UNIVERSITY OF GOTHENBURG
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University of Gothenburg
School of Business, Economics and Law

Master of Science in Finance

My word is my bond

Risk assessment of the Swedish mortgage portfolio

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A thesis submitted for the degree of
Master of Science in Finance

2017
Supervised by Evert Carlsson, PhD

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Abstract

In this thesis, we investigate risks in the Swedish mortgage portfolio, namely Swedish covered bonds, in a housing market decline. We develop a stress-model which estimates mortgages that needs to be withdrawn from the cover pool to honor the covered bond contract. Further, we extend our model to restore the initial market risk profile in the cover pool. Lastly, we use S&P Globals ratings methodology to assess covered bonds' credit ratings and credit enhancements. Our research suggest significant structural liquidity risk and maturity mismatch within the Swedish mortgage portfolio rather than credit risk. In a worst case scenario, a house price decline of 35%, SEK 446bn of cover assets would be withdrawn in order to honor the covered bond contract, an additional SEK 1380bn to restore the market risk profile and SEK 286bn to keep current ratings. Swedish mortgage institutions could have issues to refinance their covered bonds which typically have maturities of 3-5 years while mortgages have maturities of 25-30 years.

keywords: *Swedish Mortgage Portfolio, Covered Bond, Cover Pool, House Price risk, Mortgage risk, Credit risk, Liquidity risk*

Acknowledgements

We would first like to thank our thesis supervisor *Evert Carlsson*, for his expertise through this master thesis, as well as steering our research in the right direction and for providing the finance courses which made this thesis possible.

Further, we would like to mention our gratitude towards Finansinspektionen for providing us with Swedish household mortgage data.

Contents

1 Introduction

In this paper, our research focuses on banks risk exposure towards Swedish mortgages and namely covered bonds. Covered bond regulations are strict but quantifiable so we create a model which stress the Swedish mortgage portfolio and investigate potential costs Swedish banks could face. Swedish mortgage regulation reduce banks credit risk, however, covered bond regulation creates structural liquidity risk. We use the Merton model to simulate credit spreads in a market value decline. We further use methodology from S&P Global ratings and develop a credit rating model to see if covered bond ratings would be affected in a stressed scenario.

1.1 Background

Public discussions and debates have erupted during the last years regarding a possible Swedish housing bubble and its consequences for the Swedish economy (see Robert Schiller, IMF, Finansinspektionen, Riksbanken). The previous U.S housing bubble, which paved way for the global financial crisis of 2008-2009, is the major motivation for concern. Some concerns are apparent; the Swedish housing market has increased with roughly 6% annually the last thirty years while disposable incomes have increased with 4% (c.f. Valueguard, Riksbanken). Furthermore, Riksbanken has decreased interest rates and Swedish households has increased borrowing, Loan-to-values (LTV) and debt-income ratios.

Expansive central bank policies and corresponding low interest rates stimulates inflation and consumer behavior. The policies create an opportunistic environment to borrow at low rates with inflating asset prices and deflating debt. If the LTV is low and the borrower can't pay, the house forecloses and the bank receives full loan recovery. However, if $LTV > 1$, i.e. the debt is larger than the house value, the bank won't receive the full loan amount back after foreclosure but have a residual claim on the defaulter.

1.2 Differences between the Swedish and US mortgage market

A lot of research has been conducted on the American mortgage market, not least after the financial crisis of 2008-2009. Although the Swedish mortgage and housing market shows similar bubble warning signs as in US prior to the subprime mortgage crisis, i.e inflating house prices, increased debt-income ratios, declining mortgage rates and increased mortgage lending, it exists significant differences between the countries legislation for mortgage lending. The differences work in favor for Swedish mortgage institutions and investors in Swedish mortgage bonds.

The most significant difference is an option in a foreclosure. In the US, a mortgagor has the right to walk away from a loan by leaving the pledged collateral, i.e the house, and considered debt free, also called non-recourse debt. To elaborate, if the mortgagor defaults on his principal or interest payments, or the value of the house is less than the value of the debt, the mortgagor can leave the house keys at the mortgage bank without any residual claims from the lender. Thus, the financial risk lies with the lender and not the borrower (Riksbanken, 2011).

In contrast, Sweden has recourse debt. A borrower is in debt until the loan is repaid in full, regardless if the pledged collateral is worth less than the remaining loan at foreclosure. In the Swedish mortgage contract, it's the borrower who is exposed to the house price risk. For mortgage banks, credit risk occurs only if any residual claims are left after a foreclosure.

The differences in legislation between Sweden and the US works in favor for Swedish mortgage banks and lenders since it minimizes the mortgage banks' exposure to house prices (Riksbanken, 2011). Sweden has legislated a maximum loan-to-value (LTV) of 85%, while a traditional loan in the US insured by e.g. Fannie Mae allows for a maximum LTV of 97% (Fannie Mae, 2017). In addition, Sweden also utilize an amortization requirement of 2% on the total loan balance for LTVs above 70% and 1% amortization for LTVs between 50% and 70% (Finansinspektionen, 2015).

In Sweden, floating rates are dominating mortgagors choice of fixing period and most loans have a 3-month reseting period and an average fixation of 2.2 years. In US most loans are fixed for 20 years on average (Riksbanken, 2015).

1.3 Previous research on mortgage portfolio risk

Most of the mortgage risk research has been done by American researchers on the US mortgage market. Since most states in US apply non-recourse debt legislation, a mortgage can be modeled in an option pricing approach first developed by Merton (1973) and Black & Scholes (1973) on the pricing of corporate liabilities.

Souissi (2007), along with many other researchers (see Li, 2014), models the default and credit risk using option pricing theory. For a given time with discrete steps, where house prices can go up (down) with probability p $(1-p)$ with factor δ. A mortgagor faces three choices; continuation with principal and interest payments, pre-payment or default. The mortgagor will, in every period, choose the option that maximizes expected value.

Another approach is linear or logistic regression models which make use of big-data on previous defaults to quantify the default probability. The advantages of regression models are many, they are faster to implement and easy to continue with Value at Risk and Expected Shortfall using the mixed binomial logit model. The disadvantage lies within the difficulty in procuring the necessary data to conduct significant and unbiased regressions (Li, 2014).

Riksbanken and Finansinspektionen made the only research papers focusing on default rates and expected credit losses in Swedish mortgage portfolios. The Swedish mortgage banks' total credit losses in 2009 were SEK 1bn while total lending was SEK 2000bn (Riksbanken, 2011). Riksbanken and Finansinspektionen used sample data on 6800 individual loans collected quarterly from Swedish banks to examine house owners margins in terms of debt and interest rate costs in relation to disposable income. 4% of the households in the data set had negative margins to begin with. Riksbanken and Finansinspektionen continue by using stressed scenarios to make estimates of households payment abilities (Finansinspektionen, 2010).

Riksbanken's study uses three scenarios; the first one assumes the interest rate increases from 2.5 to 12.5%. The second scenario assumes income falls 0-18% and the third scenario assumes unemployment 0-20% and its consequences for income. Riksbanken assume in its calculations that credit losses and the share of households with negative disposable income after the deduction of mortgage costs have a linear relationship and increase/decrease proportionally. The first scenario, with a interest rate of 12.5%, leads to 45% of the households having negative margins and credit losses increasing from 0.05% to 0.51% (SEK 10,1bn). Scenario two and three leads to 44% and 29% of the households having negative margins, respectively, and credit losses mounting to 0.50 (SEK 10,0bn) and 0.32% (SEK 6,5bn) respectively (Riksbanken, 2011).

In Finansinspektionen's research paper, the authors point out that in 2009, 12% of the individuals had an LTV over 90% while a third of the individuals had an LTV over 80%. The research conducts a scenario assuming rising unemployment rates and declining house prices. It further assumes that households with a negative margin immediately have to sell their house. Finansinspektionen states a scenario with an unemployment rate of 20% and a price fall of 30%. The result shows that 11.1% of the households will have negative margins with an LTV over 100%, i.e negative equity in their home. The result lead to 7.4% (SEK 148bn) credit loss (Finansinspektionen, 2010).

Finansinspektion in line with Riksbanken doesn't see the Swedish mortgage market as a threat towards financial stability in Sweden. They instead raise concerns regarding LTV ratios based on the scenario above.

1.4 The Swedish banking crisis of 1990s

In the late 1980s, Swedish households and corporations started to increase borrowing due to deregulation on the credit market. Households faced flourishing conditions due to negative real interest rates caused by taxes and high inflation. Inflation reduced the loan value in favor of the borrower. Swedish households had on average negative savings. Households debt to disposable income rose from 100% to 130% between 1985 and 1989. In the early 1990s, higher interest rates started to strain both Swedish households and corporations (Riksbanken, 2011).

When the crisis was underway, corporations had high financial costs due to high leverage. Corporates didn't face the same legal consequences as households in case of insolvency. This resulted in corporate defaults with severe credit losses for the banks when corporations filed for bankruptcy. Households, in the past, had relied on the inflation to erode the loans. However, with higher interest rates, inflation decreased dramatically. House prices declined with 30% between 1990 and 1995. Despite households vulnerability, they only accounted for 10% of the banks total credit losses while the main share of credit losses were corporate lending (Riksbanken, 2011). The macroeconomic environment, characteristics of the financial system and the banks poor internal risk-management was the cause of the banking crisis rather than financial deregulation (Drees & Pazarbasioglu, 1998). Today, inflation is lower than it was 1990, implying the real debt level isn't declining at the same pace. Further, Debt to disposable income amounted to over 170% 2015 compared to 130% 1989 (Riksbanken, 2011).

2 Covered Bonds

A bond is a common way to finance a project, corporation, asset portfolio etc. A bond is often issued to more than one investor and traded on a bond market compared to a traditional bank loan. Mainly, there are two types of bonds, coupon bonds and zero coupon bonds, where the latter do not pay any coupons. The log-difference between the market price of the bond B_t and the principal amount D is the bond yield R_i.

A covered bond has pledged assets which serve as collateral in case of a default in one of the underlying loans. Therefore, a covered bond is often regarded as safer than a traditional unsecured bond. Swedish covered bonds are trading at almost the same yields as treasury bills, implying an almost risk-free investment (Nasdaq OMX Nordic, 2017).

2.1 MBSs, CDOs and the subprime crisis 2007-2009

Prior to the subprime morgage crisis in 2007-2009, commercial banks securitized thousands of mortgages and created mortgage backed securities (MBSs), which is a fixed income security backed by underlying mortgages and their respective pledged collateral (Gorton, 2009).

Mortgage backed securities had a large catalytic effect on the financial crisis in 2008. Investment banks created special purpose vehicles (SPVs), securitized pools of MBSs into collateralized debt obligations (CDOs). CDOs were structured in tranches which held different ratings from rating agencies like S&P, Moodys and Fitchs. Senior tranches were considered close to risk-free and rated with AAA. Subprime mortgages were in the lower tranches but had a higher yield (Gorton, 2009).

Clearly, with hindsight, CDOs were not risk-free. When the American housing bubble burst, subprime mortgagors faced higher costs due to the adjustable mortgage rates (ARMs). Subprime mortgagors started to default on their loans, leading to MBSs and the lower CDO tranches to default. The defaults resulted in enormous credit losses for the mortgage banks and institutions with exposure to these assets (Gorton, 2009).

2.2 Swedish covered bonds

A covered bond is an asset backed security with strict regulation (Riksbanken, 2011). Mortgage banks issue covered bonds to finance their mortgage pools. A covered bond is a claim on the emitting institute itself and the cover pool, compared to securities such as MBSs, which is a claim only on the mortgage pool. Covered bonds may consist of other loans in addition to mortgages, for example commercial loans. In Sweden however, covered bonds consist of roughly 97% mortgages. If the issuing institution can't fulfill its obligations regarding the bond, the bondholder has a claim on both the bond issuer and the underlying assets e.g. the cover pool through certain credit enhancements in the contract, compared to a traditional unsecured bond where the claim is on the issuer or an MBS where the claim is on the underlying mortgage pool. If the market value of the collateral in the covered bond decline, the issuer needs to withdraw the corresponding debt from the cover pool which no longer fulfill the cover asset requirement in the cover pool (Riksbanken, 2013).

If the value of the collateral, i.e pledged assets in the cover pool, is higher than the face value of the covered bond, the covered bond has OC (Over Collateralization). OC act as a "cushion effect" in fluctuations in the underlying market price. Thus, higher levels of OC decrease the bond's risk. Through credit enhancement contracts, covered bonds should have at least a 2% OC level (Finansinspektionen, 2016). However, to achieve higher credit ratings, mortgage institutions often have to add more OC (S&P Global, 2015a).

In an MBS, the cover pool is alleviated from the balance sheet after restructuring and securitization within its SPVs. In a covered bond however, the mortgage pools securing the covered bonds remain on the mortgage institution's balance sheet. This creates an incentive for the bank to monitor the mortgagors' credit quality instead of just lend out, securitize and sell the loans to investors. Thus, it's a shift in credit risk from the bond holder to the bond issuer (Riksbanken, 2013). Covered bonds have restrictions on what LTV ratios are allowed to act as collateral in the bond. In Sweden, the limit is an LTV of 75%. In spite of these reasons, Swedish covered bond credit quality is high and is reflected in the credit ratings, but also in form of lower yields and credit spreads. Main investors in covered bonds are domestic and global

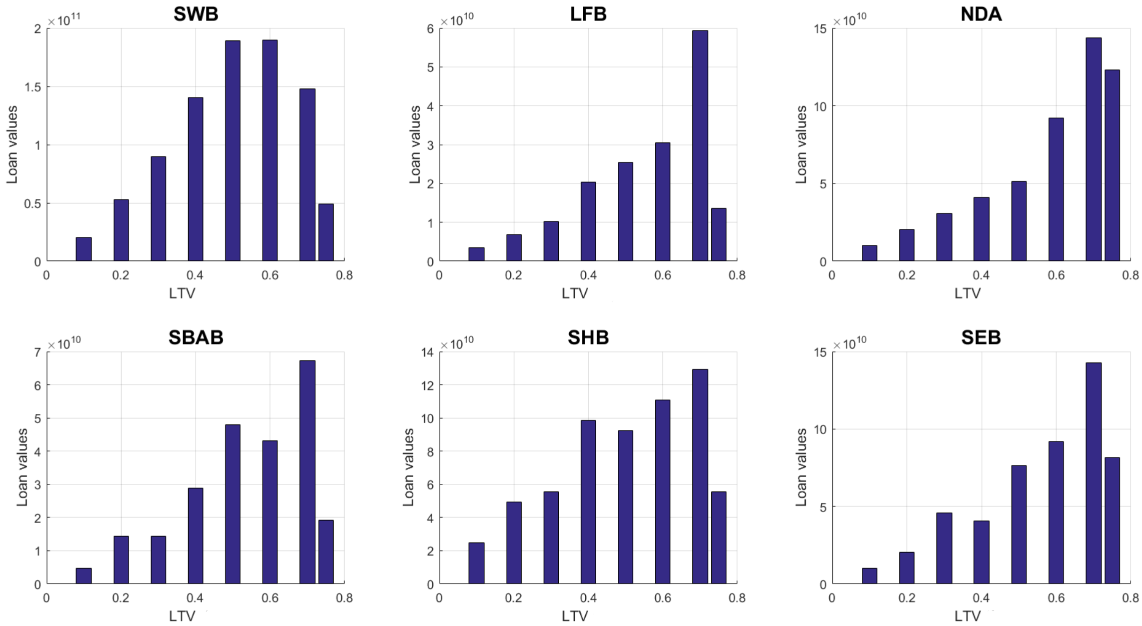

Figure 1: LTV distributions in the cover pools

institutions like banks, insurance companies and pension funds (Riksbanken, 2011).

The covered bond market is today a huge part of the Swedish financial system. The covered bonds amounted to a notional value of SEK 1940bn in 2013, roughly half the Swedish GDP (Riksbanken, 2013). The total cover pool securing the covered bonds sum up to over SEK 2800bn or 70% of Sweden's GDP in 2017. The issuers in Sweden are Swedbank, SEB, SHB, Nordea, SBAB and Länsförsäkringar Bank.

The LTV distributions for the banks differ as can be seen in Figure 1. Banks generally use waterfall distributions when they publish LTV distributions. Waterfall distribution means loans are sliced into equal parts and distributed through the LTV brackets. In Figure 1, we have collected the loans to show the true LTV distribution. The main lending volume is issued at an LTV between 50 and 75%.

Today, investors receive minimal risk premium for holding covered bonds. Given the high level of OC, banks have a buffer against house price drops, which act as extra security to investors. Furthermore, both investors and banks have an incentive to monitor the credit worthiness of the borrowers, lowering the risk for defaults on principal and interest payments. Banks withdraw loans from the cover pool which don't fulfill the cover bond regulation, i.e loans with $>$ 60 days delinquencies or exceeding an LTV of 75%.

2.3 Structural liquidity risks and maturity mismatch

Structural liquidity risks can be divided into short term and long term risk. Short term risk refers to when a bank is not able to pay its short term liabilities due to lack of liquid assets on the asset side. Examples of short term liabilities are short-term deposits and corporate accounts. Long term risk refers to the maturity mismatch between assets and liabilities. For example, funding a long-term asset, e.g a 30-year mortgage, with short-term liabilities, e.g deposits, creates maturity mismatch. Since the liabilities mature before the loan assets, there's a risk the bank can't refinance the liabilities and hence cannot repay short-term debts. A bank could have a small or non-existent short-term liquidity risk but suffer large long term liquidity risk (Riksbanken, 2016).

Public deposits in Swedish banks are not enough to finance its lending. Thus, Swedish banks issue securities on the capital market. The issuance of certificates and other short-term bank funding creates structural liquidity risks since the borrowing has shorter maturity than the lending (Riksbanken, 2016). The banks lending to home buyers are long term, often 20 to 30 years, and a covered bond usually has a time to maturity of 3 to 5 years. Refinance risk is therefor created when the bonds rollover (Riksbanken, 2011). An example is the financial crisis 2008-2009 when banks had turned to short term funding in US dollars and suffered severe liquidity problems due to lack of refinance. Covered bond issuers thus offer investors to repurchase the bonds months before maturity and offer new bonds with longer maturities at the same yield to counter refinance risk (Riksbanken, 2013).

Swedish banks have larger maturity mismatches than their European peers. In Table 1, average maturities for assets and liabilities are shown. Notable is that Swedbank, which has the largest mortgage portfolio in Sweden, also has the largest maturity mismatch.

Table 1: Maturity mismatch in Swedish banks and European peers

Bank	Assets (yrs)	Liabilities (yrs)	Maturity mismatch (yrs)
Nordea	10.3	3.4	6.9
SEB	10.1	3.1	7.0
SHB	14.8	3.7	11.1
Swedbank	15.5	3.7	11.8
Average European bank	11.1	4.2	6.9

Source: (Riksbanken, 2016)

Around 25% of banks total funding is done by issuing covered bonds. Although, roughly 20% of the banks liquidity buffer i.e short-term assets that are near cash is consisting of covered bonds (Riksbanken, 2013).

2.4 House price risk

A fall in house prices leads to financial stress for mortgage institutions and covered bonds. A 20% decline in house prices incur a loan with an LTV of 50% to rise to 62,5%. It's still allowed according to regulation to act as security in the bond. A loan with an LTV of 75% however, is not eligible after a price fall. Thus, part of the loan is removed as a security and 75% of the remaining value of the house continue to act as security (Riksbanken, 2013).

In absence of OC, a covered bond has discrepancy in value which must be covered by new assets. New assets can be treasury bills, municipal loans or cash liquidity (Riksbanken, 2011). Loans which can't serve as cover assets in the covered bond due to regulation remains on the banks balance sheet. Evidence during the financial crisis has shown the investors risk aversion towards mortgage backed securities in Europe. Covered bonds in Ireland, where the country suffered a decline in house prices of 35%, had an increase in the credit default swap of 470 basis points compared to Sweden's increase in covered bond spreads of 100 basis points (Riksbanken, 2011).

Swedish investors sold covered bonds after the Lehman Brothers collapse in 2008 and bought government bonds. The Swedish banks bought the cover bonds back from the market, but due to the risky financial environment they had a hard time finding new investors for the cover bonds, leading to a situation where the exposure towards their own covered bonds were beginning to challenge their internal regulations. Due to the liquidity that was pumped out of the system when banks bought the covered bonds back and the strain in short term funding due to the financial crisis, the Swedish banks faced severe problems. Due to the severity of the situation, the National Debt Office (Riksgälden) offered the banks funding with the covered bonds as collateral and financed the loans by selling government treasury bills (the amount raised was over SEK 300bn). Riksbanken followed suit and lent over SEK 450bn (Riksbanken, 2013; Riksbanken, 2016).

3 Credit rating

Covered bonds and other mortgage finance products are subject to extensive credit rating procedures. If one takes a mortgage, the bank makes a credit rating on the mortgagor. One convenient way to estimate default probabilities is to use logistic regressions instead of option pricing theory (Li, 2014). For example, Klarna AB uses a logistic regression to rate its customers.

S&P Global covered bond rating is an extensive but intuitive rating procedure. Cover assets are firstly separated into different groups (i.e. residential, agricultural, office or business purposes). The different groups have different LTV restrictions. Residential housing has 75% LTV, agricultural 70% and commercial 60%. On a nominal basis, the cover assets values have to be higher than the net present value of the covered bond, and consideration taken to hedging contracts and stress factors such as a 100 bps shift in the reference curve and a 10% change in the relevant foreign exchange rate (S&P Global, 2006).

A certain credit score e.g. AAA, has a specific criteria with three legs. The first leg is the legal framework. For example, if the issuing mortgage institution becomes insolvent, the cover assets which acts as collateral for the bond are separated from other bank assets and can't be touched to aid the company in its insolvency. Another example in case of bankruptcy of the issuer, is the problem to raise new funding after the bankruptcy, referring to the maturity mismatch between the cover pool assets and the covered bond. The second leg is the underlying asset quality. Higher credit rating demand assets which are more robust to stressed scenarios. Rating agencies assess the credit risk for each loan and aggregate them to estimate the risk of the entire cover pool. When calculating the risk for the entire pool, the foreclosure frequency (FF) and loss severity (LS) for individual loans are weighted with the entire cover pool. The aggregated value of exposure at default, and weighted average foreclosure frequency in the cover pool (WAFF) are multiplied with the weighted average loss severity (WALS), which gives the cumulative expected loss in the cover pool (S&P Global, 2016).

The last leg is the Cash flow analysis, which refers to the risk if the bond issuer can't make its payments to the bond holder. This analysis is done through a monte carlo model, which simulates different economic scenarios, e.g. interest hikes, liquidity shortages etc. The purpose of the analysis is to ensure the cover pool has recourse to liquidity in case if the issuer becomes insolvent.

The asset quality and cash flow analysis dictate which OC the institutions must have to overcome the risks described above and achieve AAA rating. The question whether a bank achieve AAA rating or not comes down to simulating the worst case scenario and adding credit in order to prevent a liquidity squeeze (S&P Global, 2006).

4 The Models

To get an understanding on how the market might behave during stressed scenarios we set up models of the mortgage portfolio. Our intention is to capture the deterministic of the covered bonds credit enhancement to get an estimate of quantities of loan withdrawals during certain stressed scenarios. Further, we want to get an understanding of the risk profile in the mortgage pools. We first develop a model which aims to follow the covered bond contract. Second, we develop a model in a Merton (1973) framework, which in addition to the first model aims to restore the initial credit spread and which also takes in consideration the new LTV distribution in the cover pool. Thirdly, we assess the credit risk in a stressed scenario and re-analyze the credit quality after a market value decline. At last, we replicate the S&P covered bond rating process to assess credit quality and the capital injections needed to stay at AAA-rating.

4.1 Cover pool modeling

To simulate how the cover pool reacts to changes is house value, we setup a model which, in line with the covered bond contracts and credit enhancements, removes part of the cover assets in case of a decline in house prices. Further, the part which now exceeds 75% LTV is put on the issuing bank's balance sheet and financed through regular unsecured bank funding. Since the regulations demand a strict limit of maximum 75% LTV, no loans in the cover pool will maintain an LTV higher than 75% (Finansinspektionen, 2016). In the bank's portfolio the residuals of the loans, i.e the junior tranche above 75%, are booked directly on the bank. The junior tranches represent the true LTV faced by the mortgagor. These loans are riskier in the sense that the bank doesn't have senior claim to the underlying properties and is the first to take economic losses in case of a default in the underlying mortgage pool.

$$V_{ca,i} = min[D_i, 0.75 \times V_{H,i}]$$

where $V_{ca,i}$ is value of cover asset, D_i is the nominal mortgage and $V_{H,i}$ is the market value of the house.

$$V_{bank,i} = max[D_i - V_{ca,i}, 0]$$

and,

$$LTV = \frac{D_i}{V_i}$$

Then if,

$$LTV > 0.75$$

$$V_{ca,i} = 0.75 \times V_{H,i}$$

and

$$V_{bank,i} = D_i - V_{ca,i}$$

Else if

$$LTV \leq 0.75$$

$$V_{ca,i} = D_i$$

and

$$V_{bank} = 0$$

4.2 The Merton model

Our model will assess the liquidity and credit risks banks are exposed to in the covered bond contracts. We set up a model which, in addition to the cover pool model, also price the existing debt in the LTV brackets. In addition to withdrawals of debt, the model repurchase loans to remove some of the risk which is attached to the new LTV distribution in the cover pool. Our model is calibrated towards the prices in the Swedish market for covered bonds. Our calibration results is presented in appendix C.

The Merton model is particularly attractive due to the equation is a function of observable variables D, V, r, T where D is the nominal mortgage, V is the value of the house, r is the risk-free rate and T is time to maturity. The only variable that needs to be estimated is σ, the standard deviation of the asset. Although the model is constructed for pricing debt which incorporates significant default risk, and in its most simple form, a discount-bond with no coupon payments, it can be extended to work on other types of debt. For the models assumptions, see Appendix C.

The mortgagors position can be described as; a *long position* in the *house* V_t, a *long put* with strike D and a *short position* in the risk-free asset $-De^{-rT}$. From the banks perspective the position is; a *short put* with strike D and a *long position* in the risk-free asset De^{-rT}.

To finance a house we need both equity and debt, hence the value of the house can be expressed as,

$$V_t = S_t + B_t$$

The value of the equity position, S_t is:

$$C(V_t, D, r, t, \sigma) = V_t N(d_1) - De^{-rT} N(d_2)$$

where,

$$d_1 = \frac{ln(\frac{V_t}{D}) + (r + \frac{1}{2} + \sigma^2)}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

For the bank, the corresponding value of the debt is then,

$$B_t = De^{-rT} - P(V_t, D, r, T, \sigma)$$

and we can use that $V_t = S_t + B_t$, so $B_t = V_t - S_t$ and recall also that $S_t = C(V_t, D, r, t, \sigma)$, so we can write the value of the bond as,

$$B_t = V_t - C(V_t, D, r, t, \sigma)$$

and the yield spread can be calculated as;

$$R_i = -\frac{1}{T} Ln\left(\frac{D}{B_t}\right) - R_f$$

and is defined as the spread over the risk free rate, i.e. the risky spread.

For a bond with coupon payment c_k, the price of the bond will be the sum of all coupons and principal discounted at time t_k and interest r_k

$$P_t = \sum_{k=1}^{K} B_k(r_k, \sigma, t_k, V_t, D)c_k = \sum_{k=1}^{K} B_k(r_k, \sigma, t_k, V_t, D, c_k)$$

4.3 Default probability in the Merton model

In the Merton model, a default will occur when $V_t < D$ and the probability for that event can be calculated as:

$$\mathbb{P}[V_t < D] = N\left(\frac{ln(\frac{D}{V_t}) - (r - \frac{1}{2}\sigma^2)T}{\sigma\sqrt{T}}\right)$$

The Expected economic loss is then calculated as,

$$\min(V - D, 0) \times EAD \times \mathbb{P}[V_t < D]$$

where EAD is defined as the Exposure at default and PD is probability of default. This is based on the assumption that V is an asset which can, without transaction costs, be liquidated immediately. This is however not true. Usually foreclosure is due in 18 months and transaction costs is estimated to about 7% of the nominal value of debt. There is also accrued interest and principal during the foreclosure period (S&P Global, 2006). Additionally, the probability of default is based on the logic if $V_t < D$ which is more realistic in the US than Sweden (see section: Differences between the Swedish and US mortgage market).

4.4 S&P credit rating model

The S&P methodology is one of the standard ways to conduct a credit rating process on financial instruments. We use S&Ps Swedish custom variables to calculate the necessary over collateralization (OC). S&P Global estimates the parameters from historical data and events in Sweden and from countries with similar economic structures (S&P Global, 2006).

In Table 2, estimates of a typical stressed scenario are shown where:

- FF: Foreclosure frequency, is the probability of foreclosure for each loan. A higher rating has a higher FF in order to better grasp a stressed economic environment. Higher LTV ratios are given a higher FF. Moreover, Loan repayment type, loan size, geographic concentration and affordability affect the foreclosure frequency.

- MVD: Market value decline
- IR: Post-default mortgage interest rate
- Li exp: Liquidation expense in % of default balance
- Months: Months taken to liquidate

Table 2: Parameters used to assess over collateralization and ratings

Asset type	FF(%)	MVD(%)	IR(%)	Li Exp(%)	Months
Owner-occupied properties	12	35	14	6	18
Rented residential properties	12	45	14	6	18

- PV = Property value
- NMV = New market value
- D_i = Debt for mortgage i
- AI = Accrued interest
- SE = Selling expenses
- TIC = Total interest and costs
- ML = Market loss
- TL = Total loss

$$NMV = PV - PV \times MVD$$

$$AI = D_i \times (1 + IR)^{\frac{Months}{12}}$$

$$SE = Liexp \times PV$$

$$TIC = AI + SE$$

$$ML = min(NMV - D_i, 0)$$

$$TL = ML + TIC$$

$$OC = FF \times TL$$

5 Data

Data is collected from the cover bond issuers: Swedbank, Länsförsäkringar Bank, Nordea, SBAB, Svenska Handelsbanken and Skandinaviska Enskilda Banken. The data is cover pool and mortgage portfolio data of LTV distributions (at property level), Over collateralization levels, interest rate fixing information, repayment structures and information regarding the traded cover bonds (nominal debt and credit rating). The data is public information and can be found at the mortgage institutions web page under harmonized transparency templates and it follows The Association of Swedish Covered Bond issuers (ASCB) standards. Data is updated quarterly.

Table 3: Cover Pool data

Data	SWB	NDA	LFB	SBAB	SHB	SEB	Total
Asset pool data							
Assets in cover pool (SEK bn)	878.4	506.2	168.1	240.1	626.5	510.4	2872.8
OC (in %)	67.3	53.0	38.2	40.4	11.5	62.6	42.0
avg. LTV (in %)	50.5	59.4	56.4	54.4	50.9	56.8	53.9
Cover Bonds							
Rating (S&P/Moodys)	AAA	AAA	AAA	-/Aaa	-/Aaa	-/Aaa	
Funding (SEKbn)	525.1	330.8	121.6	171.0	562.1	313.9	2025.0
Interest rate fixing							
Floating (reset within 3m)	73.5	78.9	66.0	13.0	74.0	63.9	67.2
Fixed	26.5	21.1	34.0	87.0	26.0	36.1	32.8
Weighted Avg. LTV Distribution							
*(Waterfall LTV distribution in %)**							
0-10%	23.7	-	21.0	22.0	23.95	21.0	
11-20%	21.4	-	19.0	20.0	20.97	19.0	
21-30%	18.4	-	17.0	17.0	18.12	17.0	
31-40%**	15.0	68.9	15.0	15.0	15.17	14.0	
41-50%	11.0	11.7	12.0	12.0	12.26	12.0	
51-60%	6.7	9.5	9.0	8.0	9.5	9.0	
61-70%	3.1	7.3	6.0	5.0	0.03	6.0	
71-75%	0.7	2.6	1.0	1.0	0.01	2.0	
Sum	100	100	100	100	100	100	

*For a 1 mn loan with LTV 40%, 0.25mn is distributed evenly in brackets 10 to 40%. **Nordea don't publish distributions in LTV brackets 10-40%.

The LTV waterfall distribution don't provide the true LTV distributions in the sample since every loan is sliced into equal parts. Thus, in our models, we redistribute the banks' loans to the true loan distributions and show them in Table 4 with the formula; $L_i = (D_{i-1} - D_i) \times j_i$, where $j_i = 1, 2, 3, 4, 5, 6, 7, 8$ and i denotes LTV bracket $10, 20, 30, 40, 50, 60, 70, 75$ Since Nordea don't publish distributions in LTV brackets 10-40%, we use peer mean 10-40% LTV distribution to estimate Nordea's lower brackets.

Table 4: LTV distributions in the sample in %

	Banks					
LTV Brackets	SWB	NDA	LFB	SBAB	SHB	SEB
0-10%	2.3	2.0	2.0	2.0	4.0	2.0
11-20%	6.0	4.0	4.0	6.0	8.0	4.0
21-30%	10.2	6.0	6.0	6.0	9.0	9.0
31-40%	16.0	8.0	12.0	12.0	16.0	8.0
41-50%	21.5	10.0	15.0	20.0	15.0	15.0
51-60%	21.6	18.0	18.0	18.0	18.0	18.0
61-70%	16.8	28.0	35.0	28.0	21.0	28.0
71-75%	5.6	24.0	8.0	8.0	9.0	16.0

6 Result and analysis

We simulate a downfall in the Swedish housing market of $\%\Delta H_t = [5, 10, ..., 35]$ and look at possible consequences in the Swedish mortgage institutions cover pools. We first estimate the amount of debt assets in each cover pool that has to be withdrawn (i.e cover assets now exceeding an LTV of 75%) in order to honor the covered bond contract. Estimates are done for all Swedish covered bond issuers and additionally conducted on an aggregate level.

Further, we use our Merton model (cf. Section 4.1) to price the remaining LTV tranches in the cover pool after a downfall in house prices. If the bond yield is significantly higher than the initial bond yield, i.e prior to the downfall in the collateral value, the model starts an iterative process to re-purchase SEK 2mn in debt from the cover pool. It starts with loans in the LTV 75% bracket and continues with lower brackets, e.g. 70,60,50 etc. until the target bond yield is reached. After each re-purchase, the model price the new cover pool distribution and repeats the process until the bond yield is equal to the initial yield. Our model is calibrated with traded Swedish T-bills, cover bonds and corporate bonds traded on Nasdaq OMX Nordic 2017. Next, we use Merton's PD model to estimate default risks in the cover pools. Finally, we use S&P Global ratings methodology to assess the overall risk in the cover pools. We estimate the credit enhancement/over collateralization needed in the cover pool to maintain at the highest rating. We then calculate whether mortgage institutions need to make capital injections to maintain their AAA rating. This process is done for the current situation as well as for stressed scenarios (a cover asset haircut of 10, 20, 30 and 35%). We use our data on issuers cover pools to estimate foreclosure frequency (FF). Other inputs used are market value decline (MVD), accrued interest (IR), liquidation expenses (LIE) and months until foreclosure (Month).

6.1 Structural liquidity risk

Our simulations of debt withdrawals from the cover pools during a market value decline (MVD) of $5, 10, 15, 20, 25, 30$ and 35% give us the following results in Table 5. These withdrawals are contractual in the cover bond regulation. Whether withdrawals will lead to capital injections into the cover pool depend on the banks current OC and which rating they are accepting.

Table 5: Withdrawals of debt assets from issuers cover pools in SEK bn

	Market value decline (%)						
Bank	5	10	15	20	25	30	35
SWB	2.5	10.2	20.3	30.9	53.1	75.4	102.3
LFB	0.7	3.5	7.3	11.2	17.0	22.7	29.2
NDA	6.2	17.4	31.3	45.1	64.7	84.3	105.2
SBAB	1.0	4.3	8.9	13.5	20.7	28.0	36.4
SHB	2.8	10.2	19.9	29.6	46.2	62.8	81.8
SEB	4.1	13.3	25.0	36.8	54.2	71.7	91.1
Total	17.1	58.9	112.7	167.0	255.9	344.9	445.9

A market value decline of 5% would result in forced withdrawals of SEK 17.1bn in cover assets from the aggregated cover pool. In our worst case scenario, Nordea has the highest nominal withdrawals (SEK 105.2bn) even though its cover pool is 57% of Swedbanks. Länsförsäkringar the lowest (SEK 29.2bn) but has however the smallest cover pool in the sample. Forced withdrawals would amount to around SEK 446bn (16%) of the total aggregated cover assets (see Table 3, total nominal volume SEK 2872.8bn). This would further decrease the total OC in the Swedish cover pool from 42% to 19%.

From Figure 2, we can see that the withdrawals of cover assets is growing at an exponential rate because of the concentration of loans in the 50% to 70% bracket. All issuers show similar characteristics. Swedbank's withdrawals is accelerating after 20% MVD. In Appendix A, LTV distributions for different MVDs for all banks are shown.

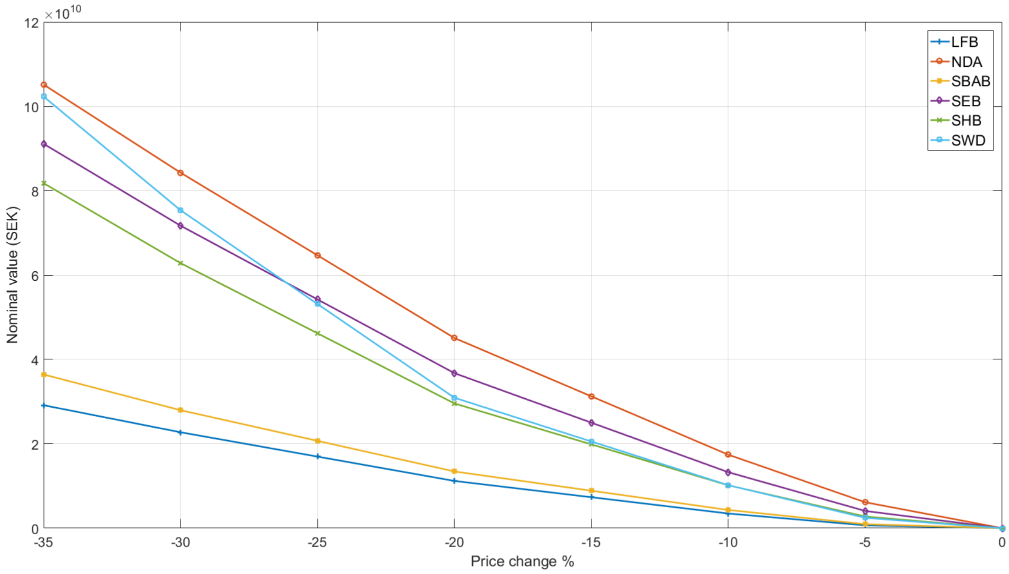

Figure 2: Withdrawals from cover pool in SEK bn

Swedbank suffers the second largest nominal value decline but smallest decline in percentage. The reason is its mortgage decomposition (LTV distribution) is much safer, i.e. less loans at higher LTV values than other banks. In Figure 3, Nordea is forced to withdraw over 20% of its total loans in a worst case scenario, followed by 18% for SEB. The banks LTV composition impact the percentage of portfolio withdrawals greatly. Nordea and SEB have 24% and 16% loans, respectively, in the LTV 75% bracket (see Table 4).

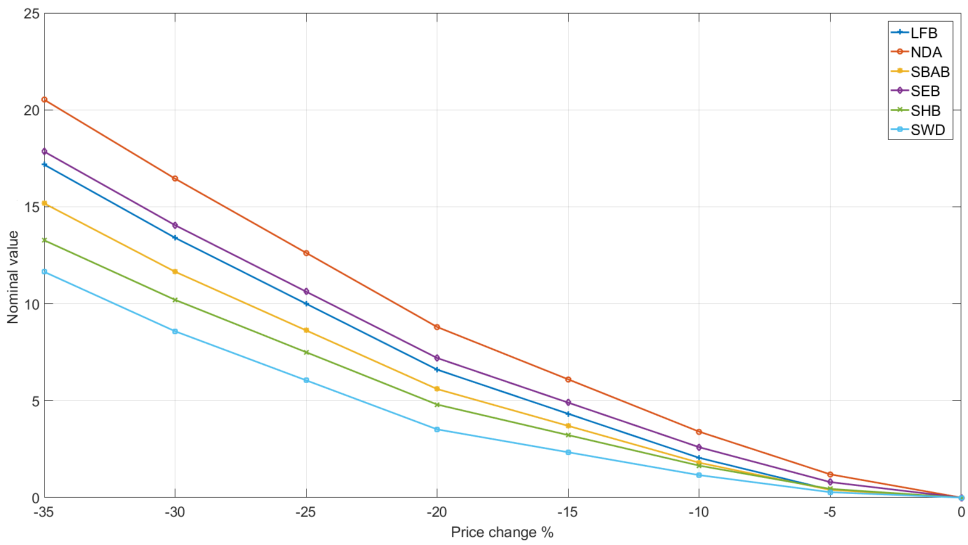

Figure 3: Withdrawals from cover pool in %

For the total portfolio, the withdrawals are accelerating at 20% MVD (see Figure 4). At a MVD of 35 %, the rating agencies benchmark and assumed worst case scenario, total market withdrawals amounts to SEK 445bn, approximately 15 % of the total mortgage portfolio or 20 % of the total funding through covered bonds. Total covered bond funding at the end of 2016 were 2025 MSEK (ASCB, Q4, 2016).

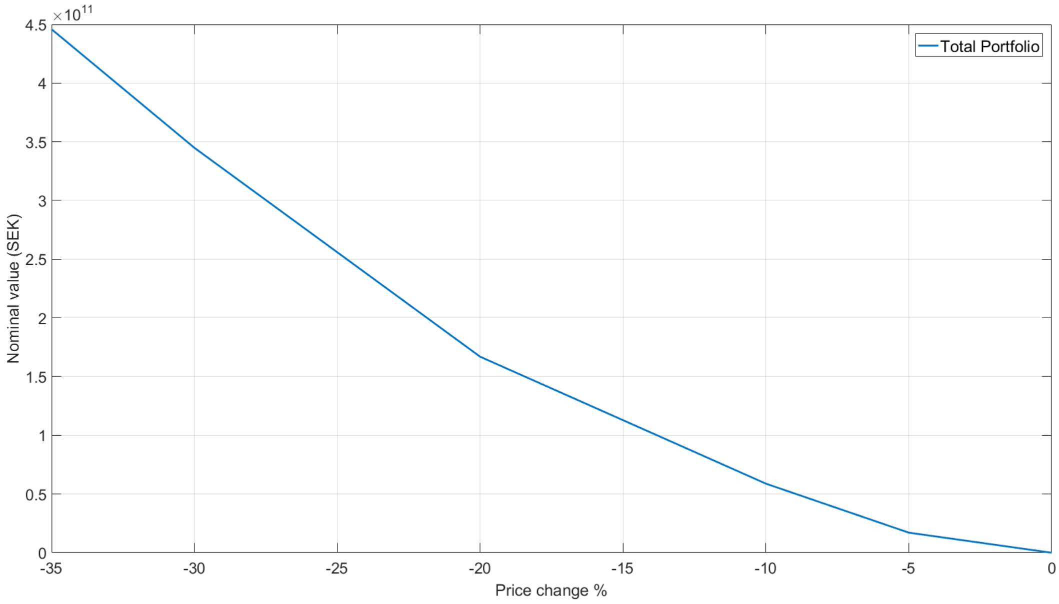

Figure 4: Withdrawals from cover pool in SEK bn

6.2 Credit spread and risk profile

We estimate the necessary debt repurchases in addition to the contractual withdrawal of cover assets for maintaining the initial credit spread of the total mortgage portfolio. Results are shown in Table 6. To illustrate the difference on LTV distributions in the remaining cover pool, Figure 5 below show the issuing banks remaining cover pool distribution after additional withdrawals to maintain the initial risk in the cover pool.

Table 6: Debt repurchases (SEK bn) in order to maintain initial risk in covered bonds

	Market value decline (%)						
Bank	5	10	15	20	25	30	35
SWB	70	140	228	302	342	416	442
LFB	28	42	52	68	72	80	86
NDA	76	120	152	198	202	216	228
SBAB	32	52	68	90	98	116	124
SHB	60	100	136	186	204	232	260
SEB	68	112	144	188	200	222	240
Total	348	572	780	1032	1118	1282	1380

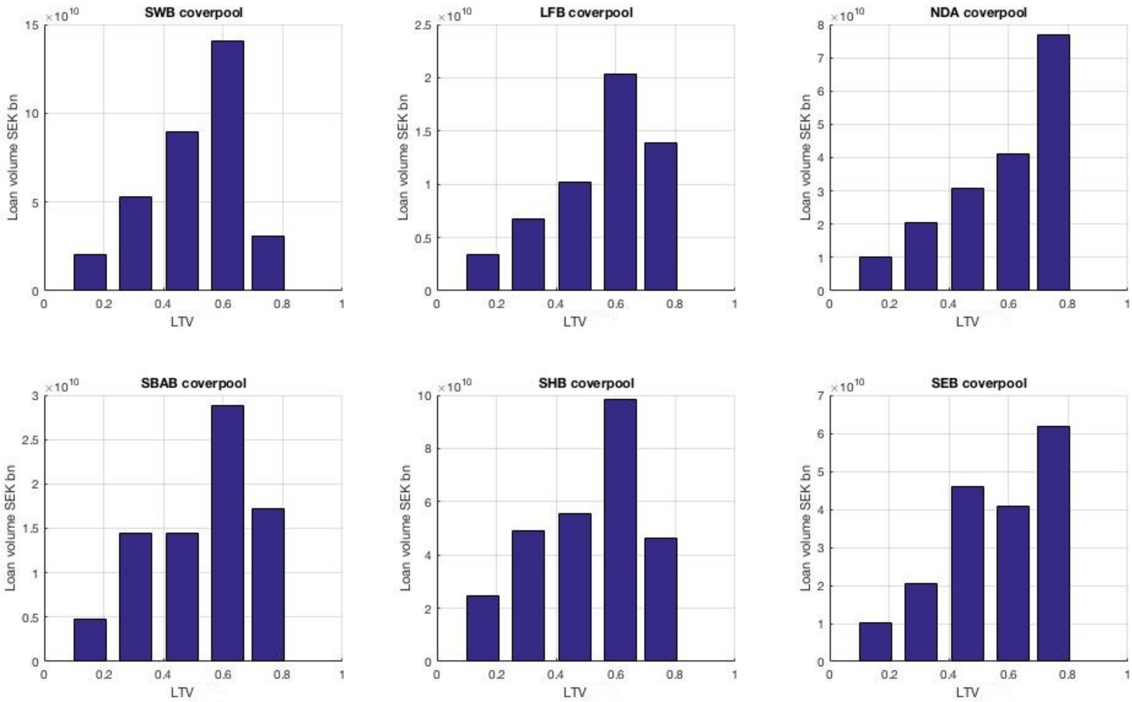

Figure 5: LTV distributions after additional withdrawals to restore initial risk and credit spread in the cover pool

We also include a credit spread analysis, where the credit spread is defined as the estimated three-year bond yield $y_i, i = swb, lfb, nda, sbab, shb, seb$ and the corresponding three-year risk-free asset R_f 2017. Results for the total funding in the cover pool are shown in Table 7 below.

Table 7: Estimated credit spreads (bps) at different MVDs

	Market value decline (%)							
Bank	Current	5	10	15	20	25	30	35
SWB	39	46	53	59	69	75	83	94
LFB	37	57	70	80	94	100	109	119
NDA	60	77	87	96	108	112	117	123
SBAB	49	58	65	74	82	90	102	114
SHB	33	39	43	48	62	69	79	90
SEB	42	60	71	81	94	100	108	117
Mean	43	56	64	73	84	91	100	110

The additional repurchases to maintain the credit quality in the portfolio is in magnitude a lot greater than the contractual withdrawals. The reason is the shift in LTV distribution, which can be seen in tables in appendix A. At an MVD of 5%, aggregated additional repurchases amounts to SEK 348bn, on average. In our worst case scenario, additional repurchases is estimated to SEK 1380bn, or 48% of the total cover pool.

In Table 8, we make a distinction between the senior covered bond funding and the subordinated funding through certificates and other unsecured short-term debt. Results are presented below.

Table 8: Credit spread (bps) estimated for Senior/subordinated tranches

	Market value decline (%)							
Bank	Initial	5	10	15	20	25	30	35
SWB	8/84	10/99	12/113	14/126	18/144	22/154	27/167	35/181
LFB	28/119	35/140	42/152	50/162	61/176	74/182	92/192	117/202
NDA	21/142	26/159	31/170	37/178	46/191	57/194	72/200	93/206
SBAB	25/107	30/126	36/138	43/150	53/165	64/173	79/185	101/197
SHB	10/94	12/109	14/120	17/131	21/145	25/151	31/161	39/172
SEB	14/125	18/142	21/154	25/163	31/177	39/182	49/191	63/200
Mean	18/112	22/129	26/141	31/152	38/166	47/173	58/183	75/193

The result show that there seems to be a diminishing effect on additional repurchases from the cover pool in order to maintain the credit quality in the portfolio. At the same time, credit contractual withdrawals are increasing with higher downfall in the underlying house prices. Nordea has the highest initial credit spread, corresponding to its riskier portfolio with high volumes of loans at LTV 70-75%. This effect however is decreasing and at 35% MVD; LFB, NDA, SBAB and SEB have almost the same credit spread on their total cover assets, while SHB and SWB have significantly lower credit spread due to a better LTV composition in their initial portfolios.

We show estimated cover bond spreads for different MVDs after contractual cover asset withdrawals (senior tranche) in Table 8. The subordinated debt is the cover assets which are pledged collateral for the covered bond but is funded through other funding sources. One can notice Swedbank and Handelsbanken have the lowest covered bond spreads which implies higher collateral quality. Nordea has significantly higher credit spreads due to the higher concentration of high LTV loans. This effect seems to smooth out given higher downfall in the market values of the collateral.

The senior tranche is secured covered bond funding and junior tranche is the unsecured funding via certificates and other issued debt. The residual funding in the existing portfolio is estimated to trade far below AAA-rating, around 200 bps. Usually, a AAA rated bond would be allowed to trade maximum 40 bps above the risk-free rate (S&P Global, 2015b).

6.3 Expected credit losses

We calculate the expected credit losses from the 3-year implied default probability and by using the S&P Globals assessment parameter 80% debt recovery. The expected

3-year credit losses are represented for each of the covered bond issuers in Table 9.

Table 9: 3-year expected credit losses in % of total portfolio

	Market value decline (%)				
Bank	Current	10	20	30	35
SWB	2.3	3.2	4.1	4.7	5.1
LFB	3.3	4.3	4.9	5.4	5.7
NDA	4.0	4.8	5.4	5.7	5.9
SBAB	3.0	3.9	4.7	5.2	5.6
SHB	2.6	3.4	4.1	4.7	4.9
SEB	3.5	4.3	5.0	5.4	5.7
Mean	3.0	3.8	4.5	5.0	5.3

3-year cumulative expected credit losses during a current state are estimated to around 3%, and average cumulative mortgage yield to maturity is around 5% over the risk-free rate which means there are still good margins for mortgage lenders. Since mortgages with 60-days delinquencies and mortgages above 75% LTV is withdrawn from the cover pool, and there is average 42% OC in the covered bonds, the potential credit losses in the covered bond are marginal and almost irrelevant. It is very unlikely that the covered bonds would suffer any credit losses due to heavy losses in the underlying cover pool because of high OC and regulation.

6.4 Credit scoring

We combine our loan-withdrawal model with our model based on S&Ps credit scoring model to calculate the OC banks must have to achieve a AAA-rating. In Table 10, we summarize the required OC issuers need to maintain in a 10 to 35% market value decline. Länsförsäkringar is required to have the highest OC based on asset quality (LTV distribution) and Swedbank the lowest.

Table 10: Target OC (in %) after withdrawal of debt from cover pool

	Market value decline (%)				
Bank	Current	10	20	30	35
SWB	14.8	18.3	18.4	25.4	27.8
LFB	27.9	32.4	32.4	39.5	42.0
NDA	26.0	29.1	29.1	32.8	34.1
SBAB	21.5	25.5	25.3	33.0	35.2
SHB	19.2	21.3	21.4	26.9	29.4
SEB	23.1	26.5	26.2	31.5	32.9
Mean	21.9	25.5	25.5	31.5	33.6

After a market value decline, banks will, ceteris paribus, have less OC. In Table 11, Nordea, Länsförsäkringar and SBAB have small OC levels at a 35% MVD and

Handelsbanken has negative OC i.e less cover assets value than issued cover bond values. However, Handelsbanken has approximately SEK 300bn un-pledged mortgage assets which they could use in the case of a MVD of 35%. These mortgages are however not published so those LTV distributions in case of a MVD are unknown. Further, at the 35% MVD, only Swedbank and SEB have enough OC to still achieve AAA rating without intervention. The variables used in the model are calibrated for each bank and can be found in Appendix B. The OC level depend on variable inputs and LTV distribution in the cover pool.

Table 11: Actual OC (in %) after debt withdrawal from cover pool

	Market value decline (%)				
Bank	Current	10	20	30	35
SWB	67.3	65.3	61.4	52.9	47.8
LFB	38.2	35.4	29.0	19.6	14.2
NDA	53.0	47.8	39.4	27.5	21.2
SBAB	40.4	37.9	32.5	24.0	19.4
SHB	11.5	9.6	6.2	0.3	-3.1
SEB	62.6	58.4	50.9	39.8	33.6
Mean	42.0	39.0	33.6	24.8	19.8

Every bank but Swedbank and SEB has to add liquidity in order to remain at the highest rating.

In Table 12 we show the necessary liquidity which has to be added in order to achieve the target OC. As noted, Swedbank and SEB don't have to add any liquidity to remain at AAA rating. Handelsbanken has to add SEK 182bn to remain at AAA rating.

Table 12: Buybacks (SEKbn) to cover target OC of debt from cover pool

	Market value decline (%)				
Bank	Current	10	20	30	35
SWB	0	0	0	0	0
LFB	0	0	4.1	24.2	33.8
NDA	0	0	0	17.4	42.6
SBAB	0	0	0	15.3	27.1
SHB	0	65.5	85.5	149.6	182.7
SEB	0	0	0	0	0
Total	0	65.5	89.6	206.6	286.1

7 Conclusions and discussion

Public discussions whether or not it exists a housing bubble in Sweden often draws parallels between the US and Swedish mortgage market. This discussion is done without taking into consideration the differences in mortgage regulations and legislations between the countries. Sweden has recourse debt, which means Swedes don't enjoy the option to become debt free after a foreclosure. With non-recourse debt, US homeowners have economic incentives to foreclose when the value of the house is significantly lower than the net present value of the debt. This can be modeled using option pricing theory. One problem when modeling the probability of default using option pricing theory as e.g. Souissi (2007), is that it requires the mortgagors in the market to act as financial engineers which constantly maximizes the expected value of future uncertain outcomes. Previous research has shown that people don't choose a default scenario just because the value of their home is below the value of the debt. Some reasons for this could be the fact that everyone needs a place to live, and in the major cities, there are shortages on housing. Secondly, there are some social costs to foreclosing on the house, especially in smaller towns because people tend to care about their reputation. Moreover, it can be troublesome to get new credit after a default in ones credit history. There are more disadvantages to default which is not included in most credit models. However, because of non-recourse debt, American homeowners still have greater incentives to default than Swedish homeowners and thus the default rate is significantly lower in Sweden. The 1990s financial crisis show that even though house prices dropped up to 30%, default rates remained low.

Mortgage institutions and investment banks in the US during the subprime crisis securitized mortgage pools into MBSs. These securities were alleviated from the banks balance sheets and sold to investors. The action removed the incentive to monitor the mortgagors and deny bad quality loans. In Sweden mortgage banks take the credit risk which gives them incentives to monitor and to deny bad credits. Thus, it's not fair to make a direct comparison between US MBSs and Swedish cover bonds. We have not seen any sign of Swedish banks starting to let subprime borrowers take out a mortgage. On the contrary, requirements to be eligible for a mortgage have increased. Thus, we argue that credit and default risk is inferior to other risks banks face and serious debates shouldn't make such direct connections to the US subprime crisis.

When comparing todays inflated house prices with how it began prior to the crisis in 1990s, there are many differences in the economic environment and there have been extensive regulations since. There are for example regulations how high LTV households may have on their mortgage and regulations of amortization for LTVs exceeding 50%. However, other economic parameters such as inflation is lower than it was in 1990, meaning that real debt level isn't declining at the same pace. Sweden has negative interest rates and mortgage rates of 1.5% today compared to sovereign debt interest rates of 14% and mortgage bond trading at 15% in 1990s (Riksbanken). Swedish commercial banks balance sheets consists of higher shares of mortgages than in 1990 (Riksbanken, 2011). Indeed, a significant part of the banks funding is done through covered bonds (Riksbanken, 2013). Debt to disposable income amounted to over 170% in 2015. Finansinspektionen warns about the high debt to disposable income ratio. But high debt to disposable income do not need to have a causal relationship with financial crises. Switzerland had an debt to disposable income of 200% before the financial crisis of 2008 and during the crisis, consumptions dropped marginally. Hungary on the other hand had a debt to income of 50% and suffered a 30% decline in consumption during the crisis (Finansinspektionen, 2015).

In this paper, our greatest concern regards the structural liquidity risk and maturity mismatch. In a potential price fall in the housing market, mortgage institutions would have a hard time to refinance the covered bonds which to a large extent are funding the total mortgage portfolio. A breakpoint is around 20%-25% market value decline, where our estimates is that the covered bond will no longer be AAA, and hence banks are forced to refinance a lot of there mortgages through certificates at significant higher rates. If the investors risk aversion to these bonds increase, the cover bonds become more illiquid which has been the case historically. If one were to look at historical facts and draw parallels to what happened in US subprime crisis of 2007, Swedish banks could face similar liquidity problems as in the US mortgage crisis. Additionally, banks would have a mortgage portfolio with significantly higher LTV ratios, which as we have pointed out would add credit risk to the portfolio. Marginal costs to maintain a good credit quality in cover assets would increase as well. The cost of having shortages of liquidity led to new Basel regulations with three pillars denoting the three largest risks, liquidity and capital requirements representing the first pillar. Even the presumption of lack of liquidity can cause panic among bank costumers which may lead to bank runs, i.e. costumers withdrawing their money. Bank runs lead to dry ups in liquidity and may cause heavy losses, and in very severe cases, a total bank collapse (c.f. Lehman Brothers, Bear Sterns, Merrill Lynch). Banks use liquidity buffers in order to counter a liquidity squeeze e.g. a bank run. 20% of banks liquidity consists of covered bonds, thus, it is crucial for a bank to have an attractive credit rating on the covered bonds. A drop in house prices could begin to strain the liquidity buffer and create significant liquidity risk.

Our result show that in a worst case scenario, the total withdrawal of funding would mount to SEK 446bn. It would reduce the total current cover pool with 16%. OC would decrease from 42% to 19% on average. This would lead to the cover bond funding having to be reduced to stay at the current OC and risk profile. Additionally, the cover pool quality would decrease as more loans are shifted towards higher LTV levels. Nordea has to withdraw over 20% of its initial cover pool, followed by SEB

(18%) and Länsförsäkringar (17,8%). Our credit spread model takes the risk profile into account and make calculations how much extra withdrawals in the cover pool that have to be done in order to restore the original risk profile. This would mean an additional reducement from the cover bonds and replace it with more expensive funding sources. This could lead to a credit squeeze on the mortgage market which would lead to higher mortgage rates, intensifying the price fall. In this model, Nordea, Länsförsäkringar and SBAB suffer the largest risks. S&P don't take the LTV distributions into account as much as our model but instead demand higher OC. The model would lead to every bank except Swedbank and SEB having to inject capital to keep their AAA rating. Handelsbanken would have to put in SEK 182.7bn. The bank has however SEK 300bn of mortgages in reserve but the question is what LTV those loans will have after a 35% MVD. All in all, in a stressed scenario with severe downfall in house prices and possible credit losses, the covered bond regulations would make the bank or institute collapse before the bond itself.

8 References

References

[1] Association of Swedish Covered Bond Issuers. (2017), *ASCB*

[2] Black, F. & Scholes, M. (1973), *The pricing of options and corporate liabilities*

[3] Cox, JC., Ross, SA. & Rubinstein, M. (1979), *Option pricing: A simplified approach*, Journal of Financial Economics

[4] Drees, B., and Pazarbasioglu, C. (1998), *The Nordic Banking Crisis: Pitfalls in Financial Liberalization. Washington DC*

[5] Fannie Mae. (2017), *Expanded 97% LTV Options*

[6] Finansinspektionen. (2010), *Den svenska bolånemarknaden och bankernas kreditgivning*

[7] Finansinspektionen. (2015), *SNS: Bostadsmarknaden och hushållens skuldsättning*

[8] Finansinspektionen. (2016), *Regulations amending Finansinspektionen's regulations and general guidelines (FFFS 2013:1) regarding covered bonds*, FFFS 2016:17

[9] Gorton, G. (2009), *Slapped in the face by the invisible hand: Banking and the panic of 2007, Federal Reserve Bank of Atlanta's 2009 Financial Markets Conference: Financial Innovation and Crisis*

[10] Li, M. (2014), *Residential Mortgage Probability of Default, Models and Methods*

[11] Merton, R. (1973), *On the pricing of corporate debt: The risk structure of interest rates*

[12] Riksbanken. (2011), *Riksbankens utredning om risker på den svenska bostadsmarknaden*

[13] Riksbanken. (2013), *The Swedish covered bond market and links to financial stability*

[14] Riksbanken. (2016), *The major Swedish banks' structural liquidity risks*

[15] Schiller, R. (2008), *The Subprime Solution: How Today's Global Financial Crisis Happened, and What to Do about It, Princeton University Press*

[16] Souissi, M. (2007), *An Option Pricing Approach to Stress-testing the Canadian Mortgage Portfolio*

[17] S&P Global. (2006), *Covered Bonds: Criteria For Rating Swedish Covered Bonds*

[18] S&P Global. (2015a), *Ratings On Swedish Covered Bonds Could Withstand Moderate House Price Declines*

[19] S&P Global. (2015b), *2015 Annual Global Corporate Default Study and Rating Transitions*

[20] S&P Global. (2016), *General: Methodology And Assumptions: Assessing Pools Of European Residential Loans*

9 Appendix

9.1 Appendix A

In this section we show the LTV-distributions for different market value declines (MVD) for all banks. The bottom row shows the percental decline in respective cover pools.

Table 13: Swedbank LTV distribution (in %)

	Market value decline						
LTV brackets	0%	10%	20%	25%	30%	35%	40%
0-10%	2.3	0	0	0	0	0	0
11-20%	6.0	2.3	2.4	2.5	2.5	2.6	2.7
21-30%	10.2	6.1	6.2	6.4	6.6	0	0
31-40%	16.0	10.3	10.6	10.9	0	6.8	7.1
41-50%	21.5	16.9	16.6	0	11.2	11.5	12.1
51-60%	21.6	21.7	0	17.0	17.5	0	0
61-70%	16.8	21.9	22.2	22.9	0	18.1	19.0
71-75%	5.6	21.5	42.0	40.4	62.3	61.0	59.0
Value decline in cover pool	0	-1.2%	-3.5%	-6.1%	-8.6%	-11.7%	-15.8%

Table 14: Länsförsäkringar LTV distribution (in %)

	Market value decline						
LTV brackets	0%	10%	20%	25%	30%	35%	40%
0-10%	2.0	0	0	0	0	0	0
11-20%	4.0	2.0	2.1	2.2	2.3	2.4	2.6
21-30%	6.0	4.1	4.3	4.5	4.6	0	0
31-40%	12.0	6.1	6.4	6.7	0	4.8	5.1
41-50%	15.0	12.3	12.8	0	6.9	7.2	7.7
51-60%	18.0	15.3	0	13.3	13.9	0	0
61-70%	35.0	18.4	16.1	16.7	0	14.5	15.3
71-75%	8.0	41.2	58.3	56.7	72.3	71.0	69.4
Value decline in cover pool	0	-2.1%	-6.6%	-10.0%	-13.4%	-17.2%	-21.7%

Table 15: Nordea* LTV distribution (in %)

	Market value decline						
LTV brackets	0%	10%	20%	25%	30%	35%	40%
0-10%	2.0	0	0	0	0	0	0
11-20%	4.0	2.1	2.2	2.3	2.4	2.5	2.7
21-30%	6.0	4.1	4.4	4.6	4.8	0	0
31-40%	8.0	6.2	6.6	6.9	0	5.0	5.3
41-50%	10.0	8.3	8.8	0	7.2	7.6	8.0
51-60%	18.0	10.4	0	9.2	9.6	0	0
61-70%	28.0	18.6	11.0	11.5	0	10.0	10.7
71-75%	24.0	50.3	67.1	65.7	76.1	74.8	73.3
Value decline in cover pool	0	-3,4%	-8,8%	-12,6%	-16,5%	-20,1%	-25,1%

*Nordea don't publish distributions in LTV brackets 10-40%. Thus, we have used Swedbanks distribution to calculate brackets 10-40%.

Table 16: SBAB LTV distribution (in %)

	Market value decline						
LTV brackets	0%	10%	20%	25%	30%	35%	40%
0-10%	2.0	0	0	0	0	0	0
11-20%	6.0	2.0	2.1	2.2	2.3	2.4	2.5
21-30%	6.0	6.1	6.4	6.6	6.8	0	0
31-40%	12.0	6.1	6.4	6.6	0	7.1	7.5
41-50%	20.0	12.2	12.7	0	6.8	7.1	7.5
51-60%	18.0	20.4	0	13.1	13.6	0	0
61-70%	28.0	18.3	21.2	21.9	0	14.1	14.9
71-75%	8	34.83	51.3	49.7	70.6	69.4	67.6
Value decline in cover pool	0	-1.8%	-5.6%	-8.6%	-11.7%	-15.2%	-19.7%

Table 17: Handelsbanken LTV distribution (in %)

	Market value decline						
LTV brackets	0%	10%	20%	25%	30%	35%	40%
0-10%	4.0	0	0	0	0	0	0
11-20%	8.0	4.1	4.2	4.3	4.5	4.6	4.8
21-30%	9.0	8.1	8.4	8.7	8.9	0	0
31-40%	16.0	9.2	9.5	9.7	0	9.2	9.7
41-50%	15.0	16.3	16.8	0	10.0	10.4	10.9
51-60%	18.0	15.3	0	17.3	17.8	0	0
61-70%	21.0	18.3	15.8	16.2	0	18.5	19.3
71-75%	9.0	28.9	45.4	43.8	58.8	57.3	55.4
Value decline in cover pool	0	-1.7%	-4.8%	-7.5%	-10.2%	-13.3%	-17.1%

Table 18: SEB LTV distribution (in %)

	Market value decline						
LTV brackets	0%	10%	20%	25%	30%	35%	40%
0-10%	4.0	0	0	0	0	0	0
11-20%	8.0	2.1	2.2	2.2	2.3	2.4	2.6
21-30%	9.0	4.1	4.3	4.5	4.7	0	0
31-40%	16.0	9.2	9.7	10.1	0	4.87	5.2
41-50%	15.0	8.2	8.6	0	10.5	11.0	11.6
51-60%	18.0	15.4	0	9.0	9.3	0	0
61-70%	21.0	18.5	16.2	16.8	0	9.7	10.3
71-75%	9.0	42.5	59.1	57.5	73.2	72.0	70.4
Value decline in cover pool	0	-2.6%	-7.2%	-10.6%	-14.1%	-17.9%	-22.4%

9.2 Appendix B

Appendix B shows the input variables used for the credit rating model. We use a base foreclosure frequency of 12% and calibrate it against geographic concentration, loan type (interest only or amortization) and LTV levels (Table 19). Table 20 shows a base case without any debt removal.

Table 19: Input variables for credit rating

	Input Variables				
Bank	FF(%)	MVD(%)	IR(%)	Li Exp(%)	Months
SWB	14.2	35	14	6	18
LFB	19.2	35	14	6	18
NDA	15.4	35	14	6	18
SBAB	16.6	35	14	6	18
SHB	15.8	35	14	6	18
SEB	15.5	35	14	6	18
Mean	15.5	35	14	6	18

Table 20: Target OC without removing debt from cover pool

	Market value decline (%)				
Bank	Current	10	20	30	40
SWB	14.8	18.7	19.6	28.4	35.5
LFB	27.9	33.4	35.6	45.7	54.2
NDA	26.0	30.4	32.4	38.9	44.5
SBAB	21.5	26.3	27.6	37.7	44.8
SHB	19.2	21.9	23.3	30.9	38.3
SEB	23.1	27.5	29.0	36.8	42.7
Mean	21.9	26.3	27.9	36.4	43.3

9.3 Appendix C

The Merton model assumptions:

- trading in assets have no effect on prices and takes place in continuous time
- there is no transaction costs, taxes or problem with indivisibility of assets
- short selling in asset is possible
- borrowing and lending can be done at the risk-free interest rate
- and the dynamics of the firm or asset value can be described by a diffusion stochastic process with stochastic differential equation

$$dV = (\alpha V - C)dt + \sigma V dz$$

where α is the instantaneous expected rate of return on the firm per unit time, C is the total payout (e.g. dividends), σ^2 is the variance of the return of the firm or asset and dz is a standard Gauss-Wiener process.

Assumption 1 and 5 are here of critical importance, while 2-4 have earlier been shown to be substantially weakened.
Calibration results and parameters:

Table 21: Calibration of sigma on market prices of covered bonds with maturity of aprox. 3y for all issuers

	Model parameters					
Issuer	C	LTV (%)	Rf (%)	T	sigma (%)	yield (%)
SSO AB	1	54.4	0.4	3.1y	18.5	0.02
LF Hypotek AB	3.25	56.4	0.45	3.3y	17.9	0.10
Nordea Hypotek	3.25	59.4	0.4	3.1y	16.5	0.02
SEB	1.5	56.8	0.4	3.1y	20.2	0.02
Stadshypotek AB	4.25	50.9	0.4	3.1y	19.6	0.02
Swedbank Hypotek	1	50.5	0.48	3.6y	19.9	0.15