a long-term (up to 30 years) loan (FRM) with an option to make penalty-free prepayments. Under the match funding principle this 30-year fixed rate callable mortgage loan is funded by cash-flow matching 30-year fixed rate callable bond. Low stable short-term interest rate has over time created a demand for 1-year adjustable-rate mortgage contracts (ARMs) as well. This is the basis of a 30-year loan, where the interest rate changes once a year based on the funding conditions at the time of refinancing of the underlying bonds. Under the match funding principle this loan is funded by a sale of fixed rate 1-year bullet bonds.

Despite a significant transformation of the Danish covered bond market over the last 10 – 15 years, the issuing banks have continued to operate according to a model, where the cash flows of the outstanding bonds precisely match those of the underlying loans (the so-called strict balance principle or match funding principle). Historically, this has been a defining characteristic of the Danish mortgage system. In practice, no doubt reflects that regulation for many years only allowed mortgage banks to hold very limited market or prepayment risk and therefore they only held credit risk.

This regulatory restriction essentially required mortgage banks to fund their lending activities by issuing mortgage bonds with cash flow that fully matched those of the underlying mortgage loans until maturity on a loan-by-loan basis. In line with the balance-principle, interest period on the bonds exactly matches the interest period for the homeowner, thereby creating a natural interest rate hedge for the mortgage bank. For each interest period of 1 year, the cash flow of the loans and the bonds issued to fund them match, and the mortgage bank is therefore fully hedge regarding interest rate, currency, and prepayment risk.

In addition, as the borrower pays the mortgage banks cost-of-funds plus a margin, the mortgage bank is also hedged against rising funding spread. The issuing bank is however exposed to the risk of a complete freeze in the funding markets when the issuance of new bonds to roll over the funding of maturing bonds is impossible at any price.

Figure 4 below, illustrates the balance principle.

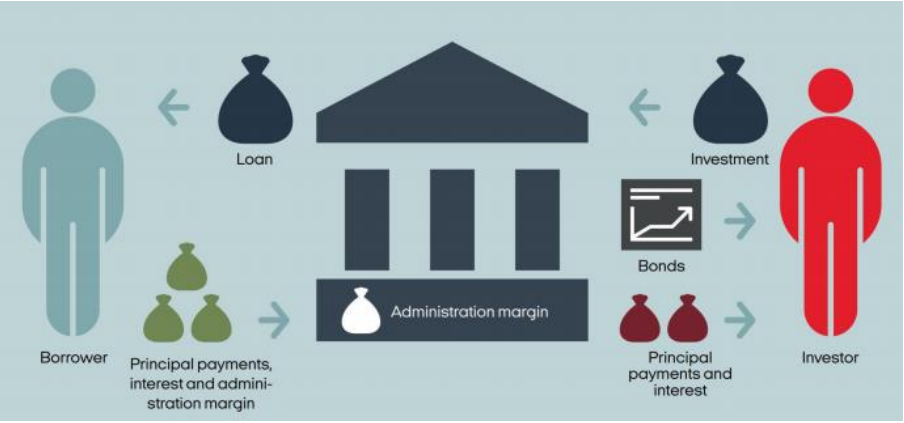

Figure 4 - Sourrce Realkredit rådet

In other words, it can be said that the loaner's interest rate reflects the market price of liquidity on the time right for the disbursement of the loan. In this way, the risk of the mortgage institution is significantly reduced.

However, there can be talk of continuing liquidation risk in the refinancing of loans. The risk lies in the fact that the maturity of the real-life loan is longer than the maturity of the bonds that finance the loan (e.g. interest rate adjustment loans, and guaranty loans). The mortgage credit institution will therefore have to sell new bonds when the old ones expire. The risk of a lack of liquidity, i.e. in the field from investors will, however, be transferred to the borrower through the interest rate. The less buying interest from investors, the higher interest rate – and vice versa.

2.4 Investor concentration

Investor concentration might matter for the liquidity of the covered bonds, as we shall seek to explore further both theoretically and empirically in part 2. The Danish government issue bonds at very large series and are rarely very concentrated with a small investor base, where covered bonds on the other hand might be held only by a few investors as we shall see evidence for later, investor concentration will therefore play an important role for the liquidity as different types of investors, have different types of investment intentions. Therefore, the investor base in the mortgage bond market may affect bond liquidity. The insurance and pension sector typically hold long-term bond to maturity to match long-term liabilities, while short-term investors such as banks and foreign investors tend to hold short-term bonds temporarily, for instance for liquidity management purposes. Banks also hold bonds to support market making activities and speculation to make trading income. A large proportion of long-term investors creates stability but may reduce liquidity in the market. Since 2007, the percentage of

bonds held by foreign investors and hedge funds of Danish investors has increased from just under 10%

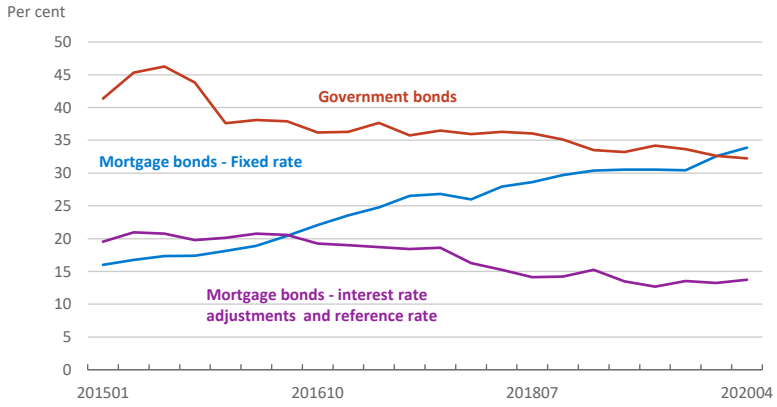

Figure 5 - Foreign ownership of Danish government and mortgage bond, in DKK. Source Denmark's Nationalbank

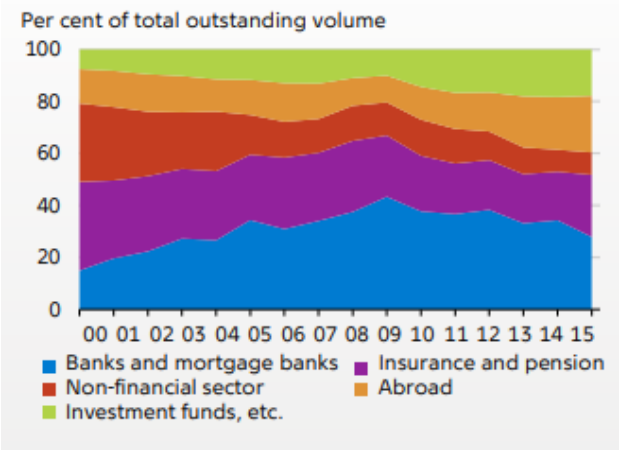

Figure 6 - Mortgage bond investors, Source Danmarks Nationalbank

Market participants have indicated over recent years, market makers have become less willing to absorb imbalances between supply and demand for mortgage bonds (Danmarks Nationalbank, 2015). This should be seen in the context that risk appetite in the financial sector has tended to decline since the financial crisis. New regulation in the form of enhanced capital and liquidity requirements has also reduced the potential for risk taking in banks as we shall look deeper into in section 4 and part 2. Internationally, it has been observed that banks have reduced their holdings of bonds for market making since the great financial crisis in 2008. Over the last year, Danish banks have also reduced their market making portfolio, as can been seen on the below figure 7.

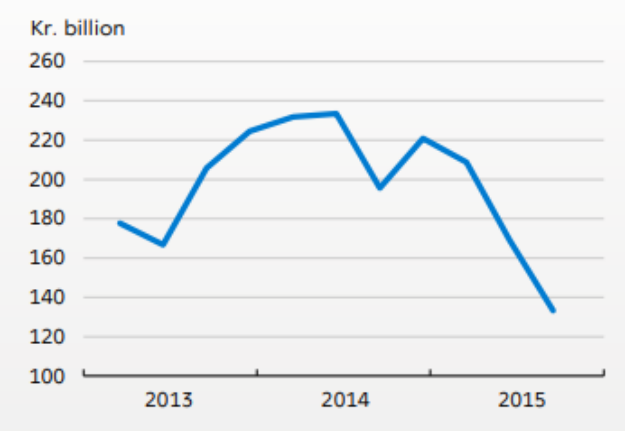

Figure 7 - Bank holdings of mortgage bonds for market making, source Danmarks Nationalbank

2.5 Covered Bond Types

Callable annuity bonds are unique to the Danish covered bond market. Traditionally, callable annuity bonds were the only type of bonds issued in the Danish covered bond market, but the introduction of new products has expanded market diversity[6].

Back then mortgage bonds had second annual payments, but since 1985 there have been quarterly payments: The 1st of January, the 1st of April, the 1st July and finally the 1st of October. The maturity of the bonds is typically 10, 15, 20 or 30 years. Callable annuity bonds are fixed rate bonds with an embedded call option. The embedded call option enables borrowers to prepay their loan at par at each payment date during the duration of the loan. Traditionally, all callable loans were issued as annuity loans. Annuity loans amortize with equal payments consisting of principal and interest, but the amount of principal repaid increases over time, while the amount of interest decrease.

There are three main types of covered bonds available in Denmark: Bullet covered bonds, callable bonds, floating rate bonds with or without cap. The different type of mortgage bonds differs in their design, coupon rate, maturity, and the repayment profile. In other words, they have different terms. Traditionally, callable annuity bonds pre-dominated the Danish mortgage bond market for many years, but after 2000 there have been a clear trend going towards bullet covered bonds as they have grown in popularity[7].

[6] Danish Covered bond Handbook 2017 – RD
[7] Nykredit Covered Bond Handbook 2020.

Callable bonds	Bullet Covered Bonds	Floaters with and without cap
Fixed-rate callable bonds	Non-callable fixed-rate bullets bonds	Capped and uncapped floating-rate bonds
Mainly DKK-denominated	DKK- and EUR- denominated	DKK and EUR denominated
Maturities: 10, 15, 20 and 30 years	Maturities: 1 – 10 years	Maturities: 5, 10, 20 and 30 years
Annuities with or without interest only option	Daily tap issuance combined with auctions in Mar., Sep., and Dec.	Annuities with or without interest-only options
Daily tap issuance	Used to fund adjustable-rate annuity loans.	Coupon typically based on 3M or 6M Cibor or Euribor plus fixed spread
Used to fund fixed-rate callable annuity	Open for issuance until maturity	Typically, with prepayment option
Open Period, typically 3 years		Daily tap issuance combined with auctions in Dec.
		Used to fund loans based on capped and uncapped floating-rate mortgage bonds with or without interest-only option.

Table 2- Source: Own creation with data from Nykredit Markets. Types of Danish Covered bonds

2.5.1 Bullet covered bonds

There are two main types of non-callable bonds: Non-callable bullets and non-callable annuity bonds. An important non-callable bonds feature is that the bonds cannot be redeemed prior to maturity. Non-callable bullets are fixed rate bonds that normally pay one annual payment for an investor. These bonds have a simple cash flow structure which provides coupon, or interest payments at regular intervals over the life of the issue and repays the full principal amount to investors at maturity. Initially, non-callable bullets were introduced in 1996 to fund adjustable-rate mortgage loans (ARMs), or interest reset loans. ARMs are traditionally grated as 10, 15, 20, 30 and up to 35 years annuity loans, they are financed through the short term non-callable annuity bullet bonds. Debtors that hold a long term non-callable loan, have a flexibility or refinancing their loan via the newly launched flex bond.

Non-callable annuity bond is a bond containing provisions allowing principal payments, in whole or in part, before the stated maturity. Thus, the core difference between non-callable bullets and non-callable annuity bond is that individual payments of non-callable annuity bonds contain increasing amounts of repaid principal and correspondingly declining amounts of interest. Meaning that borrowers pay a part of principal each year together with the interest payment, the repaid principal becomes bigger and the interest payment becomes smaller over time.

Large volumes of the outstanding bond and natural liquidity in the market from ongoing tap issuance and buyback from borrowers make take segment very attractive for liquidity purposes. For the Danish banking sector, short-term DKK covered bonds are the most important asset in liquidity management, and the need for short-term covered bonds is underpinned by the fact that the DKK government bond market is too small to fulfil the need for liquidity assets in the banking sector (Nykredit Covered Bond Handbook, 2020). Most of the bonds are typically priced very tight against the swap curve in line with euro covered bonds from Germany for example. The 1Y segment of the bond's trades at a tight spread to the Danish OIS curve (Nykredit Covered Bond Handbook, 2020).

2.5.2 Callable bonds

As non-callable bonds, callable bonds are divided into two main types: Callable bullets and callable annuity bonds. This section will focus on callable annuity bonds since the Danish mortgage market is predominated by callable annuity bonds. The main distinction between non-callable annuity bonds and callable annuity bonds is that callable annuity bonds provides the borrower with the option to repay the bond before maturity. As mentioned above, non-callable loans have only a delivery option while callable annuity loans have both a call- and delivery option. In other words, callable annuity bonds are fixed rate bonds with an incorporated call option as well as a delivery option. This means that the mortgage bank will pay the debt back by calling a bond at a par value or by buying the bond back in the market at a market price (cash loan)

Compared to a non-callable bond, the price of a callable bond is kept down when interest rates decline as debtors are likely to repay the bond at par. When a bond becomes extremely exposed to redemption, the price will fall when interest rates fall.

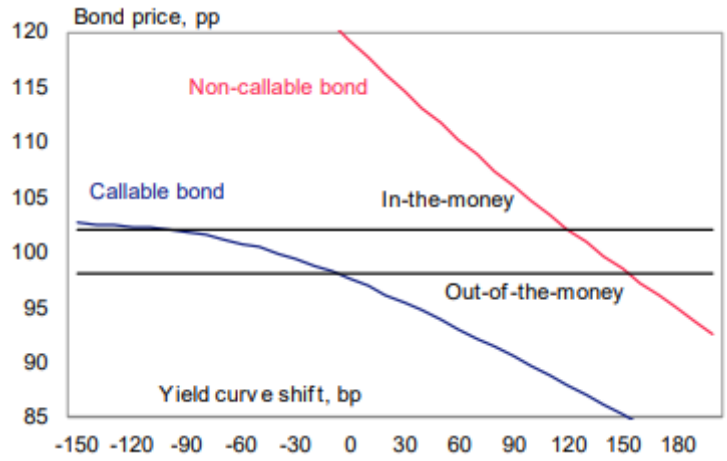

Figure 8 - Source Nykredit Markets, Pricing of callable bonds

When exercising the call option, the debtors should notify the mortgage bank two months before the next coupon payment date. Usually, the payment dates are 1st of January, 1st of April, 1st of July and 1st of October. If the borrower exercises his call option, he repays the loan by prepaying the remaining debt at par plus the cost related to the prepayment. The prepayment cost might include a new loan registration free, price spread, commissions etc. (Nykredit Covered Bond Handbook, 2020). When exercising the delivery option, the borrower bears all the risk related to the underlying bond purchase

The prepayment option means that investors obtain only a limited upside potential when interest rates fall, but on the other hand they receive a significantly higher yield relative to non-callable bonds. Successful investment in callable bonds requires an understanding of how prepayment risk affects the pricing of the bonds (Nykredit Covered bond handbook, 2020).

2.5.3 Floating rate bonds

Floaters in Denmark were initially introduced in 2000 when borrowers were offered the opportunity to raise 30-year adjustable interest rate mortgage loans with interest rate caps. As the name suggest, floaters mean that the bonds coupon rate is not fixed over the entire bonds life. Instead, it varies together with the markets interest rate. The bonds behind these loans were capped floaters with maturities of up to five years. After five years, the loans were refinanced into new five-year capped floaters, and the interest rate cap was thus, only effective for five years. In 2004 capped floaters with maturities of up to 30 years were launched, which enabled the borrowers to obtain a fixed interest rate cap covering the entire loan term. Since then, the development and introduction of new adjustable interest rate loans and bond types have continued. As a result, the floating-rate bonds with different features are now being provided to the loan market (Nykredit Covered Bond handbook, 2008).

There are two forms of floating rate bonds available in Denmark, capped and uncapped floaters. Capped floaters mainly consist of floater-to-fixed and capped floaters. Both types have an incorporated cap, which remains fixed throughout the whole maturity of the bond. Uncapped floaters are also called pure floaters, and this means that this type of bonds does not have a cap. Pure floater were launched to fund commercial lending and originally were issued with five-year maturities, but after 2007 legislation, pure floaters were issued with 10 years and 30 years maturities.

3 Danish regulation and Commercial Banks

In the section before the reader was introduced to the Danish covered bond market, its design, legislation, and the different types of covered bonds that are issued. In this section the reader will be introduced to the banking sector, why banks trading activities matter to the real economy and the importance of mortgage banks and regulation. Firstly, the Danish financial sector will be described, and how Danish market have implemented both domestic and international regulation. Lastly, the banking activities will be described and why they are important for the real economy. This section should give the reader the ability to understand the financial sector before we move into the future FRTB regulation in section 4.

3.1 The Danish Financial Sector

In Denmark, banks and mortgage banks are the main major credit providers to the real economy. As was shown for the mortgage banking in section 2, the Danish banking sector are also characterized by a high degree of concentration and measured by a ratio of GDP among the largest sectors in Europe. Banks and mortgage banks are of great significance to the Danish economy, accounting for the major share of credit intermediation in society. Banks contribute to the economy by, inter alia, converting short-term deposits to long-term loans (maturity transformation), spreading risks and ensuring that payments between counterparties are affected. Mortgage banks exclusively provide loans secured on real property. The loans are solely financed by issuing bonds – mortgage bank does not accept deposits – and for that reason the mortgage banks are the largest bond issuers in Denmark. Households can only obtain mortgage loans of up to 80% of the value of properties used as permanent residences.

3.1.1 Banking and mortgage banking sector characteristics

The Danish mortgage banking sector is characterized by a few large international groups and many small institutions. The large groups accounts for most of the total lending, and the sector is among the largest and most concentrated in Europe, measured as ratio of GDP. At end-2013, lending by banks and mortgage banks to households and the corporate sector in Denmark accounted for approximately 180% of GDP.

Bank and mortgage banks are grouped into systemically important financial institutions (SIFIs) and non-systemically important financial institutions, the section below makes an introduction to the identification of SIFIs in Denmark. SIFIs are characterized by undertaking activities that are significance

to the overall economy, a SIFI institution are defined by the Danish financial supervisor, Finanstilsynet (Danish FSA).

3.1.2 Criteria for identification of SIFIS

In Denmark, systemically important financial institutions (SIFIs) are identified at group level once a year. An institution is identified as a SIFI if at least one of the following quantitative criteria is met for two consecutive years:

- Balance sheet as a percentage of GDP > 6.5%
- Lending as a percentage of total sector lending > 5%
- Deposits as a percentage of total sector deposits > 3%

SIFIs are subject to a SIFI capital buffer requirement of 1-3% of their risk-weighted assets depending on their systemic importance.

In June 2014, the following groups met the SIFI criteria: Danske Bank, Nykredit Realkredit, Nordea Bank Danmark, Jyske Bank, Sydbank and DLR Kredit.

3.1.3 The Danish FSA.

The risk profile of the different Danish mortgage banks is closely monitored and supervised by the Danish FSA. Property valuations are reported directly

The Danish FSA's "Supervisory Diamond" for mortgage credit institutions was implemented from 2018 to 2020. The Diamond constrains five indicators with corresponding limits on risk of the mortgage banks. Below are listed the five indicators.

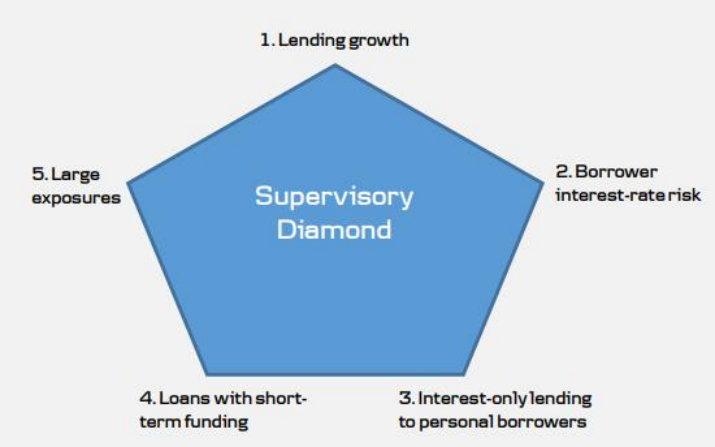

Figure 9 – Source, Danish FSA and Realkredit Håndbogen, RD.

- **Lending growth**: Growth in lending to individual customers segments should not exceed 15% per year. The four customers segments are private homeowners, rental property, agriculture, and other corporates.
- **Borrower interest rate risk**: Share of lending where loan-to-value exceeds 75% of the lending limits for Mortgage-credit institutions and where the interest rate risk is only fixed for up to two years should be less than 25%. Applies only to loans to private homeowners and rental property. Loans hedged by interest rate swaps and the like are excluded.
- **Interest only lending to personal borrowers**: The share of interest-only loans in the loan-to-value band above 75% of the lending limit should not exceed 10% of total lending. Interest only loans are included regardless of positions in order of priority.
- **Loans with short-term funding:** The share of lending to be refinanced should be less than 12.5% of the total loan portfolio per quarter and less than 25% of the loan portfolio annually.
- **Large exposure:** Sum of the 20 largest exposures should be less than the institutions CET1 (core equity tier 1 capital).

3.1.4 Refinancing risk and Interest-rate triggers

In 2014, a new law aimed to reduce refinancing risk for borrowers and mortgage banks came into place. The law first covered loans where refinancing period of the underlying bond is up to 12 months. In 2015 the law came into force for non-callable bullets, short and medium term capped floaters and floaters, there refinancing period is more than 12 months. The law was created on the backbone of the financial crisis in 2008, where market participants was afraid that, no one could be sure that covered bonds was liquid and easy to turnover in the market. International rating agencies and EU focused after 2008 their attention to risk regarding the ability to refinancing in stressed markets situations.

The below criteria are the basis for the legislation.

- **Interest-rate trigger**: If the yield at a refinancing auction increases by more than 500bp within a period of one year and the underlying bonds have a maturity of up to two years after refinancing, the maturity will be extended by one year. The yield of the extended bond will be the yield level on a corresponding bond traded 11-14 month earlier plus 500bp. A maturity extension triggered by a rise in the yield level of 500bp is limited to one year. For floating-rate bonds, the interest rate at the refinancing of a mortgage loan cannot be fixed at a rate more than 500bp above the most recently fixed interest rate. The interest rate must remain unchanged for 12 months or up to the next refinancing unless a lower interest rate is fixed

within the 12 months or before the next refinancing. The interest-rate trigger element only applies to loans where the refinancing period of the underlying bonds is 24 months or less.

- **Failed auction trigger:** If a mortgage bank is unable to sell its bonds at a refinancing auction, the maturity of the underlying bond will be extended by one year. If the mortgage bank is still unable to sell the bonds the following year, the maturity of the bond will be extended by one year every year until the mortgage bank is able to sell the bonds in the market or the loans mature. If a mortgage bank is unable to sell its bonds at a refinancing auction and the maturity is extended by one year, the yield of the maturity-extended bond will be the yield on:
    - A corresponding bond traded 11-14 months earlier plus 500bp if the maturity is less than or equal to 24 months.
    - A corresponding bond with a maturity of 11-14 month traded 11-14 month earlier plus 500bp if the maturity is more than 24 months.

Investors are exposed to the refinancing risk, but they must now also carry some of the interest rate risk, in cases where yield will increase by more than 500bp.

3.2 Universal banks and their trading activities justification to the broader economy

In section 2 and the sub sections of section 3, it was described that Danish mortgage banks are not allowed to take deposit, they can only issue covered bonds to finance its liabilities. Because of that, the Danish covered bonds market relies on Danish universal banks to act as market makers and facilitates trading activities in the secondary market. This section will shortly describe universal banks' balance sheet and list a couple of points why its trading activities matter for the real economy.

A bank accepts short-term deposits and uses them for long-term loans. Whether the profit and loss accounts show profit or loss it is in the end determined by the difference between the interest that the bank charges to borrows and the interest it pays to savers. Capital is the key to keep a bank safe and sound, banks take on risk and may suffer losses if the risk materialize. To protect its customers deposits, the bank must absorb such losses and keep doing business in bad and good times, which is where a bank needs capital. A rule of thumb, the more risk the banks takes, the more capital it needs. A bank must continuously assess the risk they are exposed to and the losses they may incur. Their assessments are checked and challenged by banking supervisors, which will be presented in the next section, section 4.

Put simply, capital is the money that a bank was obtained from its shareholders and other investors and any profit that it has made and not paid out. Consequently, if a bank wants to expand its capital base, it can do so for example by issuing more shares or retaining profits, rather than paying them out as dividends to its shareholders. Overall, every bank has two sources of funds: Capital and debt. Debts is the money that it has borrowed from its lenders and will have to pay back. Debt includes among other things deposits from its customers, debt securities issued, and loans taken out by the bank.

Funds from these two sources are employed by the bank in several ways, for example to give loans to customers, investments or to trading and market making activities. These loans and other investments are the bank's assets, along with funds that are held as cash.

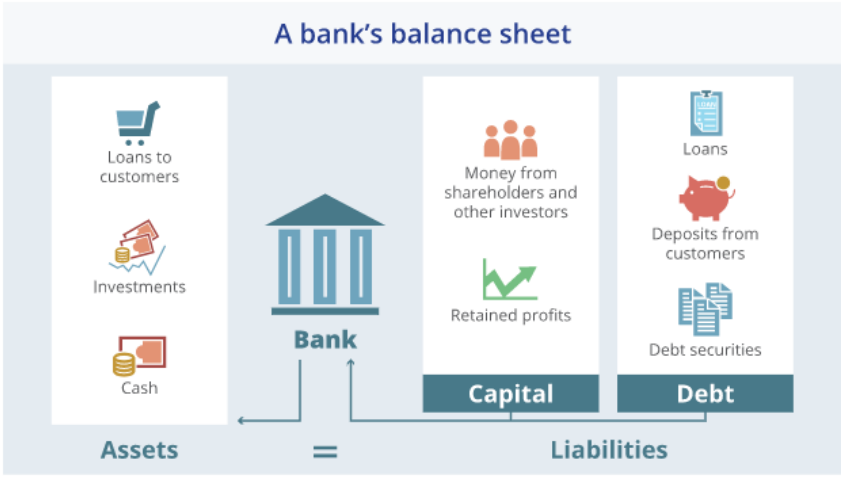

Figure 10 - Source: Banking Supervision Europe. A banks Balance sheet

Capital acts like a financial cushion against losses from the banks risk taking, it could be that borrowers are unable to pay back their loans or that some of the trading and market making business has lost money on its invested capital.

In the euro area, the capital requirements for a bank consist of three main elements:

- Minimum capital requirements, known as Pillar 1 requirements
- An additional capital requirement, known as the Pillar 2 requirement
- Buffer requirement

Firstly, all banks in the euro area must comply with the European law that sets the minimum total capital requirement, Pillar 1 at 8% of banks risk weighted assets. In the coming section we shall look at the capital requirements for market risk set out in the FRTB market risk framework which fall under the Pillar 1 capital requirements.

Wholesale banking activities are fundamental to the functioning of the Danish and European capital markets, which facilitate investment across the region. A market-based financing model provide many benefits to the Danish and European economy, some of which are summarized below.

- It allows capital formation to new and existing industries that want to expand
- Market-making services mean the cost of capital formation are kept low, and investors can sell their assets at an appropriate cost when their portfolio needs adjustment
- It limits the overreliance on bank funding and ensures risk is passed on to investors that are most capable of managing it.

In addition, financial services end users such as small mortgage banks individual mortgage takers, corporate, SMEs and investors can access crucial hedging solutions via wholesale markets.[8]

4 Basel Framework

This section set out the foundation for the international regulation proposed by The Basel Committee on Banking Supervision, why it is important and the implication of regulation. Firstly, the purpose of the Basel Committee and its regulation will be described, then a short introduction to two important liquidity requirements already implemented in Danish market will be introduced, and finally from section 4.4 and forward the reader will be provided with a comprehensive introduction and review of the 2019 revised FRTB capital requirements.

Given the significance of the financial sector to the overall economy, financial institutions are subject to more comprehensive regulations than other firms, the great financial crisis in 2008 and 2009 put renewed focus on the regulation of the financial sector and tightened the requirements for the financial institutions capital and liquidity. The purpose of the new tightened regulations is to make the financial sector more resilient to future financial crises.

[8] ISDA, Position Paper CRD V/CRR II: Fundamental Review of the Trading book, March 2017

4.1 The Basel Committee

The Bank for International Settlements is an organization based in Basel, established in 1930, and is not accountable to any government. The Bank for International Settlement (BIS) is an intergovernmental organization of central banks which fosters international monetary and financial corporations and serves as a bank for central banks. The meetings take place in Basel, where the secretariat is established, this committee is known as the Basel Committee. The official name reads: Basel Committee on Banking Supervision.

The Basel Committee on Banking Supervision (BCBS) was established in 1974 in the aftermath of a currency market disturbances. The purpose of the committee was to improve the quality of banking supervision to thereby enhance financial stability. The committee was also to serve as a forum for supervisory authorities of the member countries, which a first was the G10 countries. Today the BCBS's members come from 27 jurisdictions. Members of BCBS are either from central banks or supervisory authorities and represent over 80% of the worlds GDP. BCBS purpose is still the same today as when the committee was founded, to improve security in financial institutions, this is done in general by focusing on the balance sheets, capital adequacy and liquidity requirements of the financial institutions.

The BCBS committee's accords are not legally binding but acts as standards for supervisors. It is up to each supervisory authority to determine if and how to implement the standards recommended by the committee. In 1998 the BCBS released the first accord, known as The Basel Accord[9]. This marked start of international standards for bank regulation, the 1988 accord is the foundation upon which following regulation are build. In most of Europe, these binding capital rules come in the form of CRD IV, which is the EU implementation of Basel III and applies to banks and investments firms.

The BIS is therefore a very important organization for banks since it regulates capital adequacy and encourages reserves transparency as a goal to create and maintain a financial safety net. Banks cannot escape from the fact that they will have to fulfill certain requirements and maintain compliance. These standards and guidelines set out by BIS are created to reduce the probability of insolvency for banks, one of the consequences for banks is that they must reserve more capital than they might originally want to. After all, reserving capital cost money for the banks, since stakeholders demand a return on equity, and reserving more capital means less money to earn these profits with.

[9] https://www.bis.org/bcbs/history.htm

4.2 Purpose of regulation

Banking regulation in the financial sector is motivated by two main arguments. Firstly, it is a tool to limit the total risk exposure of the government and the taxpayers money, and secondly, it functions as a safety net to protect the economy from negative externalities caused by banking failures especially based on systemic risk[10] from which the 2008 financial crisis emerged. Governments are concerned about the systemic risk that a default of one financial institution could create a "ripple effect" that would threaten the stability of the whole financial system.

Thus, banking regulation ensures that financial institutions keep enough financial instruments for the risks they take. It is impossible to eliminate the risk of default, but governments want to ensure that risk of default is minimized[11]. This will create a stable financial market, where taxpayers and investors have confidence in the financial sector.

The choice of equity and debt financing was basically an internal decision before the Basel I amendment because financial institutions where less related to the risks of each other. The structure of the financial sector at the time was regulated by interest rate and market structure rather than international framework for minimum capital requirements.

4.3 Liquidity requirements

Liquidity risk is inseparably linked with the transformation function of banks: raise of funds with short maturities, saving and deposits, and convert them into long-term loans, mortgages. During the financial crisis in 2008, financial markets faced large shortages of liquidity. Therefore, the BIS created a set of guidelines for banks to apply more stringent standards to reflect that banks liquidity risk profile.

The Basel Committee has developed two standards for supervisions to use in liquidity risk supervision: The LCR and the NSFR. The LCR addresses the sufficiency of a stock of high-quality liquid assets to meet short-term liquidity needs under a specified acute stress scenario. NSFR addresses longer-term structural liquidity mismatches.

[10] "The Role of Capital in Financial Institutions" Berger, Allen N; Herring, Richard J; Szego, Gerorgio P. 1995
[11] Hull, J.C, 2009. " Risk Management and Financial Institutions", 2nd Edition.

4.3.1 Liquidity Coverage Ratio

The Liquidity Coverage Ratio (LCR) will ensure that financial institutions hold liquid assets that more than exceed their outbound net payments over a period of 30 days of financial turmoil, with financial markets initially freezing up. The amount of liquid assets to be held by each institution will depend on the liquidity risks of the institutions.

LCR shall be calculated as follows:

$$LCR = \frac{HQLA\ (High\ quality\ Liquid\ Assets)}{30\ Day\ net\ Cash\ out\ flow} \geq 100\%$$

LCR are created to ensure that financial institutions can within stand financial turmoil, with getting any public rescue funding or grants.

High quality Liquid assets are the institutions holding of recognized liquid assets, defined by EU commission in CRD IV[12]. The recognized liquid asset is split into two. Level 1 assets (L1) and level 2 assets (L2). This recognition caused a lot of noise in the Danish financial sector when first purposed because Danish covered bonds was not recognized as a liquid asset that could count as a HQLA. Covered bonds was in the final draft and proposal recognized as HQLA[13].

Among the main observation points which have a significant influence for Danish covered bonds are:

1. Covered bonds may be included in L1 assets if the bonds have been issued for a minimum of EUR 500 million, and the bonds hold a rating of at least AA-
2. To avoid the liquidity coverage requirement becoming too dependent on mortgage-backed securities, a 7% value is introduced, why covered bonds of asset class L1 only count with a market value of 93%.
3. Covered bonds with a minimum issues size of EUR 250 million, and a rating of A- are recognized as L2 assets.
4. Covered bonds under asset class L2 have a haircut of 15% and count with a market value of 85%
5. Overall, mortgage bonds in asset classes L1 and L2 may not exceed 70% of the liquidity buffer
6. In addition, an overcapitalization of 2% and 7% respectively must be maintained respectively for L1 and L2 assets, in the capital centers from which bonds are issued.

[12] Basel III, The Liquidity Coverage Ration and Liquidity risk monitoring tools.
[13] Basel III, The liquidity Coverage Ration.

In Denmark it was decided that SIFI-institutions should apply the requirements of LCR by 1st of October 2015.

4.3.2 The Net Stable Funding Ratio

To promote more medium and long-term funding of the assets and activities of banking organizations, the BCBS has developed The Net Stable Funding Ratio (NSFR). This metric establishes a minimum acceptable amount of stable funding based on the liquidity characteristics of an institution's assets and activities over a one-year period. The NSFR is defined as the available amount of stable funding, divided by the amount of required stable funding. This ratio must be greater than 100% all the time.

The NSFR ratio looks as follow:

$$\frac{Available\ amount\ of\ stable\ funding}{Required\ amount\ of\ stable\ funding} \geq 100\%$$

BCBS defines stable funding in Basel III as follows[14]:

- Capital
- Preferred stock with maturity of equal to or greater than one year.
- Liabilities with effective maturities of one year or greater
- Portion of non-maturity deposits and / or term deposits with maturities of less than one year what would be expected to stay with the institution for an extended period in an idiosyncratic stress event
- The portion of wholesale funding with maturities of less than a year that is expected to stay with the institution for an extended period in an idiosyncratic stress event.

4.4 Fundamental Review of the Trading Book

The purpose of this sections is intended to give the read a complete overview of the Fundamental Review of the trading book ruleset before digging into the analysis and calculations in part 2.

The Fundamental Review of the Trading Book (FRTB) is a comprehensive collection of capital rules developed by the Basel Committee on Banking Supervision (BCBS) as part of Basel III regulation, intended to be applied to banks wholesale trading activities. Finalized in January 2016 as the Minimum

[14] Basel III: The net stable funding ratio

Capital Requirements for Market Risk, it aims to address several identified shortcomings in the existing Basel II.5 framework.

The purpose of the FRTB is to revise the common global rules for calculating market risk capital charges on positions in the part of the banking sector where risk is held for the purpose of trading. The framework offers two methods for calculating risk: The standardised approach (SA) and the Internal Model approach (IMA). Banks must apply to gain approval for using the IMA, but even when they receive IMA approval they must also calculate and report the capital charge based on the SA.

In January 2019, the final piece of Basel III fell into place with the publication of the revised framework for market risk capital, known as FRTB. The FRTB makes several important changes, including the introduction of a more risk-sensitive SA, desk-level approval for internal models, and a capital add-on for non-modellable risk factors (NMRFs).

Now that the ruleset is finalized, markets attention turns to the different national implantation. All jurisdictions must meet the BCBS 2022 implementation target

Following the global financial crisis, the BCBS initiated an overhaul of market risk capital rules, with the aim of replacing the Basel 2.5 framework with a more coherent and risk-sensitive package.

The BCBS's objective was to address shortcomings in Basel 2.5, reduce the variability of risk weighted assets (RWAs) across jurisdiction and strengthen the relationship between the SA and the internal approach (IMA).

The FRTB framework are designed to:

- Revise the boundary between the trading book and the banking book
- Overhaul the IMA to focus on tail risk, and take market liquidity during a period of stress into account
- Establish stringent trading desk-level IMA approval processes, including a new profit and loss attribution test
- Introduce a stressed capital add-on for risk factors failing model ability test, known as NMRFs
- Ensure the SA is more risk-sensitive, explicitly captures default and other residual risks, and serves as a credible fallback for the IMA.

Figure 11 below gives a great illustration of the set-up of the FRTB market risk ruleset, the different components in the both the internal models approach and the standardised approach. This thesis will only cover the SA as mentioned in the delimitation section in section 1. The IMA are based on banks own models and quantitative assessment and would be a whole thesis just to cover some of the assumptions behind such models.

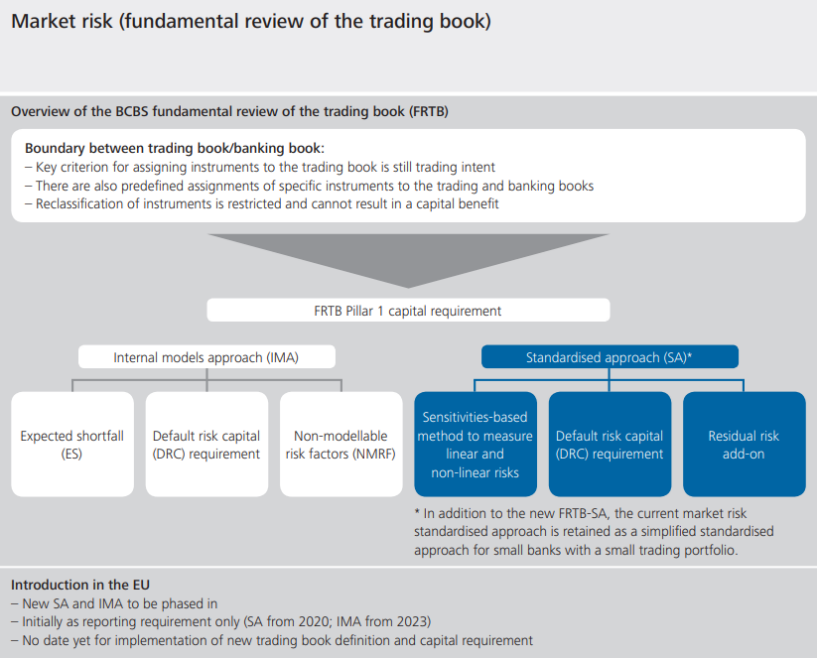

Figure 11 - Source Deutsche Bundsbank & Basel III

4.5 Standardised Approach

The updated FRTB framework overhauls the standardised approach, bringing it up to date by implementing some of the points that the industry has criticized the old legislation not to cover. The intent is to have the standardised approach (SA) to be able to serve as a simple model for smaller banks, as well as having it as a risk floor for larger banks to fall back for the internal model approach, if their models are not approved.

When calculating the capital charge under the SA, it is the simple sum of three main components, where each component has individual calculation based on the specific instruments one needs to calculate the requirements upon. The three main components are:

- The Sensitivities-based Method (SbM), which is the main and most complex component calculated by aggregating three risk measures: Delta, based on sensitivities on a bank's trading book to regulatory delta risk factors; vega, based on sensitivities to regulatory vega risk factors; curvature, which captures the incremental risk not captured by the delta risk of price changes in the value of an option.
- The Default Risk Charge (DRC), which captures the jump-to-default risk for the whole trading portfolio.
- The Residual Risk Add-On (RRAO), to account for additional market risks not being captured in the standardized approach.

The standardized approach results in a capital requirement that is a mentioned the simple sum of the three components.

- K_{SBM}: Capital requirement under the sensitivity-based method.
- K_{DRC}: Capital requirement of default risk capital.
- K_{RRAO}: Capital requirement of residual risk add on.

That is

$$K_{SA-FRTB} = K_{SBM} + K_{DRC} + K_{RRAO}$$

The sensitivities-based method categorizes trading book market risk into seven risk classes, in the following sub-section an overview of the sbM will be provided. After introduction to the sbM, an overview of DRC will be provided, DRC tries capitalizes the jump-to-default risk, which is not captured by credit spread shocks under SBM. Finally, a sub-section will provide an overview of RRAO, which captures the exotic risks not included in the other two components.

4.5.1 Instruments subject to each component of the sensitivities-based method

In applying the sensitivities-based method, all instruments held in trading desk as set out in MAR12 and subject to the sensitivities-based method, are subject to delta risk capital requirements. Additionally, the instruments specified in bullet (1) to (4) below are subject to vega and curvature risk capital requirements.

(1) Any instruments with optionality (recall the different types of Danish covered bonds from section 2)
(2) Any instruments with an embedded prepayment option (recall the different types of Danish covered bonds from section 2)
(3) Instruments whose cash flows cannot be written as a linear function of underlying notional. For example, the cash flows generated by a plain-vanilla option.
(4) Curvature risks may be calculated for all instruments subject to delta risk, not limited to that subject to vega risk as specified in (1) to (3) above.

4.6 The sensitivity-based method

The starting point of the sensitivity-based method is the three risk measures, delta, curvature and vega. Delta measures the first order changes in value, whereas curvature captures any non-linearities, for covered bonds it will be the embedded options, and finally vega measures the volatility risk of the instrument.

Each risk measure defines a list of risk factors and corresponding risk weights. We let k be such a risk factor, s_k the net sensitivity in the trading book for that risk factor and RW_k the corresponding risk weight. The weighted sensitivity, WS_k is given as

$$WS_k = RW_k * s_k$$

It quantifies how much the value of the instruments in the trading book changes in accordance with a change in the underlying risk factor. Note that RW_k specifies how much the risk factor is expected to change in an adverse scenario.

The weighted sensitivities are then grouped together based on each individual instrument characteristics, e.g. tenors of interest rate curves, currency, or sector and so on, these different groups are in the FRTB framework called risk buckets. The aggregated capital requirement of a risk bucket, K_b where b is a bucket is calculated using bucket-correlations, ρ_{kl}, prescribed by the FRTB market risk framework in MAR21.46[15].

$$K_b = \sqrt{\max\left(0, \sum_k \sum_l \rho_{kl} WS_k WS_l\right)}$$

The risk buckets are again aggregated according to prescribed between-bucket-correlations to derive the capital requirement in the specific risk class. It is not possible to calculate the total requirement for the specific risk class, which now just the simple sum of all three risk measures.

$$K_{RiskClass} = K^{Delta}_{RiskClass} + K^{Vega}_{RiskClass} + K^{Curvature}_{RiskClass}$$

Finally, K_{SBM} is the sum of all $K_{RiskClass}$. In the FRTB market risk framework, there are a total of seven risk classes, in this thesis we are interested in the General Interest Rate Risk (GIRR) and the Credit Spread Risk (CSR) when calculating the market risk for Danish covered bonds. The below figure provides an illustration the seven risk classes.

[15] This refers to the different sections and number in the FRTB regulation. This type of references will be used throughout the thesis. The document that are referred to is: Basel Committee on Banking Supervision, January 2019: *Minimum capital requirements for market risk* and can be found in the bibliography

Figure 12 - Risk classes in FRTB, source Scanrate and BIS

In similar form to how we would calculate the variance of a portfolio from the variances and covariances of the instrument it contains, the risk position K_b is calculated from the weighted sensitives with the predefined correlations from the legal framework. This means, if both positions in a portfolio are long or both are short, the less correlated the instruments are, and the lower the capital requirement will be.

Buckets for delta CSR non-securitisations — Table 3

Bucket number	Credit quality	Sector
1	Investment grade (IG)	Sovereigns including central banks, multilateral development banks
2		Local government, government-backed non-financials, education, public administration
3		Financials including government-backed financials
4		Basic materials, energy, industrials, agriculture, manufacturing, mining and quarrying
5		Consumer goods and services, transportation and storage, administrative and support service activities
6		Technology, telecommunications
7		Health care, utilities, professional and technical activities
8		Covered bonds[15]
9	High yield (HY) & non-rated (NR)	Sovereigns including central banks, multilateral development banks
10		Local government, government-backed non-financials, education, public administration
11		Financials including government-backed financials
12		Basic materials, energy, industrials, agriculture, manufacturing, mining and quarrying
13		Consumer goods and services, transportation and storage, administrative and support service activities
14		Technology, telecommunications
15		Health care, utilities, professional and technical activities
16	Other sector[16]	
17	IG indices	
18	HY indices	

Footnotes

[15] *Covered bonds must meet the definition provided in paragraphs 68, 70 and 71 in the following publication: Basel Committee on Banking Supervision. Supervisory framework for measuring and controlling large exposures. April 2014, www.bis.org/publ/bcbs283.pdf.*

[16] *Credit quality is not a differentiating consideration for this bucket.*

Table 3 - Source BIS, Market Risk Framework

The risk weight for bucket 8 in the delta SCR non-securitizations are 2.5%. For covered bonds that are rated AA- or higher, the applicable risk weight may at the discretion of the specific bank be 1.5%.

4.6.1 Delta

The delta risk charge is then determined by aggregating the risk position in the buckets using predesignated correlations, $\gamma_b c$, being the correlation between bucket b and c:

$$Delta = \sqrt{\sum_b K_b^2 + \sum_b \sum_{b \neq c} \gamma_b c \, S_b S_c}$$

This gives us the capital requirement for the delta risk.

4.6.2 Vega

The vega charge is calculated in the same manner as delta, but with different risk weights, different correlations and of course vega sensitivities.

$$Vega = \sqrt{\sum_b K_b^2 + \sum_b \sum_{b \neq c} \gamma_b c \, S_b S_c}$$

4.6.3 Curvature

The curvature measure captures the incremental risk not captured by the delta measure. The measure requires the calculation of two stress scenarios. One with a downward shock and one with an upward shock, with the worst scenario being used for further calculations.

The net curvature risk charge CVR_k is calculated for each risk factor k.

$$CVR_k = -\min\Big[\sum_i \Big\{V_i\left(x_k^{(RW^{(curvature)}+)}\right) - V_i(x_k) - RW_k^{curvature} * s_{ik}\Big\}, \sum_i \Big\{V_i\left(x_k^{(RW^{(curvature)}-)}\right) - V_i(x_k) - RW_k^{curvature} * s_{ik}\Big\}$$

Where i being an instrument with curvature risk exposure to risk factor k. x_k is the current level of the risk factor k.

$V(x_k)$ is the price of instrument i given the level x_k.

$V_i\left(x_k^{(RW^{(curvature)}+)}\right)$ and $V_i\left(x_k^{(RW^{(curvature)}-)}\right)$ being the price of the instrument after a shift upward or downward in the level of the risk factor.

Finally, $RW_k^{Curvature}$ is the delta risk weights when the instrument is an equity or FX instrument, and for all other the most punitive weight of the given weights.

The net curvature risk charges are then aggregated on a bucket level using the aggregating formula:

$$K_b = \sqrt{\max\left(0, \sum_k max(CVR_k, 0)^2 + \sum_k \rho_{kl} CVR_k CVR_l \psi(CVR_k CVR_l)\right)}$$

With $\psi(CVR_k CVR_i)$ being 0 if both CVR_k and CVR_i are negative, and 1 otherwise.

ρ_{kl} is squared delta correlation.

Again, like the delta risk, the aggregation considers the correlations by using the same correlations as for delta across each bucket.

Finally, the risk position is aggregated across buckets:

$$Curvature\ risk = \sqrt{\sum_b K_b^2 + \sum_b \sum_{b \neq c} \gamma_{bc} S_b S_c \psi(S_b, S_c)}$$

Again with γ_{bc} being the square of the correlations used in the delta aggregation.

4.7 Default Risk Capital

The Default Risk Capital (DRC) requirements capture the jump-to-default risk for instruments subject to credit risk as set out in market risk framework, MAR22.2. It is calibrated based on the credit risk treatment in the banking book to reduce the potential discrepancy in capital requirements for similar risk exposures across the specific bank. Some hedging recognition is allowed for similar types of exposures (corporates, sovereigns, and local governments/municipalities)

The DRC requirement is intended to capture jump-to-default (JTD) risk that may not be captured by credit spread shocks under the sensitivities-based method. DRC requirements provide some limited hedging recognition.

Instruments subject to the default risk capital requirement are the following

- Non-securitization portfolios
- Securitization portfolio (non-correlation trading portfolio, or non-CTP)
- Securitization (correlation trading portfolio, or CTP)

$$JTD(long) = \max\left(LGD * notional + P\&L, 0\right)$$

$$JTD(short) = \min\left(LGD * notional + P\&L, 0\right)$$

Covered bonds are defined within MAR21.51, are assigned an LGD of 25%.

Below table illustrates how the P&L can be calculated for each instrument.

Examples of components for a long credit position in the JTD calculation — Table 1

Instrument	Notional	Bond-equivalent market value	P&L
Bond	Face value of bond	Market value of bond	Market value – face value
CDS	Notional of CDS	Notional of CDS – | mark-to-market (MtM) value of CDS |	– | MtM value of CDS |
Sold put option on a bond	Notional of option	Strike amount – | MtM value of option |	(Strike – | MtM value of option |) – Notional
Bought call option on a bond	0	MtM value of option	MtM value of option

P&L = bond-equivalent market value – notional.

With this representation of the P&L for a sold put option, a lower strike results in a lower JTD loss.

Table 4 - Source Market Risk Framework, FRTB

4.8 Residual Risk Add-on

The committee acknowledges that not all market risk can be captured in the standardised approach, as this might necessitate an unduly complex regime. Therefore, Residual Risk Add-on (RRAO) is set out in MAR23.8. The RRAO is introduced to capture any other risk beyond the main risk factors already captured in the sensitivities-based method and the Default Risk Charge. It will provide a simple and more conservative capital treatment for the universe of more sophisticated trading book instruments for which the Basel Committee has refrained from detailed specification under the SA, so to limit excessive risk-taking and regulatory arbitrage incentives. The instruments which the bank is required to calculated RRAO on are set out in MAR23.2 and are the following:

- Instruments with an exotic underlying are trading book instruments with an underlying exposure, that is not within delta, vega or curvature. Example could be exposure to longevity risk, weather, or natural disaster.
- Instruments subject to vega or curvature risk capital requirements in the trading book and with a payoff that cannot be written or perfectly replicated as finite linear combination of vanilla options with a single underlying equity price, bond price etc.
- Behavioral risk, risk of change in exercise/prepayment outcomes such as those that arise in a fixed income mortgage product where retail clients may make decision motivated by factors other than financial gain.

The last criteria are relevant for some types of the Danish covered bonds described in section 2. As stated in the Minimum Capital Requirements for market risk framework (2019) Callable bonds may only be possible having behavioral risk if the right to call lies with the retail client.

The calculations are set out in MAR23.8. The RRAO must be calculated in addition to any of the 4 other capital requirements within the SA. The RRAO must be calculated as follows:

- The scope of the instrument that are subject to the RRAO must not have an impact in terms of increasing or decreasing the scope of risk factors subject to the delta, vega, curvature or DRC treatments in the SA.
- The RRAO is now the simple sum of gross notional amounts of the instruments bearing residual risks, multiplied by a risk weight
    - The risk weight for instruments with an exotic underlying specified risk, is 1%
    - The risk weight for instruments bearing other residual risk is set to 0.1%

Covered bonds bearing behavior risk will become subject to the multiplied risk weight of 0.1%

4.9 The Trading Book – Definition

The Fundamental Review of the Trading Book outlines a new boundary between the banks banking and trading book. The aim is to reduce the incentives to arbitrage between the two books, and to hold instruments relevant to trading in the trading book, and vice versa. This is also important as it defines the scope of the new regulation, and the definitions found here are also used for bank implementation of internal models. The instruments to be included in the trading book are subject to the market risk capital requirements and those instruments to be included in the banking book are subject to credit risk capital requirements.

4.9.1 Boundary between Trading book and Banking book

A trading book consists of all “trading book instruments”. Trading book instruments are all instruments that are held for:

- Short-term resale
- Profiting from short-term price movements
- Locking in arbitrage profits
- Hedging risks that arise from instruments meeting criteria 1, 2 or 3.

The following instruments are therefore seen as being held for at least one of the purposes listed above and must be included in the trading book:

- Instruments in the correlation trading portfolio.
- Instruments that is managed on a trading desk as defined by criteria set out bellow.
- Instruments giving rise to a net short credit or equity position in the banking book.
- Instruments resulting from underwriting commitments.

Furthermore, a bank may only include a financial instrument, foreign exchange, or a commodity in the trading book when there is no legal impediment against selling or fully hedging it. The Bank must fair-value daily any trading book instruments and recognize any valuation change in the profit and loss (PnL) account. Standards for assigning instruments to the trading book.

As such an instrument not held for any of the purposes listed above must be assigned to the banking book. The following instruments must be assigned to the banking book:

- Unlisted equities
- Instruments designated for securitization warehousing
- Real estate holding
- Retail and SME credit
- Equity investments in a fund, including but not limited to hedge funds, in which the bank cannot look through the fund daily or where the bank cannot obtain daily real prices for its equity investment in the fund
- Derivative instruments that have the above instruments type as underlying assets
- Instruments held for the purpose of hedging a particular risk of a position in the types of instruments above

It is also presumed that the following instruments are being held for at least one of the purposes of the trading book are therefore trading book instruments:

- Instruments held as accounting trading asset or liabilities
- Instruments resulting from market-making activities
- Equity investment in a fund excluding paragraph 15(e)
- Listed equites
- Trading-related repo-style transaction
- Options including bifurcated embedded derivatives from instruments issued out of the banking book that relate to credit or equity risk.

However, the bank can be allowed to deviate from the presumption. If the banks believe that it needs to deviate from the presumptive list for an instrument, it must submit a request to its supervisor and receive explicit approval. In its request, the bank must provide evidence that the instrument is not

held for any of the purposes of the trading book. In cases where this approval is not given by the supervisor, the instrument must be designated as a trading book instrument. Banks must document any deviations from the presumptive list in detail on an on-going basis. Lastly any foreign exchange or commodity position held in the banking book must be included in the market risk charges. For regulatory capital calculation purposes, these positions will be treated as if they were held on notional trading desks within the trading book.

With the changes and detailed exemplification of which asset types belong to which books the risk of banks either intentionally or unintentionally holding asset in the wrong book. The clear definitions reduce the risk of unintentional allocation to a wrong book and given the need for senior management to write off on any deviations from the pre-established allocation, the risk of banks intentionally holding assets on the wring book should be reduced.

4.9.2 Definition of a Trading Desk

A trading desk is defined as a group of traders or trading accounts that implements a well-defined business strategy operating within a clear risk management structure. Trading desk are defined by the bank but subject to the regulatory approval of the supervisor for capital purposes. Within this supervisory approval desk structure, banks may further define operational sub-desk without the need for supervisory approval. These sub-desks would be for internal operational purposes only and would not be used in the market risk capital framework.

The key attributes of a trading desk are as follows:

- A trading desk for the purposes of the regulatory capital charge is an unambiguously defined group of traders or trading accounts. Each individual trader or trading account must be assigned to only one trading desk.
- The desk must have a clear reporting line to senior management and must have a clear and formal compensation policy linked to its pre-established objectives.
- A trading desk must have a well-defined and documented business strategy, including an annual budget and regular management information reports (including revenue, costs, and risk-weighted assets).
- A trading desk must have a clear risk management structure. This must include clearly defined trading limits based on the business strategy of the desk. The desk must also produce, at least weekly, appropriate risk management reports. This would include, at a minimum, profit and loss reports and internal regulatory risk management reports.

The definition set out by the Committee for the desk are important for supervisors' review and approval of the banks internal model.

5 Theory – Liquidity risk

As mentioned previously in section 1, this thesis would like to analysis how the liquidity in Danish covered bonds are affected by more regulation regarding banks capital requirements and with a special focus on the FRTB market risk requirements. To analysis the liquidity of specific financial instruments, it is important to have a knowledge of different liquidity measures and how they are applied. This section and the following sub-sections have the purpose to explain what liquidity risk are, and which liquidity measures this thesis will use throughout the analysis.

5.1 Market liquidity

In short, liquidity risk is the risk that a bond cannot be sold in market at the very time the seller desires at a price that is in line with equivalent bonds in the market. The liquidity risk for an institution such as the National Bank of Denmark is the risk that they cannot free up funds to support the Danish kroner, for example part of the foreign exchange reserve are placed in bonds. If these bonds cannot be traded in the market without price reductions, it may be more difficult or more expensive to support the krone rate (National Bank 2004). This example can also be translated to other retail or institutional investors trying to free up some of their capital invested into bonds, this has three possible outcomes. 1) The seller are able to sell the bond to the marked price and suffers no loss through the selling, 2) The seller, sells the bond in the marked but to a lower price than the fair price or, 3) The seller are not able to sell the bond in the marked. This means that even though the seller has the bond in his custody account he cannot be sure to sell the bond in the marked.

Another type of liquidity risk is if even small trades can affect the price of the bond. This type of liquidity risk is strongly linked to market depth. This means that if you must sell your position in the market you can end up pushing the price downwards and thus create unfavorable conditions for yourself. Thus, an assessment of liquidity risk has a major impact on portfolio managers' risk management of their respective portfolios. Limited liquidity for bonds can be described according to these three dimensions, as in (National Bank, 2013).

- The width of the market. This indicates the cost of sales/purchases right after paper has been purchased/sold. The width is typically reflected in the bid/ask spread.

- The depth of the market for each paper. This indicates the amount that can be traded without changing the market price.
- Recovery capacity for the paper. This indicates how quickly the market recovers from a trade that does not provide further information to the market.

From these criteria we can define how liquid a market can be graded by a large/small width, large/small depth, and lastly low/high recovery capacity. These types of liquidity risk can be described as the market liquidity risk.

5.2 Liquidity measures

Another way of perceiving liquidity is by looking at inventory risk and demand pressure as described in (Jong and Rindi, 2011). A demand pressure occurs because not all agents are in the market at all times, which means that if an agent has to sell his or her paper quickly, the "natural" buyer will not necessarily be in the market at that point in time, which means that the seller will have to sell the paper to another agent. If the buyer is a market maker, the paper is bought for the intent of being able to sell it in the market at a later stage, during the time the market maker is looking for the right buyer, he will be exposed to a risk linked to the price of the paper when the paper is in the market maker's inventory, worst case scenario the price of the security can fall. For taking this risk, the market maker needs some sort of compensation, the seller of the securities needs to compensate the market maker.

5.2.1 Turnover – a liquidity measure

The simplest way to calculate a measure for liquidity for a specific bond, are by looking at the turnover. Turnover is given by the ratio of total trading volumes measured in kroner to the total amount of outstanding principal measured in kroner. The turnover on bond i, at time t, in year y, can be represented by the following equation:

$$TurnOver_{iyt} = \frac{Trading\ volume_{ity}}{Outstanding\ amount_{iyt}}$$

The above formula shows that if a bond is traded a lot, i.e. in a quantity that is almost equal to the outstanding amount on a given day, then the turnover will be close to 1. Conversely, the turnover will be close to 0 if the total trading amount are small. This means that there is a positive relationship between liquidity and turnover, so that turnover is high if the bond is traded extensively in the market. If you want to sell your bond in the market, there will often be the "right" buyer for the bond. This therefore means that, as a seller of the bond, you do not have to pay as high a cost to, for example a market maker, because the market maker will be able to quickly sell the bond into the market again.

However, turnover cannot be used solely to assess whether a bond is liquid or not. There may also be situations where a bond is not traded as much in the market, as the bond is already placed with investors who intend to hold the bond for longer. If you use turnover as a measure of liquidity, you may end up in a situation where you assess that the bond is not very liquid, even if this is not the case. There may well be a lot of investors who are interested in buying the bond but cannot buy the bond without having to pay more than the true value of the bond. Therefore, you also must assess the liquidity in terms of the depth of the market, i.e. how much the price changes when trading a unit of the bond. Such as measure will be introduced in the coming sub section.

5.2.2 Amihud – a liquidity measure

In Amihud (2002) it is described that the expected market liquidity has a positive effect on the return of stocks. This is because there is a form of illiquidity premium in the excess return of the security. At the same time, Amihud (2002) shows that returns on shares are negatively affected by unexpected illiquidity. In addition, it is described that illiquidity is most important for small businesses compared to large businesses. The modelling of illiquidity in Amihud (2002) is based on shares. Although this thesis studies covered bonds, the method in Amihud (2002) for calculating the illiquidity can easily be translated into the Danish covered bond market, as will be shown both empirically and theoretically in part 2.

Illiquidity are as described above not easy to measure. Liquidity cannot be measured directly from the market but contains a lot of aspects that cannot be caught in a single computable measure (Amihud, 2002). Illiquidity is reflected by the impact on the asset's price of a given demand – the discount that the seller must be willing to meet or the premium paid by the buyer in the execution of a market order. One way to define an asset's illiquidity is to look at the average ratio of numerical returns to total trading volumes measured in kroner on the same day. This relationship can be represented by $\frac{|R_{iyt}|}{VOLD_{iyt}}$. Where R_{iyt} are the return on security i, on time t, in year y. $Vold_{iyt}$ are the total trading volume on one day on security i, on time t, in year y. The ratio gives a numerical (percentage) change in the price per unit dollars as trading on the individual day or in other words the daily impact on the price in relation to the volume traded. It can also be seen as a measure of the depth of the market as set out in the equation below. In Amihud (2002), the average annual illiquidity is represented by:

$$ILLIQ_{iyt} = \frac{1}{D_{iy}} \sum_{t=1}^{D_{iy}} \frac{|R_{iyt}|}{VOLD_{iyt}}$$

The formula represents the average annual illiquidity using the daily illiquidity targets. In the connecting letter, the number of days on which the paper is traded must be known and this

represented by D_{iy}.The formula shows that the more days the paper is traded, the less the illiquidity of the given paper becomes all else equal. In this way, the average size of liquidities can be found in the respective year. $ILLIQ$ is thus a method of measuring the illiquidity of a given paper, at a given time; You therefore look at the recurring of the price per unit traded by looking at the totaling quantity that has been traded and by at the same time using the price information that has been the respective day.

However, Amihud's measure of illiquidity cannot be used as the sole measure of liquidity. It is only an approximation and should therefore be combined together with other objectives in order to achieve a robust result around the liquidity of the security. In addition, the risk associated with investing in a given bond in the form of market risk, which may be a risk associated with the market rate,[16] or other macroeconomic factors, have a positive impact on the illiquidity target (Amihud, 2002). At greater risk, the difference in the bid and offer price of the bond will widen, as a market maker fears the risk, he assumes by buying the bond. This means that the change in the price of trading in one unit will increase as the gap between the bid price and the offer price increases.

Now we have looked at two objectives that capture the activity in each bond and the price change in bond trading. The two objectives therefore capture the narrow aspects of liquidity. Turnover can be a useful target for newly issued bonds, as these bonds are most often traded a lot for a period after the issue. After that, they will typically be placed in the holdings of those investors who wish to hold the bond for an extended period of time, and thus in these cases, turnover may be a bad target (longstaff et al., 2005). Amihud $ILLIQ$is better able to measure the effect of trading bonds. Note that the targets are completely contradictory in the sense that turnover measures cash flow and measures illiquidity. According to Amihud (2002), the targets are thus negatively correlated.

[16]In Denmark, the market rate is often CIBOR (Copenhagen Interbank Offered Rate). If the market rate rises, it will all else being equal should negatively affect the prices of the Danish bond market.

Part 2: The Analysis

Part 2 of this thesis are the analytic part, as described in section 1.5. The structure of the analysis builds on a range of other research papers. I have chosen to build the analysis this way to better answers the overall research question, since assessing covered bond market liquidity are a very comprehensive task, most of the Danish covered bonds are traded OTC, and it is very difficult to get hold of any market data which individual researchers can construct or develop models on. Therefore to better provide the reader with a comprehensive understanding of what drives the market liquidity research from Danmarks Nationalbank will be used, since they have a very large and precise dataset on the Danish covered bond market, constructed over years of MiFID transactions reports collected from transaction made by each bank engaging in the market.

First, I will try to calculate the actual requirements such that we are able to see how much more capital a bank and market maker a required to hold. When in section 7 a model will be introduced, a model from Brunnermeiner and Pedersen (2009) that describes a theoretical set-up that should be able to provide a better understanding of what drives the market and funding liquidity in the Danish covered bond market. To support the model, I have taken data and calculation output from a research paper by Jens Dick-Nielsen et al. (2019) which tries to describe how the liquidity of the Danish covered bond market have evolved since the great financial crisis in 2008.

6 Capital requirements calculations

This section tries to show how the new FRTB capital requirements effects a portfolio of different types of covered bonds. The section will construct calculations based on the regulations mentioned in the previous sections in Chapter 1, and the requirements will be calculated on RTL and FRN bonds, due to the difficulties regarding callable bonds in the Danish market, these will only be disused and not calculated since they are very cumbersome.

This part analysis the impact of the FRTB market risk framework on the Danish covered bond market Our first task in calculating capital requirements under SA-FRTB is to identify the relevant risk factors. They are listed in Basel (Jan 2019) 21.8 and 21.9, but I can be a bit unclear how to apply those guidelines to the different bonds in the Danish market.

In order to simplify the analysis and highlight main channels of the impact on capital requirements of the FRTB, the portfolio we set up is stylized yet representative since it captures the typical risk factors

of a trading portfolio (interest rate, market movements), the associated liquidity horizon required by the review.

This portfolio will be ideal for examining how a Danish covered bond investor will be affected by the new requirements and therefor also how the market will be affected.

6.1 The calculation of capital requirements under the SA

In this section we present the calculation of the capital requirement under the newly proposed regulation, we will only focus on the SA approach in this section. All the calculation of capital requirements for the different types of bonds presented in following sections are based on figures presented in articles by Scanrate (2020), the FRTB capital requirements calculations and the required inputs are extensive for the different covered bonds, and it has not been possible to receive any sensitives or yield curves form any of the Danish mortgage institutions. Therefor this section will present the calculations from Scanrate and discuss the relevance.

6.1.1 Non-Callable mortgage-backed bullet bonds (RTL)

This section tries to outline how the SA-FRTB guidelines presented in section 5, should be calculated on Danish RTL bonds. The calculation presented in this section of the SA-FRTB minimum capital requirements are based on a for non-hedge, single bond portfolios. As described in section 5, the intention of the FRTB framework are based on a diversified portfolio of covered bonds, but this section only use one bond to best illustrate the different calculation steps.

Scanrate (2020) have chosen to use “1 RD T RTL 2023” (DK0009295065) to illustrate the FRTB calculations in a simple setup. As mentioned above, our portfolio will only consist of this single bond with a notional of 100.

6.1.1.1 Delta GIRR

We start be using the methodology of Delta GIRR described in section 5.1 to identify the different risk factors for the specific bond, we can then calculate the vector of the risk factor sensitivities for our test bond and apply the sensitivities to the SA-FRTB guidelines of Delta GIRR. The below table presents the calculation based on the sensitivities calculated by Scanrate (2020). The sensitivities are expressed for 1% bucket shift, the risk weight is specified in the Basel Jan 2019 point 21.42.

KEY RATE	SENSITIVITY (s_k)	RISK WEIGHT (RW_k*)	WEIGHTED SENSITIVTY (WS_k)
0.25	0.0010	1.7% / $\sqrt{2}$	0.0012
0.50	0.0036	1.7% / $\sqrt{2}$	0.0043
1	0.0080	1.6% / $\sqrt{2}$	0.0091
2	0.0206	1.3% / $\sqrt{2}$	0.0189
3	2.7607	1.2% / $\sqrt{2}$	2.3425
5	0.8030	1.1% / $\sqrt{2}$	0.6246

Figure 13 - GIRR delta sensitivities, 21/10/2019. Source Scanrate (2020)

For GIRR the sensitivities for each instrument are grouped into different buckets by the securities quotation currency. We can now calculate the capital requirement by recalling the equation from section 5.1 and using the correlations matrix specified in Basel Jan 2019 point 21.46. That is, we need to evaluate the formula $\sum_k \sum_l \rho_{kl} WS_k WS_l$ where $k\ and\ l$ runs through the specified risk factors of the key rates of DKKCITA curve. Because of simple portfolio are constructed of one single RTL bond, there are not other risk bucket we need to calculate. We know have the following result of K_{GIRR} from Scanrate (2020)

$$K_{GIRR} = K_{GIRR,DKK}^{Delta} = \sqrt{\left(\sum_k \sum_l \rho_{kl} WS_k WS_l\right)^+} = 2.9837$$

6.1.1.2 Delta CSR

Here we use the methodology of the CSR delta described in section 5.2, the calculation of CSR Delta is done the same way as GIRR Delta, for CSR we have however different risk buckets instead of only the currency for GIRR Delta. The risk bucket for our CSR calculation are sector and rating. Recall from section 5.2 that Danish mortgage bonds fits into category 8 (covered bonds)[17]. AS described in section 5.2, the risk weight for bucket 8 for covered bonds provided in FRTB are 1.5%. Scanrate (2020) have however chosen to use the proposed risk weight in CRR2 which is 1.0%[18]. This will give us a slightly lower capital requirement but should still be representative for a further analysis of the liquidity impact of higher capital requirements.

KEY RATE	SENSITIVITY (s_k)	RISK WEIGHT (RW_k)	WEIGHTED SENSITIVITY (WS_k)
0.5	0.0045	1%	0.0045
1	0.0183	1%	0.0183
3	2.7710	1%	2.7710
5	0.8030	1%	0.8030

Figure 14 - CSR Delta sensitivities, 21/10/2019. Source Scanrate (2020)

The sensitivities are also here expressed for 1 pct. bucket shift.

[17] CSR risk buckets, risk weights and correlations are found in Basel (Jan 2019) 21.51 – 21.54
[18] European Parliament (2019/876) Article 325ah

We can now use the weighted sensitivities from the above table together with the correlation's matrix provided from the FRTB market risk framework. As our simple portfolio also contains one single RTL bond, we have from the FRTB market risk framework a single issuer name correlation of 0.65. With all that combined we get a $K^{Delta}_{CSR,cov\ Bond,AAA}$ capital requirement form Scanrate(2020) of:

$$K_{CSR} = K^{Delta}_{CSR,cov\ Bond,AAA} = \sqrt{\left(\sum_k \sum_l \rho_{kl} WS_k WS_l\right)^+} = 3.3658$$

As mentioned earlier our RTL covered bond are only exposed to GIRR and CSR delta, so we end up with an SBM capital requirement of:

$$K_{SBM} = K^{Delta}_{GIRR} + K^{Delta}_{CSR} = 6.3485$$

6.1.1.3 Default Risk Capital

The Default Risk Capital calculation in the standardised approach[19] presented earlier in section 5.3 are a more straightforward task than the GIRR, CSR and Vega sensitivities. Recall form section 5.3 that the LGD (loss given default) is 25% for covered bonds and the risk weight for a AAA-rated bond is 0.5%. The calculation date is still the same as earlier, the 21st of October 2019. Scanrate (2020) has presented a market price of 104.938 DKK for the "1 RD RTL 2023" bond. By using the equation in section 5.3 we can calculate the following DRC capital requirement.

$$DRC = (Notional * LGD_{covBond} + P\&L) * RW_{AAA}$$

$$= (100 * 0.25 + 4.938) * 0.005$$

$$= 0.1497$$

We are now able to calculate the total Standardised approach capital requirement based on the three sub calculations above:

$$K_{SA-FRTB} = K_{SBM} + K_{DRC} + K_{RRAO} = 6.3485 + 0.1497 + 0 = 6.4982$$

We have a capital requirement of 6.4982 for our single RTL bond portfolio with a nominal of 100. We would of course receive benefits if we had a more diversified portfolio and we can also use hedging instruments to get a lower capital requirement. But for an illustrative purpose we can now make a comparison with the current capital requirement setup.

[19] Basel (Jan 2019) 22.9 – 22.30

6.1.1.4 *Comparison with the current capital charge*

This section makes a comparison of the current capital requirement calculation and the just calculated FRTB capital requirement, again we start by using just one RTL bond.

As presented in section 5, we have that in the current Danish capital requirement regulation general interest rate risk capitalization shall be calculated by the duration-based method required by CRR[20]. The spread risk is a pillar II capital requirement, and for mortgage bonds the Danish regulator, Finanstilsynet, advises that the spread is shocked by a minimum of 50bps. To determine default risk, the specific risk component in CRR should be used according to Finanstilsynet (2019) section 6.4.1.

RISK TYPE	FRTB	CURRENT
Interest rate risk	GIRR	General
Spread risk	CSR	Pillar II
Default risk	DRC	Specific risk

Figure 15 - Source Scanrate (2020)

The above table illustrates the different types of risk under both FRTB and the current legislation associated with a Danish mortgage bond.

We use the same bond as in our FRTB calculation, that is "1 RD T RTL 2023" and we use the same calculation date the 21st of October 2019. We begin by calculating the general interest rate risk, we have market price from Scanrate (2020) of 104.938 and a modified duration of 3.3971. We could use information from other of the large Danish mortgage institutions which also calculate the market price and modified duration, but to replicate the result we use the same source. From legislation we have the bond have a risk weight of 0.85%. We can now perform the below calculation:

$$DW_{CRR} = ModDuration * Price * RiskWeight = 3.0301$$

We have that DW_{CRR} is our duration-weighted capital requirement for our bond portfolio exposure. Because we use a simple one bond portfolio, we can disregard the match algorithm of article 340.

From Scanrate (2020) we have a credit spread risk key figure of 3.5908. We can now calculate the pillar II spread risk capitalization for portfolio of one mortgage bond as:

$$SpreadRisk * 50bp = 1.7954$$

Total calculate the interest rate risk under CRR, we need the time-to-maturity risk-weight from CRR and multiply the risk weight with our market value of our bond: $104.938 * 0.016 = 1.6790$

We now have a total capital requirement for our RTL bond of 6.5045 under the current capital requirement legislation.

[20] European Parliament (2013/575) Article 340.

Recall our FRTB capital requirement capital charge was 6.4982, the current legislation is a little bit higher than our SA-FRTB capital requirement.

6.1.1.5 FRTB Impact on a whole range of single RTL bonds

We have now presented the different capital charge for a single RTL bond, both under the future FRTB regime and under the current Danish regime. This section will continue to present the calculation from Scanrate (2020) but we will now look at whole range of RTL bonds from the Danish market, the bonds have different maturities and therefore also different durations. The list of bonds is seen in the table below.

ISIN	BOND NAME	MATURITY DATE	OUTSTANDING AMOUNT	DURATION (PV01)
DK0009294761	1 RD T RTL 2020	2020-04-01	43.07	0.4496
DK0009294845	1 RD T RTL 2021	2021-04-01	48.33	1.4954
DK0009294928	1 RD T RTL 2022	2022-04-01	69.98	2.5281
DK0009295065	1 RD T RTL 2023	2023-04-01	41.58	3.5969
DK0009295149	1 RD T RTL 2024	2024-04-01	31.31	4.6491
DK0009295222	1 RD T RTL 2025	2025-04-01	2.96	5.6997
DK0009295305	1 RD T RTL 2026	2026-04-01	3.05	6.7480
DK0004602570	1 RD T RTL 2027	2027-04-01	2.72	7.7590
DK0009515363	1 NYK H RTL 2028	2028-01-01	1.59	8.5840
DK0004607538	1 RD T RTL 2029	2029-04-01	1.52	9.7637

Figure 16 - Danish RTL bonds. Source Scanrate (2020)

All the numbers are DKK and the calculation date for maturities and duration are again the 21st of October 2019. The capital requirements calculations will for each of the RTL bonds be performed as we have just shown in the above sections. Therefor we get the pure capital charge for each bond without any diversification or hedging effect. The calculation results from Scanrate (2020) are illustrated on the below figure 20. We see the single largest capital charge increase for the RTL bond maturing in 2029, which is subject to a 27%. We also note that quick surprisingly that the capital charge for the RTL bonds maturing in 2 and 3 years, “1 RD T RTL 2022” and “1 RD T RTL 2023” are negative. General Interest risk capital is roughly unchanged. The CSR capital charge is about 80% higher than the current pillar II spread risk capital charge imposed by the Danish regulator, but the default risk capital charge is on the other hand reduced.

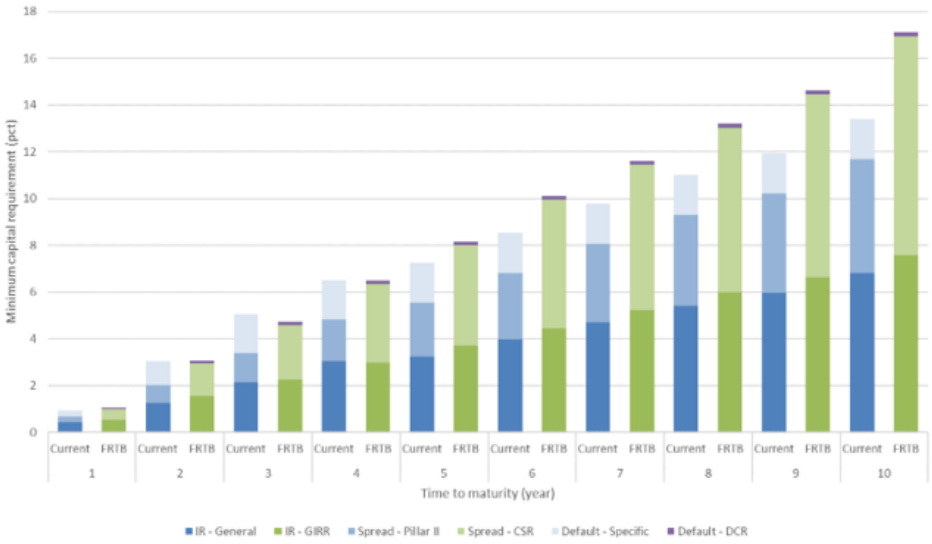

Figure 17 - Capital impact of FRTB on Danish RTL bonds. Source Scanrate(2020)

Estimated capital impact of RTL bonds for Danish banks. For each maturity segment, the largest RTL bond series is chosen. We estimate that the 3Y and 4Y bond will be subject to a smaller capital charge under the new framework. The capital increase target by the Basel committee is 30-40%. We should however note that, so fare we have compared the FRTB framework with the current legislation, If the disregard the default specific risk, we would from the Scanrate(2020) calculation get much closer to the 40% estimated by Basel for our entire list of Danish RTL bonds.

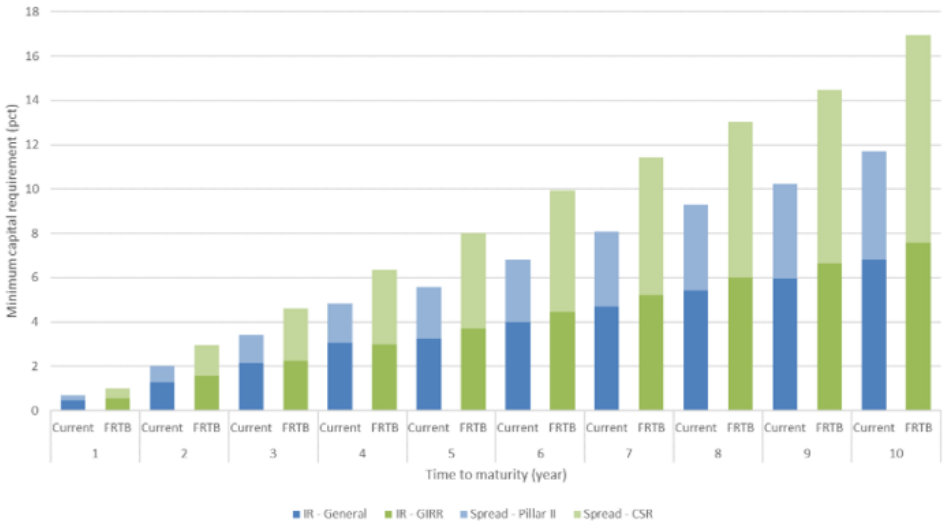

Figure 18 - Capital impact of FRTB on Danish RTL bonds, only SBM. Source Scanrate (2020)

6.1.1.7 Issuer diversification effects

As mentioned earlier and recall from section 4, the FRTB market risk framework due recognizes a potential issuer diversification effect when we calculate the CSR capital charge. In our calculation earlier we used a correlation of 0..85 when we only had a portfolio containing one bond, if we have a portfolio of bonds with different issuers, we can use a correlation between spread risk factors of

different bond issues of 0.35. This section will use the calculation form Scanrate (2020) to see the effects of adding extra diversification to one's bond portfolio. We chose a portfolio constructed of bonds from the five largest RTL series with maturity in 2023.

ISIN	BOND NAME	MATURITY DATE	OUTSTANDING AMOUNT	DURATION (PV01)
DK0002041029	1 NDA 2 RTL 2023	2023-10-01	9.82	4.1225
DK0006345301	1 DLR B RTL 2023	2023-10-01	8.38	4.1105
DK0009295065	1 RD T RTL 2023	2023-04-01	41.32	3.5909
DK0009391021	1 JYK E RTL 2023	2023-04-01	8.68	3.5954
DK0009796864	1 NYK H RTL 2023	2023-07-01	26.14	3,8590

Figure 19 - 5 RTL bonds with maturity in 2023. Source Scanrate (2020)

We construct the portfolio of five RTL bonds, by adding one bond at a time to better see how the issuer diversification effects are distributed. Each bond has the same invested amount. We begin with "1 RD T RTL 2023" in the portfolio and then add one bond at a time distributing the invested amount in each bond uniformly, as the add more bonds to a portfolio, we should benefit because the correlation multiplier for bonds of different issuers should reduce the overall CSR charge. Figure 23 below from Scanrate (2020) calculations illustrates our results. We see that the CSR capital charge decreases from 3.36 for a portfolio of one bond to 2.45 when we have a portfolio of five RTL bonds with five different issuers. That is an overall reducing of approximately 27%

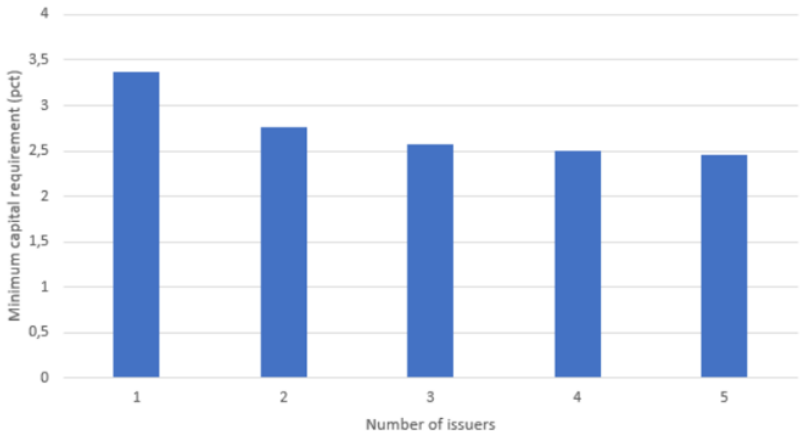

Figure 20 - Diversification effect for CSR. Source Scanrate (2020)

6.1.1.8 RTL Bonds Key Takeaways

In the above section and sub-section, we have presented calculations of the new FRTB market risk framework for a portfolio of one RTL bond and compared how the capital charge changes with the current legislation. We saw that for RTL bonds with short maturities the new framework had decreasing effect on the capital charge, for bonds with more time to maturity we showed when disregarding the DRC component that we could expect a 40% increase in the capital charge, in line

with what the Basel committee are aiming for. Compared with the current Danish legislation we showed that for the 10-year bonds with can expect 27% higher capital requirements. One should note that we used a 1% risk weight for bucket 8 in our Delta CSR capital instead of the proposed 1.5%, this have led to a lower capital charge and finally the total FRTB impact for a banks trading desk would also depend on how the has chosen to hedge its positions which we have not been able to cover here.

6.1.2 Floating Rate Mortgage Bonds

This section and the following sub-sections try to outline how the SA-FRTB guidelines presented in section 5, should be calculated on Danish floating rate mortgage bonds. The calculation presented in this section of the SA-FRTB minimum capital requirements are based on a for non-hedge, single bond portfolios just as our calculation for RTL bonds. As described in section 5, the intention of the FRTB framework are based on a diversified portfolio of covered bonds, but this section only use one bond to best illustrate the different calculation steps.

The calculation presented in this section and the following subsection are based on results from Scanrate (2020). Our portfolio of one floater with and without cap to illustrate the FRTB calculations in a simple setup. As with the RTL bonds Scanrate (2020) also uses the 21st of October as calculation date.

6.1.2.1 GIRR calculation for a single capped floater mortgage bond

The calculation on capped floaters are based on the following bond: "NYK Cibor6M 3%cap 2028" (DK0009515959). Scanrate (2020) has calculated the delta GIRR vector and are illustrated in the below figure, we will also use the sensitivities for calculating the curvature capital requirement.

CURVE	KEY RATE	SENSITIVITY (s_k)	RISK WEIGHT (RW_k*)	WEIGHTED SENSITIVTY (WS_k)
DKKCITA (risk-free)	0.25	0.0001	1.7% / $\sqrt{2}$	0.0001
	0.50	0.0000	1.7% / $\sqrt{2}$	0.0000
	1	0.0002	1.6% / $\sqrt{2}$	0.0003
	2	0.0019	1.3% / $\sqrt{2}$	0.0017
	3	0.0151	1.2% / $\sqrt{2}$	0.0128
	5	2.3702	1.1% / $\sqrt{2}$	1.8436
	10	6.5067	1.1% / $\sqrt{2}$	5.0610
DKK6M (fixing)	0.25	0.2043	1.7% / $\sqrt{2}$	0.2456
	0.50	-0.0044	1.7% / $\sqrt{2}$	-0.0053
	1	0.0014	1.6% / $\sqrt{2}$	0.0016
	2	0.0022	1.3% / $\sqrt{2}$	0.0020
	3	-0.0042	1.2% / $\sqrt{2}$	-0.0036
	5	-2.5414	1.1% / $\sqrt{2}$	-1.9767
	10	-5.9852	1.1% / $\sqrt{2}$	-4.6554

Figure 21 - GIRR Delta vectors. Source Scanrate (2020)

The sensitivities are expressed for a 1pct. shift size. As the bond are maturing in 2028, the key rates for maturities above 10 years are zero. We have that the sum of our sensitivities vector s_k is 0.5669 while GIRR delta becomes 0.5278 using the prescribed correlations and recall the equation from section 5 on how to calculate the GIRR delta. Our durations indicate losses when positive and to fit them into the CVR equation in section 5 we need to multiply them with -1. By multiplying be -1 we have transposed the duration into reflecting the actual slope of our yield curve. We now get a $s_{ik} = -0{,}5669$ from Scanrate (2020).

The risk weight $RW^{up/down}$ is in GIRR determined as the largest delta risk weight which is equal to $\frac{1.7\%}{\sqrt{2}}$. The first order effect is the up scenario is hence equal to $s_{ik} * RW^{up} = -0.5669 * \frac{1.7\%}{\sqrt{2}} = -0.6814$ and must be subtracted from the total loss. The table below shows the results in each scenario.

TERMINSTRUKTUR	SCENARIE	RISIKOVÆGT (RW)	TAB	DELTA	NET CURVATURE
DKK	Up	$1.7\%/\sqrt{2}$	-0.8861	-0.6814	0.2046
	Down	$1.7\%/\sqrt{2}$	0.5559	-0.6814	0.1256

Figure 22 - Curvature capital requirement. Source Scanrate (2020)

We can now calculate the required capital for curvature losses on our "NYK Cibor6M 2%cap 2028" bond as:

$$-\big(-0.8861 - (-0.6814)\big) = 0.2046$$

Recall the quite extensive vega sensitive calculation, with 25 ATM Swaption, here we use a calculated parallel vega of 0.71 for the bond from Scanrate (2020). The reason to use a parallel vega, is that I should be seen as an upper boundary, because we should not have a capital discount since we don't have a correlation between the individual swaptions in the vega vector Scanrate(2020). By using the parallel vega vi can now calculate our K_{GIRR} capital requirement:

$$K_{GIRR} = K^{Delta}_{GIRR,DKK} + K^{curvatur}_{GIRR,DKK} + K^{Vega}_{GIRR,DKK}$$

$$= 0.5278 + 0.2046 + 0.71 + 1.4424$$

In the current legislation we have a general interest rate capitalization of 0.5766 from Scanrate (2020), so the new framework introduce a substantially higher K_{GIRR} for our bond "NYK Cibor6M 3%cap 2028". The current legislation consist only of a first-order risk measure, we see that the increase from the new framework are mainly driven by curvature and vega, however the bond does not exhibit a lot of curvature because the 3% cap option is far out of the money due to the very low interest environment I the Danish economy at the moment.

6.1.2.2 The Standardised approach Impact on FRNs

In the above sections we have seen how the new FRTB framework changes the capital charge for a single FRN bond. The following sections the follow the same methodology as with RTL bonds and begin to look at whole range of different floating rate notes with different reference rates, with and without cap/floors and in different maturity segments. The bonds are listed in the below table and are provided in Scanrate (2020).

ISIN	BOND NAME	REF. RATE	MATURITY	OUTST. AMOUNT	CAP	FLOOR
DK0004605672	RD CIBOR6M 2021	CIBOR6M	2021-07-01	20.22		
DK0009521684	NYK CITA6M 2023	CITA6M	2023-01-01	15.44		
DK0002044478	NDA CIBOR6M 2023	CIBOR6M	2023-07-01	13.30		
DK0009516098	NYK Cibor6M 1.5% 2023	CIBOR6M	2023-07-01	3.17	1.5%	
DK0009523540	NYK Cibor6M 1% 2025	CIBOR6M	2025-07-01	0.86	1.0%	
DK0009508822	NYK Cibor6M 4% 2026	CIBOR6M	2026-07-01	4.01	4.0%	
DK0009515959	NYK Cibor6M 3% 2028	CIBOR6M	2028-07-01	11.08	3.0%	
DK0004717394	TK Cibor6M 0%, 6% 2036	CIBOR6M	2036-10-01	1.20	6.0%	0.0%
DK0009361628	JYK Cibor6M 0%, 5% 2038	CIBOR6M	2038-07-01	2.52	5.0%	0.0%

Figure 23 - Danish floaters, with and without cap. Source Scanrate (2020)

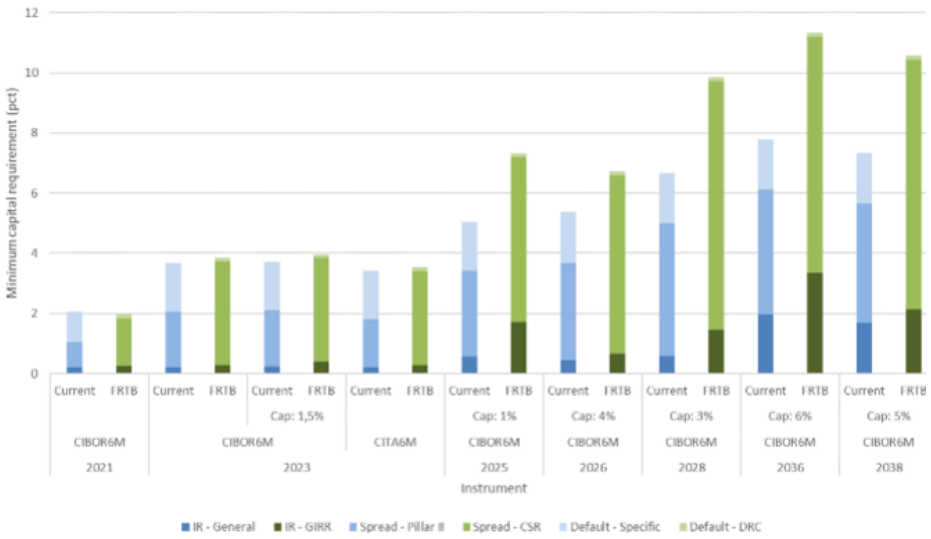

Figure 24 - Capital impact of FRTB, floating rate notes. Source Scanrate (2020)

As with RTL we can see that the capital requirement for short-term FRNs are roughly unchanged, but for FRNs with longer maturities will be impacted with a 30-40% increase in capital charge compared with the current legislation. The increase is primarily driven by the capital charge on the CSR credit spread.

6.1.2.3 GIRR Curvature

As mentioned earlier because of the very low interest rate environment in Denmark, all our floating rate bonds cap option are currently out of the money, this influences the curvature component in our GIRR calculation. To figure out how the capital charge might change with higher interest rates, the below figure from Scanrate (2020) presents a decomposed GIRR to show the effects and we see that only "NYK Cibor6M 1% 2025" is subject to significant curvature risk. One is also able to see the effect of the parallel vega GIRR component. We note that for the long-term bonds the vega effect are quit large, and as previously noted these bonds has a minimal curvature component due to the option being out of the money, but the increase in volatility greatly affects the moneyness of the cap which lowers the value of the floating rate note.

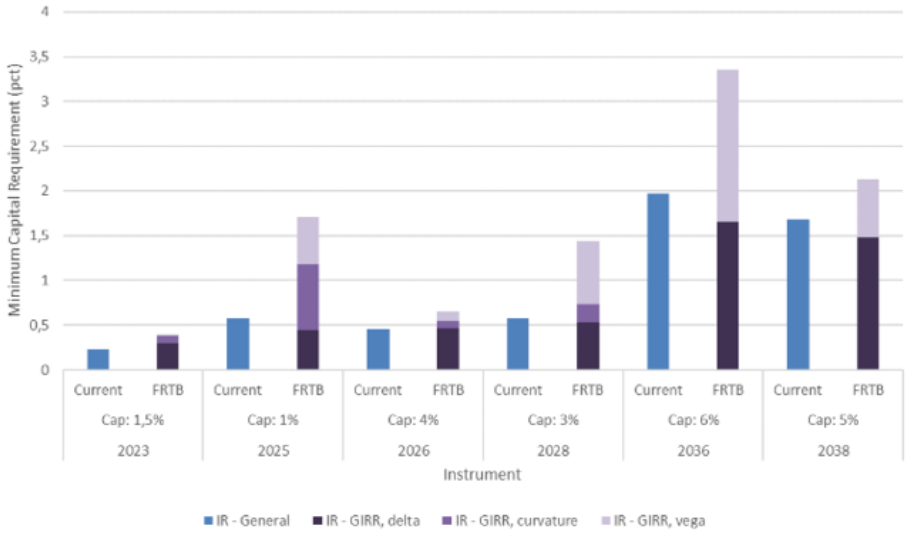

Figure 25 - GIRR decomposed, capped floaters. Source Scanrate (2020)

The numbers in the figure is compared to the current Danish legislation, and some of the bonds will face a tripling in the GIRR component because of the introduction of curvature and vega risk in FRTB. A third thing to notice from the above figure, is that the current legislation creates higher first order (delta) capital needs than FRTB for the two longest bonds This is because the risk weights are higher in Basel II and CRR. Here, the risk weights are fixed for all tenor points on the yield curve and are solely determined by the duration (DV01) of the bond. "TK Cibor6M 0% 2036" and "JYK Cibor6M 0%,5% 2038" have a DV01 of 2.21 and 1.88, respectively. In CRR they are assigned a risk weight of 0.85%. On the other hand, FRTB and CRR2 recognize that the shortest interest rate fluctuates the most, and the introduction of yield curve tenor risk factors enables longer tenors to be assigned with smaller risk weights.

Figure 29 are a good illustration of why the capital charge for GIRR are decreasing for our two capped bonds with the longest time to maturity. The figure shows that our capped floater "TK Cibor6M 0%,

&% 2036" is most sensitive to changes in the long-term interest rate, in the figure the regular delta vector of the fixing and pricing curve are shifted simultaneously and they draw the tenor risk factors together with the delta vector, we see that the lower risk weights for longer tenors in the standard approach decrease the delta capital requirement for GIRR

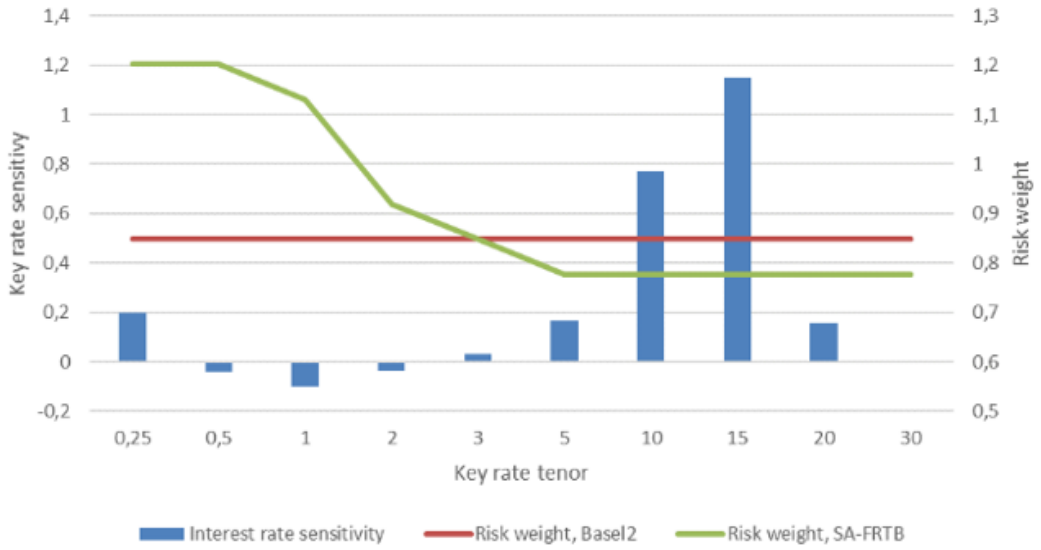

Figure 26 - Comparison of risk weights. Source Scanrate (2020)

We have showed that because of the cap option on our floaters being out of the money, the capital requirements are not increasing as much as expected. But the below figures from Scanrate (2020) tries to illustrate the effect of a rising interest rate environment. Scanrate (2020) have studied a long-term non-callable capped floater, while adjusting the cap values. We can see from the below figure that, when our cap mores more into the money, the vega and curvatures requirements slowly starts to increase. With a cap value of 0% we can see that our option are into money, and the floater begins to behave more like a traditionally fixed-rate bond and we can expect it be more sensitive to interest rate changes, as we have also shown in the above figure. This also makes intuitively sense when our option gets closer to being in the money, we would expect more interest rate sensitives because this would drive the price of our bond.

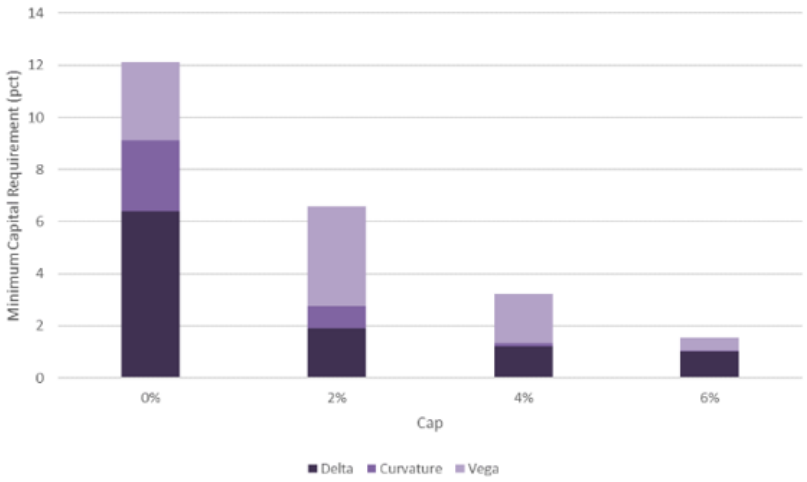

Figure 27 - GIRR decomposed, capped floaters. Source Scanrate (2020)

GIRR capital requirement for a non-callable capped floater maturing in 2038 for different cap values. When the moneyness of the cap increases so does the capital requirements.

6.1.2.4 FRNs Bonds Key Takeaways

The minimum capital requirements for short-term Danish floating mortgage bonds are almost unaffected by SA-FRTB compared to the current Danish implementation of the rules.

Capped floaters introduce curvature risk, but at the time of writing, the cap is far out of the money, and only a couple of bonds have a significant curvature component. The capital impact on capped floaters – relative to Basel 1- lies around 40% for the longer bonds aligning with the estimates from the Basel committee. We show that general interest rate risk capital requirements can decrease for bond when they are sensitive to long-term interest rates, but their overall duration is low. This unexpected behavior arises because the risk weights in the current legislation are fixed across all factors with lower risk weights for longer tenors. We have also shown preliminary estimates of vega capital risk.

7 Market Liquidity Model

This section tries to introduce a model from Markus K. Brunnermeier and Lasse Heje Pedersen (Market Liquidity and Fund Liquidity, 2009), the theoretical model should help us to better understand what the drives behind market liquidity are. Firstly, this section will briefly try to argue why the model are relevant for the Danish mortgage market, the model finally highlights the links between the covered bond market liquidity and the different market participants funding liquidity. The general set-up is that traders provide market liquidity and their ability to do so depends on their availability to obtain

funding, by setting up the model, we should be able to show that traders capital and margin requirements in the end influences the overall market liquidity. After the model have been introduced and we have shown the theoretically drivers of market liquidity, the following section will provide evidence of how the model have worked historically to describe market liquidity, this is done by introducing extensive research by Dick-Nielsen et. al (2013, 2019) and by Danmarks Nationalbank (2015).

7.1 The model

The model introduced in Brunnermeier and Pedersen (2009), can be applied to the Danish mortgage market because of the specific characteristics described in section 2 and 3, recall the high investor concentration, also note that in the same section we showed that the largest Danish banks have reduced their holdings of covered bonds for trading and market making[21], the proprietary trading desk of banks have declined their activities and therefore reduced the speculative liquidity providers from the market and the market have seen an increase in Danish hedge funds and foreign investors instead. In the model below we will introduce three market participants, "Customers", which in the Danish market can be described as large institutional investors as we have very low level of retail engagement, "speculators" which can described as hedge fund and banks proprietary trading desk and the market makers and finally the last agent in our model are the "financiers", which are the large Danish and International banks who help finance the speculators position through their access to the credit, funding and repo market.

Our theoretical economy has J risky assets, traded at different times denoted as t = 0, 1, 2, 3. At time t = 3, each security j pays of v^j, a random variable defined on a probability space $\Omega, \mathcal{F}, P$. There is no aggregate risk because the aggregate supply is zero and the risk-free interest rate is normalized to zero, so the fundamental value of each bond is its conditional expected value of the final payoff $v_t^j = E_t[v^j]$. Fundamental volatility has an autoregressive conditional heteroscedasticity (ARCH) structure. Specifically, v_t^j evolves according to

$$v_{t+1}^j = v_t^j + \Delta v_{t+1}^j = v_t^j + \sigma_{t+1}^j + \varepsilon_{t+1}^j \qquad (1)$$

Where all ε_{t+1}^j are i.i.d across time and asset with standard normal cumulative distribution function Φ with zero mean and unit variance, and the volatility σ_t^j has the following dynamics

$$\sigma_{t+1}^j = \underline{\sigma^j} + \theta^j \left|\Delta v_t^j\right| \qquad (2)$$

[21] Danmarks Nationalbanken

Where $\underline{\sigma^j}, \theta^j \geq 0$. A positive θ^j implies that shocks to fundamentals of our instruments will increase future volatility, this we will look more into, with real market data in section 9. As described in the beginning, we have three groups of market participants in our model, "customers" and "speculators" trade assets while "financiers" finance the speculators positions. The group of customers consists of three risk-averse agents. At time 0, customers $k = 0,1,2$ has a cash holding of W_0^k Government bonds and zero Danish mortgage bonds, but finds out that he will experience an endowment shock of $z^k = \{z^{1,k}, \dots, z^{j,k}\}$ bonds at time $t = 3$, where z are random variables such that the aggregate endowment shock is zero, $\sum_{k=0}^{2} z^{j,k} = 0$. With probability $(1 - a)$, all customers arrive at the market at time 0 and can trade securities in each time-period, 0, 1, 2. Since their aggregate shock is zero, they can share risk and have no need for intermediation. The basic liquidity problem arises because customers arrive sequentially with probability a, which gives rise to order imbalance in our model.

Before a customer arrives in the marketplace, his demand is $y_t^k = 0$, and after he arrives he chooses his security position each period to maximize his exponential utility function $U(W_3^k) = -\exp\{\gamma W_3^k\}$ over final wealth. Wealth W_t^k, including the value of the anticipated endowment shock of z^k bonds, evolves according to the following equation:

$$W_{t+1}^k = W_t^k + (p_{t+1} - p_t)'(y_t^k + z^k) \qquad (3)$$

The vector of total demand shock of customers who have arrived in the market at time t is denoted by: $Z_t \coloneqq \sum_{k=0}^{t} z^k$

The early customers trading needs is accommodated by speculators who provide liquidity/immediacy. Speculators are risk-neutral and maximize expected final wealth W_3. Speculators face the constraints that the total margin/capital requirements on their positions x_t cannot exceed their capital W_t:

$$\sum_j (x_t^{j+} m_t^{j+} + x_t^{j-} m_t^{j-}) \leq W_t, \qquad (4)$$

Where $x_t^{j+} \geq 0$ and $x_t^{j-} \geq 0$ are the positive and negative parts of $x_t^j = X_t^{j+} - x_t^{j-}$, respectively, and $m_t^{j+} \geq 0 \; and \; m_t^{j-} \geq 0$ are the kroner margin on the trading desk long and short positions. Equation 4 will therefore represent our capital constraint for the market participants in the theoretically setup. We are now able to define how each financier in the markets, sets their margin to limit each other's counterparty credit risk. The margin is set such that each financier ensures to cover the positions π-value-at-risk:

$$\pi = \Pr\left(-\Delta p_{t+1}^j > m_t^{j^+} | \mathcal{F}_t\right) \qquad (6)$$

$$\pi = \Pr\left(\Delta p_{t+1}^{j} > m_t^{j^-} | \mathcal{F}_t\right) \quad (7)$$

So, the margin depends on the financier's information set $\mathcal{F}_t$. In Brunnermeier and Pedersen (2009) they use two different types of financiers, one who knows the fundamental value and the liquidity shocks z, $\mathcal{F}_t = \sigma(z, v_0 \dots, v_t, p_0, \dots, p_t, \eta_1, \dots, \eta_t)$, and a group of uniformed financiers who only observes the prices $\mathcal{F}_t = \sigma(p_0, \dots, p_t)$.

The simple setup from the model first presented in Brunnermeier and Pedersen (2009) have now been introduced, in the following sub-section, the institutional features related to this key constraint in equation (4) will be discussed for different types or our speculators like hedge funds, bank, and market makers in the Danish mortgage market for covered bonds, and the key implications for what drives liquidity in the Danish mortgage market will be discussed based on the theoretically setup just presented.

7.1.1 Liquidity Model for the Danish market

Recall from section 3, that a bank's capital consists of equity capital plus its long-term borrowing, this can also include credit lines secured from commercial banks or other institutions, reduced by assets that cannot be readily employed (goodwill, intangible assets, property, equipment, and capital needed for daily operations). Recall also that the market risk framework calculated in section 6 are used to calculate the Pillar 1 capital requirements which fits perfectly into equation 4, in our model setup. The financing of a banks trading activity is largely based on collateralized borrowings, banks can finance long positions using collateralized borrowings from corporations, other banks, insurance companies and the Danish National Bank, through the banks' prime brokerage business they can borrow securities to short sell from mutual funds or pension funds that holds securities for long only purposes. This kind of transactions typically requires margins that must be financed by the bank capital, as captured by the funding constraint in equation 4. Equation 4 can also be translated into the regulatory capital requirements that the bank must satisfy, for each trading desk. As we have shown in section 6, we so that for a majority part of the Danish covered bonds instruments, a trading desk can expect a 27%-40% increase of capital requirements based on the SA method. This is due to the risk weight on assets, recall the risk weight from section 4 on covered bonds, the capital requirements from legislation can therefore captured by equitation 4. In Brunnermeier and Pedersen (2009) they show the implications in market liquidity of different margin of 0%, 4% and 8% based on the Basel Accord from 1988.

Let's take a deeper look at equation 4 and some of the propositions presented in Brunnermeier and Pedersen (2009) to see how we can build a theoretically set that can explain what influence and drive the market liquidity for the Danish covered bond market.

Let's define an equation to capture the price deviation from its fundamental value as: $\Lambda_t^j = p_t^j - v_t^i$ (8), Brunnermeier and Pedersen (2009) defines the measure of market illiquidity as the absolute amount of this deviation $|\Lambda_t^j|$, this is similar to the liquidity or illiquidity measure presented section 6 by Amihud. Bases on the above, we are now ready to define a competitive equilibrium in the theorical framework.

Equilibrium definition: An equilibrium is price process p_t, such that (i) x_t maximize the speculators expected final profit subject to the capital constraint in equitation (4); (ii) each y_t^k maximizes customer k's expected utility after their arrival at the marketplace and is zero before that. Margins are set according to equation 6 and 7, and (iv) the market clear, $x_t + \sum_{k=0}^{2} y_t^k = 0$.

The derivation of the optimal strategy is shown in the appendix, the derivation is created as shown in Brunnermeier and Pedersen (2009).

Proposition 3, destabilizing margins: When the financiers are uniformed about the fundamental value, then as $a \to 0$, the margins on long and short positions approach:

$$m_1^j = \bar{\sigma}^j + \bar{\theta}^j |\Delta p_1^j| = \bar{\sigma}^j + \bar{\theta}^j |\Delta v_1^j + \Delta \Lambda_1^j| \qquad (23)$$

Margins are increasing in price volatility and market illiquidity can increase margins.

Intuitively, since liquidity risk tends to increase price volatility, and since uninformed financiers may interpret price volatility as fundamental volatility, this increases margins. We have that Equation 23 corresponds closely to a real-world margin setting, which is primarily based on volatility estimates from past price movements, this introduces a procyclicality that helps to amplify funding shocks.

Proposition 4, fragility: There exist $\underline{x}, \underline{\theta}, \underline{a} > 0$ such that:

(i) With informed financiers, the market is fragile at time 1 if speculators position $|x_0|$ is larger than $\underline{x}$ and of the same sign as the demand shock Z_1.

(ii) With uninformed financiers the market is fragile as in (i) and additionally if the ARCH parameter θ is larger than $\underline{\theta}$ and the probability, a, of sequential arrival of customers is smaller than $\underline{a}$.

7.1.2 Liquidity Spirals

To further emphasize the importance of speculators funding liquidity, we now show how it can make market liquidity highly sensitive to shocks. We identify two amplification mechanisms: A "margin spiral" due to increasing margins as speculator financing worsens, and a "loss spiral" due to escalating speculator loss. We can from Brunnermeier and Pedersen (2009) define the spirals mathematically in following proposition:

Proposition 5, liquidity spirals: If Speculators capital constraint is slack, then the price p_1 is equal to v_1 and insensitive to local changes in speculators wealth. Liquidity spirals, in a stable illiquid equilibrium with selling pressure from customers, $Z_1, x_1 > 0$, the price sensitivity to speculator wealth shocks η_1 is

$$\frac{\partial p_1}{\partial \eta_1} = \frac{1}{\frac{2}{\gamma(\sigma_2)^2} m_1^+ + \frac{\partial m_1^+}{\partial p_1} x_1 - x_0} \tag{24}$$

And with buying pressure from customers, $Z_1, x_1 < 0$

$$\frac{\partial p_1}{\partial \eta_1} = \frac{-1}{\frac{2}{\gamma(\sigma_2)^2} m_1^- + \frac{\partial m_1^-}{\partial p_1} x_1 - x_0} \tag{25}$$

A margin/haircut spiral arises if $\frac{\partial m_1^+}{\partial p_1} < 0 \; or \; \frac{\partial m_1^-}{\partial p_1} > 0$, which happens with positive probability if financiers are uniformed and a is small enough. A loss spiral arises if speculators previous position is the opposite direction as the demand pressure, $x_0 Z_1 > 0$

This proposition is intuitive. Imagine first what happens if speculators face a wealth shock of 1DKK, margins are constant, and speculators have no inventory, $x_0 = 0$. In this case, the speculators must reduce his position by $1/m_1$. Since the slope of each of the two customer demand curves is $\frac{1}{\gamma(\sigma_2)^2}$, we get a total price effect of $\frac{1}{\frac{2}{\gamma(\sigma_2)^2} m_1}$. The two additional terms in the denominator imply amplification or dampening effects due to changes in the margin requirements and to PnL on the speculators existing positions.

We should also note that spirals can also be started by shocks to liquidity demand Z_1, fundamentals v_1 or volatility. It is straightforward to compute the price sensitivity with respect to such shocks. They are just multiples of $\frac{\partial p_1}{\partial \eta_1}$. For instance, a fundamental shock affects the price both because of its direct effect on the final payoff and because of its effect on customers estimate of future volatility and both effects are amplified by the liquidity spirals.

This can be translated into a real-world problem, we would for example define a shock to the Danish mortgage market liquidity, if a market maker suddenly would close down a trading desk. This I not unrealistic as we have seen in section 3, the large Danish banks have reduced their trading holdings of covered bonds. We would also expect further reducing in trading holdings if it is no longer attractive to trade covered bonds under the new FRTB framework. Therefore, if one of the large banks closes a trading desk, we should be able to define its as liquidity spiral in our theoretically setup. A shock to market liquidity could also be, that a trading desk/bank are not able to get its Internal Model approach approved, and therefore need to apply the SA as a floor for its market risk capital requirements and needs to close down its market making desk if is no longer are profitable due to the new capital requirements.

7.1.3 Commonality and flight to quality

We investigate the cross-sectional implications of illiquidity. Since speculators are risk-neutral, they optimally invest all their capital in securities that have the greatest expected profit, that is $\left|\Lambda^j\right| \, per \, capital \, use$, i.e., per DKK margin m^j, as expressed in equation (14) from the appendix. That equation also introduces the shadow cost of capital ϕ_1 as the marginal value of an extra DKK. The speculators shadow cost of capital ϕ_1 captures well the notion of funding liquidity: a high ϕ means that the available funding – from capital W_1 and from collateralized financing with margins m_1^j is low relative to the needed funding, which depends on the investment opportunities deriving from demand shocks z^j. The market liquidity of all assets depends on the speculators funding liquidity, especially for high-margin assets, and this has serval interesting implications:

Proposition 6, commonality, and flight to quality: There exits $c > 0$ such that for $\theta^j < c$ for all j and either informed financiers or uninformed with $a < c$, we have

(i) Commonality of market liquidity. The market illiquidity $|\Lambda|$ of any two securities, k and l, co-move.

$$Cov_0\left(\left|\Lambda_1^k\right|, \left|\Lambda_1^l\right|\right) \geq 0 \qquad (26)$$

and market illiquidity co-moves with funding illiquidity as measured by speculators shadow cost of capital, ϕ_1.

$$Cov_0\left(\left|\Lambda_1^k\right|, \phi_1\right) \geq 0 \qquad (27)$$

(ii) Commonality of fragility. Jumps in market liquidity occur simultaneously for all assets which speculators are marginal investors.

(iii) Quality and liquidity. If asset l has lower fundamental volatility than asst k, $\underline{\sigma}^l < \underline{\sigma}^k$, then l also has lower market illiquidity:

$$\left|\Lambda_1^l\right| \leq \left|\Lambda_1^k\right| \tag{28}$$

If $x_1^k \neq 0 \; or \; \left|\mathrm{Z}_1^k\right| > \left|\mathrm{Z}_1^l\right|$.

(iv) Flight to quality. The market liquidity differential between high- and low-fundamental-volatility securities is bigger when speculators funding is tight, that is $\underline{\sigma}^l < \underline{\sigma}^k$ implies that $\left|\Lambda_1^k\right|$ increases more with a negative wealth shock to the speculator,

$$\frac{\partial\left|\Lambda_1^l\right|}{\partial(-\eta_1)} \leq \frac{\partial\left|\Lambda_1^k\right|}{\partial(-\eta_1)} \tag{29}$$

if $x_1^k \neq 0 \; or \; \left|\mathrm{Z}_1^k\right| > \left|\mathrm{Z}_1^l\right|$. Hence, if $x_1^k \neq 0 \; or \; \left|\mathrm{Z}_1^k\right| > \left|\mathrm{Z}_1^l\right|$ a.s, then:

$$Cov_0\left(\left|\Lambda_1^l\right|, \phi_1\right) \leq Cov_0\left(\left|\Lambda_1^k\right|, \phi_1\right) \tag{30}$$

7.1.4 Key takeaways from our theoretical liquidity framework

The theoretically model from Brunnermeier and Pedersen (2009) was introduced, and the above section introduced some of the institutional elements from the Danish mortgage market, and showed how the model can explain that speculators capital and volatility are state variables which has a direct effect on the market liquidity and risk premiums, we showed that a reduction in capital would create a reduction in market liquidity, especially if capital is already low. We showed the competitive equilibrium of the model based on equation 4 which are directly linked to a bank's capital constraint and explored its liquidity implications, we also defined market liquidity as the difference between the transactions price and the fundamental value, and funding liquidity as speculators scarcity of capital, this I also in line with the liquidity and illiquidity measures presented in section 5 in part 1.

We found that a significant liquidity driven divergence of prices from fundamental in the covered bond market after capital shocks to the main liquidity providers, if the market makers in the Danish mortgage bond market would see an increase of 30% to 40% of capital requirements, we would see a capital shock to the main liquidity providers and thus expect a drop in liquidity.

Our model suggests that an exogenous shock to speculators capital should lead to a reduction in market liquidity (proposition 5). Hence, a clean test of the model would be to identify exogenous capital shocks. The model also implies that the effect of speculator capital on market liquidity is highly

nonlinear, a marginal change in capital has small effect when speculators are far from their constraints, but large effect when speculators are close their constraints – illiquidity can suddenly jump. Finally, the model predicts that the sensitivity of margins and market liquidity to speculator capital is larger for securities that are risky and illiquid on average. Hence, the model suggests that a shock to speculator capital would lead to a reduction in market liquidity through a spiral effect that is stringer for illiquid securities.

7.2 Danish Covered bond market liquidity

In this section we will look at the Danish covered bond market liquidity and volatility in the past. The section will present how the theoretically setup introduced in section 8.1 can help explain how the Danish mortgage market have performed in the past, this would help us to better understand how we can expect the FRTB market risk framework to change the market liquidity in the future.

7.2.1 Liquidity differences across different mortgage bonds

As we have shown theoretically bond liquidity is highly dependent on the properties of each securities. Firstly, the credit rating is an important factor in determining whether a bond is liquid, especially in a capital requirement setup, where each bond get a haircut on its properties. Firstly, the credit rating is an important factor in determining whether a bond is liquid. The high credit ratings of Danish mortgage bonds are reflected in the level of liquidity, which is assessed in several analyses as being high, for instance in (BIS, 2013), (Buchhloast, Gyntelberg and Sangil, 2010), and (Dick-Nielsen, Gyntelberg and Sangil (2012). Across mortgage bonds, properties such as the volume of bond series, remaining maturity and the holders of the securities are significant factors in determining the level of liquidity Danmarks Nationalbank (2015). This is also in line with what we have shown in section 8.1 above, if we look at proposition 6, we described theoretically how market liquidity co-moves in securities, but different fundamentals would drive liquidity in one instruments compared to another. In the Danish covered bond market, we can see historically that properties of the securities have had a significant influence of its liquidity.

As described in section 2, Danish mortgage bonds are currently issued by six mortgage banks, the largest three of which issued just over 80% of the outstanding volume is increasingly concentrated in large series.

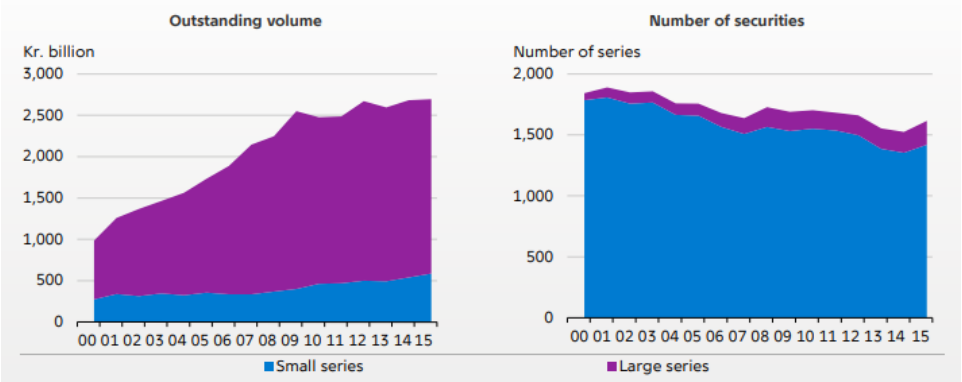

Figure 28 - Outstanding volume and number of securities broken down by series volume, Source Danmarks Nationalbank

As we can see from figure 31, the numbers of smaller series have steadily decreased over the last couple, however most mortgage bonds issued still remain in many smaller series remain in many small series shown in the figure 30, taken from Danmarks Nationalbank (2015). This can be explained be the wide range of loans types that mortgage banks are offering to its customers. We have shown in section 2 that the popularity of adjustable-rate mortgage loans has served to disperse the total outstanding volume on series with different fixed-interest period a variable interest rate. Recall our description of the mortgage market in section 2, that Danish mortgage banks issue bonds under the balance principle, this entails that there must be a direct relationship between payments on loans and bonds, the wide range of loan types is reflected in an equally higher number of bonds. The principle also means that a bond series cannot be closed if borrowers are still repaying loans under the series. This contributes to further increasing the numbers of outstanding series. To counter the refinancing risk of 1-year bonds, mortgage banks have, since 2010, sought to spread refinancing auctions on four annual settling periods (furthermore, the supervisory Diamond for mortgage banks contains requirements for limitation of the refinancing risk of each institution). This is reflected in the sales of mortgage bonds. In recent years, sales have been spread over the year to greater extent than previously when a very large volume of mortgage bond was sold once a year.

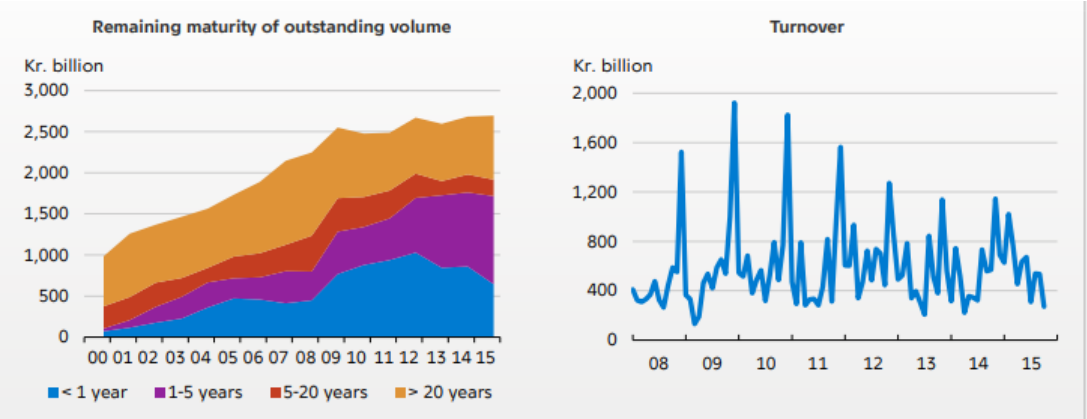

Figure 29 - Remaining maturity and turnover of mortgage bonds, source Danmarks Nationalbank

In 2014, the legislative amendment on contingent maturity extension of mortgage bonds introduced contingent maturity extension for bonds underlying loans with refinancing. Viewed in isolation, both measures have led to an increase in the numbers of outstanding series. Trade in the many small bond series may be challenged in a situation of declining market liquidity. As a result, it may become more difficult to sell the bonds at auction, and it may be more expensive to sell them in the secondary market. Moreover, the new liquidity requirement, the LCR, which took effect on 1st of October 2015, may impact demand across series volumes since the volume in the series affects whether it may be included in the required liquidity buffer. The largest series of at least 500 million euro can be included at a haircut of 7 per cent, while series between 250 and 500 million EUR can be included at a haircut of 15 per cent. Series below 250 million EUR cannot be included in the new liquidity requirement. At issuance, demand for these bonds will depend on expectations about the ultimate volume of the series. This was obvious at the refinancing auctions in November 2015 when the bond series expected to belong to a small series were sold with an interest rate premium.

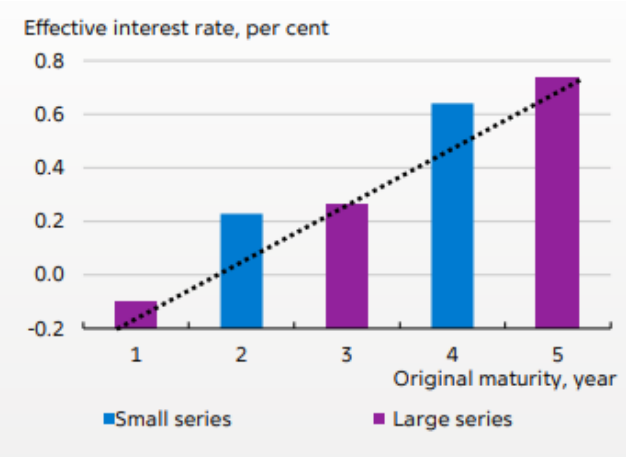

Figure 30 - Premium on small bond series. Source Danmarks Nationalbank

7.2.2 Liquidity across series volumes

Recall our description of liquidity in section 5, we noted that market liquidity is not easily measurable from the market directly. Because of that, if one needs to assess market liquidity, it needs to be based on several different indicators. In Danmarks Nationalbank (2015) they have based their research on transactional data from each Danish universal banks trading desks, and calculated on the trading data for Danish covered bonds the average monthly turnover to assess the level of trading activity for each bond series. Recall the turnover calculation presented in section 5, a higher turnover makes it easier for the individual market participant to buy and sell even large volumes of bonds on an ongoing basis in the market. Moreover, high trading activity helps to ensure that prices are rapidly restored after exogenous shock to the market. The concentration of the outstanding volumes of large series is

reflected in the turnover ratio in the market where transactions in large series accounts by far the largest share, one explanation are again the LCR capital requirements, we have seen that larger series have a smaller haircut and therefore are less capital intense. This is also in line with proposition 5 and 6 from our theorical model.

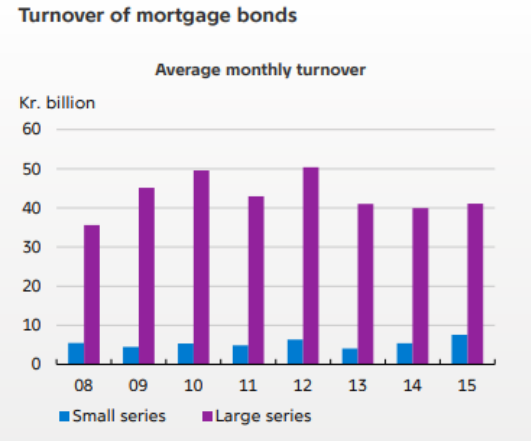

Figure 31 - Average monthly turnover, source Danmarks Nationalbank

There is no clear evidence of a declining turnover, both in the small and large series over the last couple of years. The below figure shows the percentage share of traders larger than 250 million in the market which have been not clear sign of large changes beside the seasonal refinancing changes.

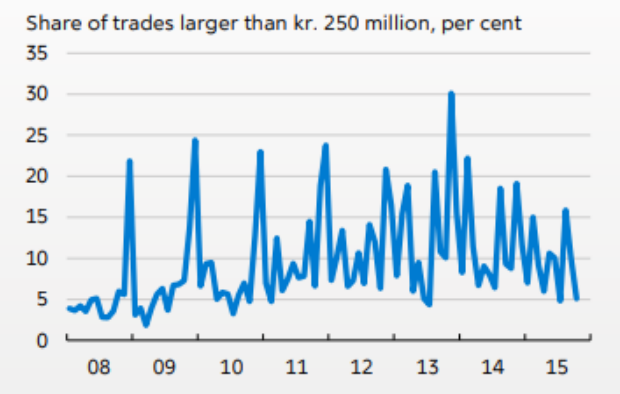

Figure 32 - Share of large transactions, source Nationalbanken

One factor to keep watching for the financial supervisors then observing for a declining market liquidity should be that market participants no longer will execute very large transactions, this has been the case in the US market for corporate bonds over the last couple of years (Nationalbanken, 2015). When doing an assessment of the market liquidity, and other observation point is the volume of bonds that market participants can trade at a specific price, we know that in a very liquid market, large transaction will show a little to no effect on the traded price. Recall our measure of illiquidity from section 5, empirically the dimension of liquidity shall be estimated by calculating the price impact of transactions, also known as the difference between the price from the latest traded price before a

transaction to the traded price of transaction. From the MiFID transaction data collected by Danmarks Nationalbank, they reported the estimated price impact of transactions in the market for mortgage bonds back in 2015 and it was estimated to be generally low. From Nationalbanken (2015) we can see that over the entire estimated period, the impact is slightly lower for transactions in large series, but it seems to grow during periods of increased market volatility, such as the Lehman Brothers collapse in September 2008 and, most recently, in connection with increases in the long-term bond yield in the 2nd quarter of 2015. The lower liquidity in small series is most pronounced for the smallest series, while the impact gradually diminishes with increasing volume of the series.

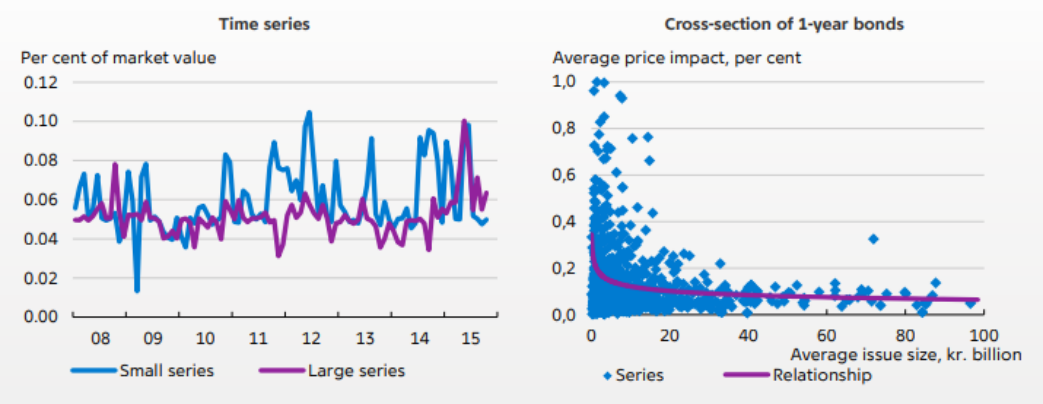

Figure 33 - Price impact of transactions broken down by series volume, source Danmarks Nationalbank

7.2.3 Remaining maturity and liquidity

Another property of the different bond types, that can also have an influence of the market liquidity is the remaining maturity of the different bonds, bonds with long remaining maturities generally have high duration, and bond with short remaining maturities have low duration since these bonds are set to mature at par within a short time. When market participants are trading in bond they would expect bonds with longer maturities to fluctuate more in true value and market makers would see this a being more risk to its inventory, therefore this effect is reflected in a stronger price impact of transactions in mortgage bonds with remaining maturities exceeding 20 years than in bonds with remaining maturities of less than 1 year. From Nationalbanken (2015) this can be illustrated in figure 37 below. It is seen that the price impact of longer maturity bonds had a large increase in the 2nd quarter of 2015. This was triggered by the increase in long-term yields in the euro area (Nationalbanken,2015). The increase caused the duration of long-term callable bonds increase – and thus also the interest rate risk of these bonds as the effect was explained above. Recall that a borrower in callable bonds have the option to redeem the bonds at par value at any year before bonds maturity date, we have that if the price of bond falls, the expected duration of bond will increase within because of the decreasing probability of a redemption.

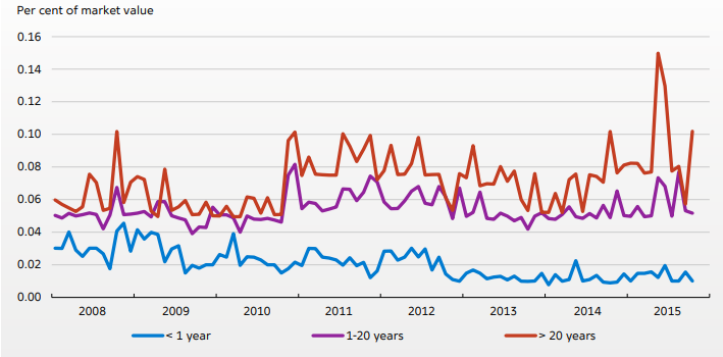

Figure 34 - Price impact of transactions broken down by remaining maturity, source Danmarks Nationalbank

7.2.4 Market conditions affect liquidity

As was shown theoretically in section 7.1, market liquidity will not only be affected by the bond's different properties, but also by different market conditions. In section 3 it was shown that the Danish universal banks have had reducing in inventory and created a development towards reduced risk appetite because of the increased regulation which may have affected the market liquidity, in the other hand Nationalbanken (2015) that banks have become more resilient to market shocks .

In the Danish market, covered bonds are mainly traded through wholesale banks acting as market makers, therefore commercial banks crucial role in mortgage bond trading is due to conditions in both the primary and the secondary markets, making it difficult to match buyers and sellers of bonds directly. In the primary market. Recall from section 2 that mortgage banks issue under the balance principle, that is each loan is financed by a corresponding bond issue in the primary market. However an institutional investor want to buy bonds in very large volumes, commercial banks wholesale department therefore needs to act as intermediary in the market between borrower and investor by purchasing bonds in the primary market by the issuer and then sell them in the secondary market in large blocks to institutional investors. By doing this, commercial banks can use its balance sheet to for buying and selling bonds, thus help to absorb imbalances between supply and demand for covered bonds, which will help to support the market liquidity. Banks' earnings from market making activities are primarily derived from the bid-ask spread, i.e. the difference between the prices at which they buy and sell the bond Nationalbanken (2015). The market will expect that during financial turmoil, banks are not as willingness to take the same risk with its inventory, and this will cause them to pull out of the market and stop providing the same amount of liquidity, it is therefore not optimal for the individual market participant to supply the amount of liquidity that will be optimal for the market. We can therefore not be guaranteed that the Danish banks market making operations are liquidity resilience in all market conditions. Danmarks Nationalbank (2015) measures the variation of the price impact across bond transactions, which provides them with an indication of this resilience, i.e. an

indication of the potential price impact of a transaction and thus a measure of the liquidity risk. From the below figure 38, we can see that by the end of 2014, volatility in the Danish covered bond market has been higher than historically, which indicates market liquidity has become less resilient.

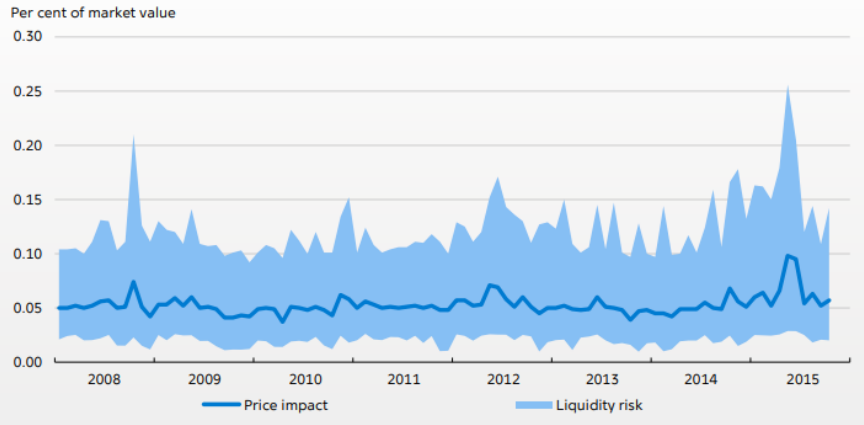

Figure 35 - Liquidity risk, source Danmarks Nationalbank

Consequently, the market can expect that smaller shocks may cause liquidity to disappear more quickly. The liquidity measure shows a temporary sharp contraction in liquidity and a strong increase in risk in the 2nd quarter of 2015. Previous periods of substantial changes in interest rates and volatility in long-term yields have not led to the same extent of falls in liquidity in the market for mortgage bonds.

7.2.5 Significance of the credit markets for market making

Recall from section 3 and 7.1 that commercial banks act as market makers through their wholesale business branch and to do so, they need access to credit and hedging facilities in the financial markets. This is also the case for the Danish mortgage market where a significant causal relationship can be demonstrated between banks access to the credit markets and liquidity in the mortgage bond market as was demonstrated theoretically in section 7.1. This relationship between banks access to finance their market making activities and liquidity in the market for mortgage bonds was analyzed in Dick-Nielsen, Gyntelberg and Lund (2013) and Dick-Nielsen et. al (2019). They show the development on the price impact of transactions can be explained by a change in the spread between the 3-month CIBOR rate and the 3-month CITA Swap rate for the Danish money market. In Danmarks Nationalbank (2015) a statistical regression analyses is conducted with an updated time series, the results from the regressions and test of granger causality shows that the development in the spread is a significant driver of the development in the price impact for bonds with short remaining maturities in the Danish market for mortgage bonds.

A Banks access to the credit market are dependent on the overall stability of the financial system and the banks creditworthiness of course. It is not possible to measure a specific banks access to the credit market, but in Danmarks Nationalbank (2015) they use an indicator to provide a proxy, the spread between the collateralized interest rate on interest rate swaps and the interest rate on an uncollateralized loan in the interbank market is used as proxy. From figure 39 below, we can see that the interbank market increased in credit risk during the financial crisis in 2008 and 2009, both in the euro area and in Denmark. The credit risk is reflected by the increased spread between collateralized and uncollateralized in interest rates during the period.

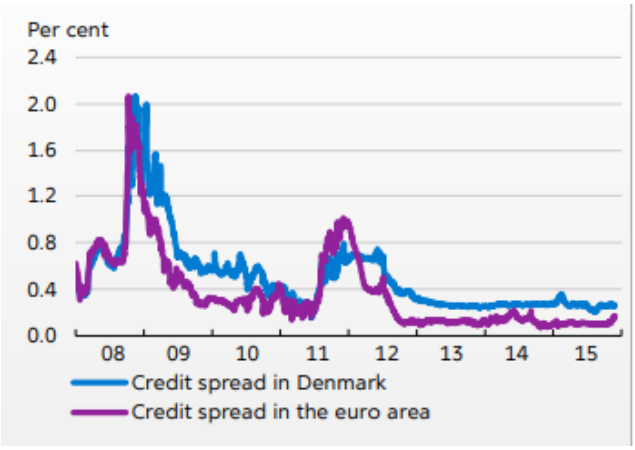

Figure 36 - Credit spreads for banks, source Danmarks Nationalbank

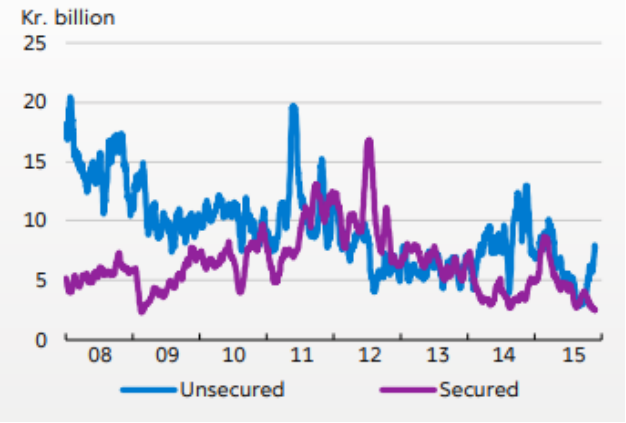

Figure 37 - Turnover in the interbank market

Since 2012, turnover of collateralized loans, such as repo transactions, has dropped considerably. Repo transactions, which are loan transactions against securities as collateral, are widely used for hedging and financing of market maker positions. Similarly to the way in which structural developments in the form of lower risk appetite and increased regulation can affect banks willingness to hold mortgage bonds in their portfolios, these developments may also be factor in the falling turnover in the repo market. The reduction in banks inventories of mortgage bonds and the declining turnover in the repo market imply that market making activities will focus on fewer bonds and, in

general, be reduced. The result may be a more order-driven bond market. This tendency is generally confirmed by market participant indicating that this is especially the case for bonds that are not issued anymore. Previously, the market was more price-driven, which enabled market participants to trade most bonds relatively easily via market makers at a price level given by the banks current price quotation. In an order-driven market, transactions will depend more on market makers being able to match buyer and seller directly. Transactions may become more time-consuming in an order-driven market, depending on how often a bond is traded.

7.2.6 Key takeaways from the Danish covered bond market

Based on the data presented in this section firstly provided in an article from Danmarks Nationalbank (2015), it was shown that up until 2015 the overall level of liquidity in Danish covered bonds is still classified to be relatively high. We have however seen that, since 2014 the market volatility has increased, which can cause market liquidity to become less resilient if shocks occur. The risk for smaller shocks to cause liquidity to vanish is in line with the conclusion from the theoretically framework, presented in the proposition regarding spiral effects, that is stringer for illiquid securities. As shown in the theoretical setup in section 7.1 and in section 3, Danish commercial banks play a vital role in providing liquidity to the Danish covered bond market by absorbing imbalances between supply and demand in the market through their market making activities and speculative trading desk. From Danmarks Nationalbank (2015) market participants have indicated that over recent years, market makers have become less willing to absorb these imbalances, and therefore not being able to provide all the necessary liquidity. New regulation in the form of tighter capital and liquidity requirements has also affected banks risk-taking Danmarks Nationalbank (2015), recall the new liquidity requirements presented in section 4, the LCR and NSFR which takes a haircut for Danish covered bonds. This requirement has influenced the risk-taking since it has a direct effect on how much capital a bank must hold to cover its trading balance sheet. On the one hand, this development has made banks more resilient and should provide them with a higher creditworthiness, on the other, it has lowered banks risk appetite and new regulatory requirements have reduced banks market making activities and from our theoretical model in section 7.1 also reduced the general market liquidity in the Danish covered bond market. The current accommodative monetary policy and resulting in lower interest rates could affect liquidity in various ways. As a case in point, the accommodative monetary policy stance could contribute to keeping liquidity premiums low despite growing concerns over market liquidity, the low interest rate environment in Europe and the rest of World created by the ECB and the FEDs different QE programs, have pushed investors to other markets. The ECB are not buying Danish covered bonds nor government bonds, but they are creating an opportunity for foreign investors to seek to the Danish

bond market. As we have a relatively low amount of outstanding government debt in Denmark, foreign investors have increased their purchased of covered bonds, which is a direct consequence of ECBs aggressive asset purchases programs. On the other hand, the exceptionally low level of interest rates could cause market makers to reduce their bond exposure, since their holdings and trading intentions are based on future return expectations, if the interest rate levels are at its lows, market makers would expect to earn less on future holdings, recall the price movements on bonds when interest rates raise. On indication that banks are reducing market making is their reducing over the last year of portfolios of mortgage bonds for the business area. The data presented in this section also shows that properties of the different mortgage bonds also influences liquidity. Smaller series are assessed to be less liquid. This could mean that trading in the many small bond series may be challenged in a situation with declining market liquidity. At the same time, new liquidity requirements make it less attractive for credit institutions to hold bond series below a certain volume (Danmarks Nationalbank, 2015), this statement from are in line with what our theoretical model above described in proposition 6.

8 Discussion and Conclusion

The purpose of this thesis was to examine how the current FRTB market risk framework from January 2019 will affect the liquidity of the Danish covered bond market. After an extensive work and research on the topic with many different perspectives to choose from, the conclusions is that there seems to be a handful of negative consequences for the market and many market participants have already indicated the negative tendencies for more capital requirements for the Danish covered bond market. The market has also seen a large decline in Danish commercial banks inventory for Danish covered bonds, which could suggest that the FRTB framework would provide the final push through a broker style model. It is however necessary to keep in mind that, the results are based on a minimum amount of data analysis, and the latest transactional data presented was from 2015. The effects from the LCR regulation has already been shown in the data presented, and the analysis of the liquidity in Danish covered bonds and the theoretically setup presented shows a clear trend of higher capital requirements regulation, and should be interesting to following in the coming years.

Throughout the analysis of the liquidity of Danish covered bonds, a description of the Danish covered bond market, the current legislation has been made, and how it have changed over time to the most recent legislation from 2015, where the supervision diamond and interest triggers was introduced to prevent issues in the primary market, when Danish mortgage institutions are issuing covered bonds. In section 2, the different types of covered bonds were introduced and provided the reader with a solid foundation of the different properties of the main type of covered bond in the Danish market. Furthermore, the relevance of Danish universal banks to act as market makers was shown in section 3. This was shown from the paper by Danmarks Nationalbank (2015), that evidence was found of the five largest universal banks in Denmark have reduced their net positions available for market making by 100bn since mid-2013-2014. To a lesser extent, Danish Universal banks will use its balance sheet to act as market makers and provide the market with liquidity, and rather act as a broker between buyers and sellers in the market.

The FRTB market risk framework considers the banks' trading books and related capital requirements, and the implementation of FRTB is postponed until 2022 by Basel. FRTB will replace the current method of internal models and provide a new standardised approach, which in short will be complicated compared to the current Danish implemented legislation. In addition, capital must be set aside for the risk of default, when purchasing mortgage bonds, the floor for the risk of a default of the issuer is 0.5bp for AAA rating. For the standardised approach, there has been a massive softening of capitalizing covered bonds in the form of a nearly halving of the credit spreads from 400bp to 250bp. In practice, this means a large reduction in the capital requirement for banks holding mortgage bonds.

However, the overall effect is still very difficult to calculate, as the standardised approach is built on a portfolio approach. That is, one needs to take all the banks holding of tradable asset and portfolio diversification elements into consideration, when calculating the standardised approach on a bank level. However, this suggests that the new standardised approach will have a factor of 27%-40% increase on the capital requirement compared to the current Danish legislation. 250bp is therefore still a large and significantly credit spread capitalization, and significantly higher than the spread widening observed in the Danish covered bond market during the financial crisis of 2008. Moreover, Danish callable bonds will be charged additionally because of the ”Curvature” element in the SA method, because of the negative convexity property of the bond, which needs to be hedge in the same currency. Therefore it can be concluded, that the proposed Standardised approach are providing the banks with higher capital requirements compared to the current legislation, which marks it more default to run a profitable market maker business unit in Danish covered bonds market.

The theoretically model from Brunnermeier and Pedersen (2009) was introduced, and the institutional futures of the model was introduced to fit the market participants in the Danish mortgage market. The model showed that speculators capital and market volatility are state variables, which will have a direct effect on how the market liquidity and risk premiums are given. It was shown that a reduction in capital, would create a reduction in market liquidity, especially if capital for speculators was already low. It was presented how the model introduced a capital constraint that was like real world constraint and would be directly linked to a bank’s capital constraint and explored its liquidity implications. The market liquidity was defined as the difference between the transactions price and the fundamental value, and funding liquidity as speculators scarcity of capital.

From the introduction of the Danish mortgage model, that due to tap issuance, the market maker function of universal banks in Denmark, plays a central role in providing liquidity to the covered bond market, as professional investors are mostly unwilling to buy in small batches. Onwards, market makers remain the main source of liquidity in the Danish covered bond market. However, higher capital charges, liquidity and the low interest rate climate have put pressure on the profitability of market making

The findings in this thesis are interesting from a regulatory perspective for at least two reasons. Is has been shown that the Danish mortgage market are unique compared to the rest of the world and the design have been recognized internationally. It has been shown that a properly designed balance system, mortgage bonds are highly liquid and have been safe historically even during a global crisis, the bonds should become eligible for use in regulatory buffers as high-quality liquid instruments like other safe assets. Second, the availability as described in the model of short-term funding drives bond

market liquidity across covered and government bond markets. Therefore, regulation impacting, the repo markets, which are popular markets for market makers and speculators to obtain funding, will have the side effect of changing bond market liquidity.

Considering the above, it can be concluded that an increasing capital requirements regulation will be a decisive factor for increasing volatility in the markets and an explanation for the trends that right now point towards deteriorating market liquidity. The increase in capital requirements will not doubly provide the financial system with more robust institutions, but it will be on the expense of less robust markets. We can expect that Danish banks to a lesser extent stop as being market makers and instead shifting to a broker model which more time spent on searching for the right bond to its customers. With the clear direction of more regulation in the future, the Danish mortgage market must demand more innovation and pensiveness thinking if the Danish mortgage bonds are to remain the cornerstone of Danish financial system.

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11 Appendix

Equilibrium derivation:

The optimal strategy for customers and speculators is derived in Brunnermeiner and Pedersen (2009) by using dynamic programming. They start from time 2 and work backwards. A customer's value function is denoted Γ and a speculators value function is denoted J. At time 2, customers k's problem is:

$$\Gamma_2\left(W_2^k, p_2, v_2\right) = \max_{y_2^k} -E_2\left[e^{-\gamma W_3^k}\right]$$

$$= \max_{y_2^k} - e^{-\gamma\left(E_2[W_3^k] - \frac{\gamma}{2}Var_2[W_3^k]\right)}$$

Which has the following solution:

$$y_2^{j,k} = \frac{v_2^j - p_2^j}{\gamma\left(\sigma_3^j\right)^2} - z^{j,k}.$$

All customers are presented in the market at time 2, the unique equilibrium is $p_2 = v_2$. We get that, when prices in the market are equal to its fundamental price, the aggregate customer demand must be zero, $\sum_k y_2^{j,k} = 0$, and the speculators will also have a zero demand. The customers value function are: $\Gamma_2\left(W_2^k, p_2 = v_2, v_2\right) = -e^{\gamma W_2^k}$ and the speculator has the following value function: $J_2(W_2, p_2 = v_2, v_2) = W_2$. The equilibrium before time 2 depends on whether the customers arrive sequentially or simultaneously. If all customers arrive at time 0, then the simple arguments above show that $p_t = v_t$ at any time $t = 0,1,2$. We are interested in the case with sequential arrival of the customers such that the speculators liquidity provision is needed. At time 1, customers 0 and 1 are presented in the market, but customer 2 has not arrived yet. As above, customers $k = 0,1$ has demand and value function of

$$y_1^{j,k} = \frac{v_1^j - p_1^j}{\gamma\left(\sigma_2^j\right)^2} - z^{j,k}$$

$$\Gamma_1\left(W_1^k, p_1, v_1\right) = -\exp\left\{-\gamma\left[w_1^k + \sum_j \frac{(v_1^j - p_1^j)}{2\gamma\left(\sigma_2^j\right)^2}\right]\right\}$$

At time 0, customers $k = 0$ arrives in the market and maximizes $E_0\left[\Gamma_1\left(W_1^k, p_1, v_1\right)\right]$. At time $t = 1$, if the market is perfectly liquid so that $p_1^j = v_1^j$ for all j, then the speculators are indifferent among all possible positions x_1. If some securities $p_1 \neq v_1$, then the risk-neutral speculators

invest all his capital such that his margin constraint binds. The speculators optimally trade only in securities with the highest expected profit per dollar used. The profit per dollar used is $(v_1^j - p_1^j)/m_1^{j+}$ on a long position and is $-(v_1^j - p_1^j)/m_1^{j-}$ on a short position. A speculators shadow cost of capital, denoted by ϕ_1, is 1 plus the maximum profit per dollar used if he is not bankrupt:

$$\phi_1 = 1 + \max_j \left\{ max \left(\frac{v_1^j - p_1^j}{m_1^{j+}}, \frac{-(v_1^j - p_1^j)}{m_1^{j-}} \right) \right\}$$

Where the margins for long and short positions are set by the financiers as in equation 17 to 20. If the speculators are bankrupt, $W_1 < 0$, then $\phi_1 = \varphi_1$. Each speculators value function is therefore.

$$J_1(W_1, p_1, v_1, p_0, v_0) = W_1 \phi_1.$$

At time $t = 0$, the speculators maximize $E_0[W_1 \phi_1]$ subject to his capital constraint in equation 4. The equilibrium prices at time 1 and 0 do not have simple expressions by we can characterize their properties starting with a basic result from which much intuition derives (Brunnermeier and Pedersen, 2009).