Operationalization of Risk Appetite - balance sheet projections of banks

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Abstract

The financial crisis in 2008 enlightened several shortcomings in the performance of the banking sector. As a result of this a more rigid regulatory framework, Basel III, has been developed which raises the requirements of banks' capital and liquidity structure and internal capital adequacy processes. This involves evaluating potential future risks related to the strategy and risk appetite of a bank. Therefore it is crucial that a bank has an understanding of how their business plan would affect the balance sheet under different economic scenarios.

The goal of this study is therefore to demonstrate how this can be implemented by using quantitative projection methods, incorporating important risk factors such as yield curves, credit spreads and default probabilities. The projections involve the development of a deterministic mathematical model, based on credit migrations, under which business plans can be tested and evaluated under scenarios based on historical downturns such as the recent financial crisis.

The evaluation is done by incorporating four key risk metrics into the model followed by a study of the results from the risk metrics using balance sheet data from an American bank. These risk metrics are considered under three different scenarios and four proposed business plans. Risk appetite targets and limits are defined where a breach serves as an indication to the bank that the business plan should be revised.

The results show potential risks involved in the different business plans and supports a modest growth of the current balance sheet and a sound balance between trading and lending activities in order to stay within limits under severe scenarios. The conclusion is that the model can serve as a base for setting a risk appetite framework at a bank, but in order to validate key assumptions and robustness of the results a more thorough investigation with access to bank data is needed.

Preface

This thesis began as a suggestion from the Quantitative Advisory Services (QAS) at EY in Copenhagen. The idea was to work with regulatory requirements in Basel III and more specifically to develop a capital planning tool which operationalized risk appetite for banks. This sounded like an interesting topic with respect to the the current financial climate and with the financial crisis still in mind. During my work at EY I have received great support and I would especially want to thank Richard Hunter for insightful comments and knowledgeable help. Also, I would like to thank Jim Gustafsson for supporting me extensively throughout the process. I would also like to thank Johanna Carlsson, Anna Silén and Karin Gambe for helping with additional input and comments.

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1 Introduction

1.1 Background

The fundamental purpose of a bank is the provision of long term financing to the real economy. This is done through borrowing from customers in the form of deposit taking or from wholesale markets and transforming this short term debt into long term debt by lending to businesses and individuals. By standing in the middle of these transactions the bank takes on credit risk, and by transforming the duration of debt it takes on liquidity risk. In order to balance the level of these risks against the risk capacity of the business it is vital that the bank understands how they will evolve over time and in different economic scenarios and how this evolution can be affected by the business plan.

The evaluation of the recent financial crisis in 2008 showed some critical shortages in the behavior of the banking sector. One main reason for the crisis was that banks in many countries had built up excessive on- and off-balance sheet leverage. Combined with a weaker capital base and insufficient liquidity buffers, the banking sector was unable to take care of larger exposures of the off-balance sheet and the systemic trading and credit losses that occurred when the crisis was at hand. This led to a degeneration in the market's trust of the banks and in the end this was transmitted to the whole economy. Due to this turn of events, a new and stricter framework for regulating risks taken by banking institutions was developed in the form of Basel III[1].

The lack of stability in the banking world during the crisis showed the importance of assessing that enough capital is covering the risks of banks. With an uncertain future where many scenarios could potentially undermine the capital base of a bank, it is crucial to have a process in place that captures these issues. This can be done by incorporating business plans into scenario building and stress testing through projections of a bank's balance sheet[2]. It is an important part of Basel III and is specified under Pillar II.

The model developed is deterministic and is based on credit migrations and discounting principles. Through constructing a mathematical model based on credit migrations and through implementing this in a tool where a bank can project its assets and liabilities, this thesis provides a risk appetite framework under which a bank can evaluate and quantify the future risks of its current business plan.

1.2 Aim of thesis

The goal of this thesis is to demonstrate how quantitative projection methods can be used to challenge a bank's business plans and ensure that the risk taking activities of the bank do not exceed its risk capacity. The projection methodology will be to consider asset and liability allocations, incorporating both business plans and the effect of key risk drivers. By considering a number of scenarios, reflected in the projection through stressed risk drivers, we see how risk appetite limits can be used to limit or promote risk taking activities in order to ensure the continuing financial strength of the bank and the fulfillment of the sharpened requirements in Basel III.

Key metrics are defined to be used in a risk appetite framework and both tolerances and limits for these metrics are defined. These metrics are projected quarterly over a five year time horizon based on balance sheet and required capital projections across a number of extreme but plausible scenarios. If the limits are breached in any of these scenarios then the risk appetite is considered to be breached and the business plan should be revised to avoid excessive risk in the company. A number of alternate business strategies are investigated, such as an aggressive growth agenda and a focus on trading assets on the balance sheet and show that the performance of the risk metrics shows a clear differentiation between the impacts of the strategies on the financial strength of the company in adverse scenarios.

1.3 Outline

The thesis is structured as follows. Section 2 describes the background and focus of Basel III and the definition and idea behind risk appetite and how it can be operationalized. Section 3 describes some of the most important risks under Basel III. Section 4 describes the structure of a bank's balance sheet. Section 5 describes how the projections of the balance sheet are done with explanations of chosen risk metrics and risk factors. Section 6 describes different business plans and under which scenarios those are tested. Section 7 shows the results. Section 8 concludes. Section 9 discusses further improvements. An overview of the different parts and how they are connected can be seen in figure 1.

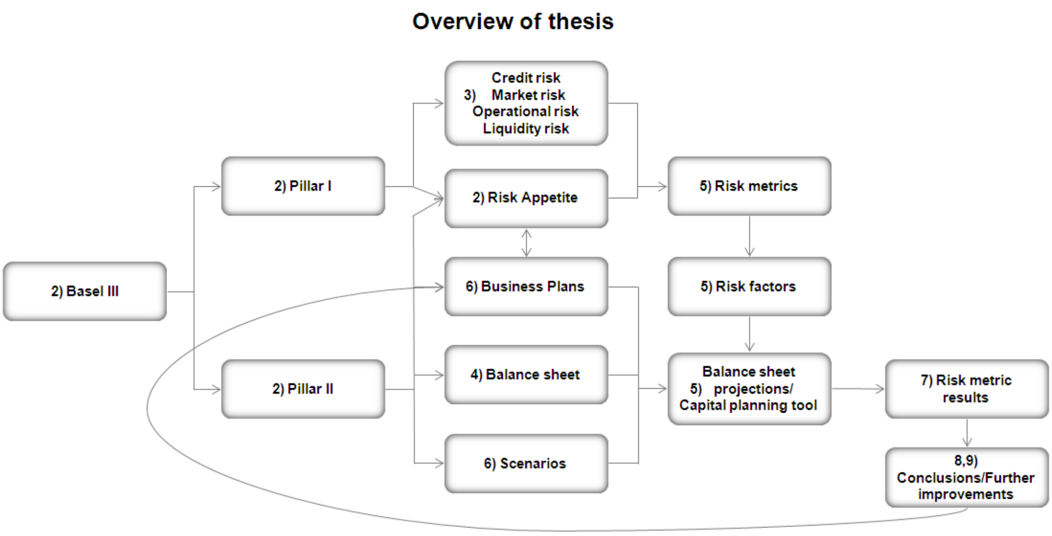


Figure 1: *Overview of the different parts of the thesis.*

2 Basel III

2.1 Basel Accords - History

The first Basel accord was created in 1988 by the Basel Committee of Banking Supervision, a committee established by the Central Bank Governors of the Group of Ten (G-10) in 1974. With this an important step towards an international minimum capital standard for banks was taken. However, it can be concluded that many of the approaches in Basel I were far too coarse and failed to measure and aggregate risk sufficiently. It also failed in treating the risk of derivatives, at that time a relatively new set of instruments that had quickly gained popularity. The focus in the first accord was on credit risk.

A second framework, Basel II, was introduced in 2004, again with focus on credit risk. This time banks were allowed to choose between internally developed approaches and certain defined standard methods to measuring risk. The three-Pillar concept was introduced, with Pillar 1 subject to the calculation of a minimum capital charge. The capital charge was calculated for credit risk, market risk and operational risk. Pillar 2 was introduced as the supervisory review process, which enhanced the importance of governance of the banks' internal assessments to their overall risk. In other words, that sound management methods were in place and that enough capital (described in Pillar 1) was allocated to the different risks. Pillar 3 was subject to public disclosure of risk measures with greater insight to the risk management of banks, in order to improve market discipline.

During and after the financial crisis in 2008 several shortcomings of Basel II were revealed which led to the development of a third accord, Basel III. Much of the framework of Basel II is the base of Basel III, with some important differences[10]. The structure of Basel III will be described further ahead. An overview of the regulatory framework can be seen in figure 2.

2.2 Pillar 1 - Capital requirements under Basel III

One of the key lessons learned from the financial crisis was that many banks had insufficient amounts of high quality capital. It was also revealed that the definition of capital was different across jurisdictions, making it hard to supervise if capital standards of the previous regulation framework, Basel II, were to be appropriately met. In order to deal with these shortcomings Basel III was introduced. The definition and views of the regulatory capital is, as in Basel II, addressed in Pillar 1.

Regulatory capital is defined as the minimum requirement of capital that

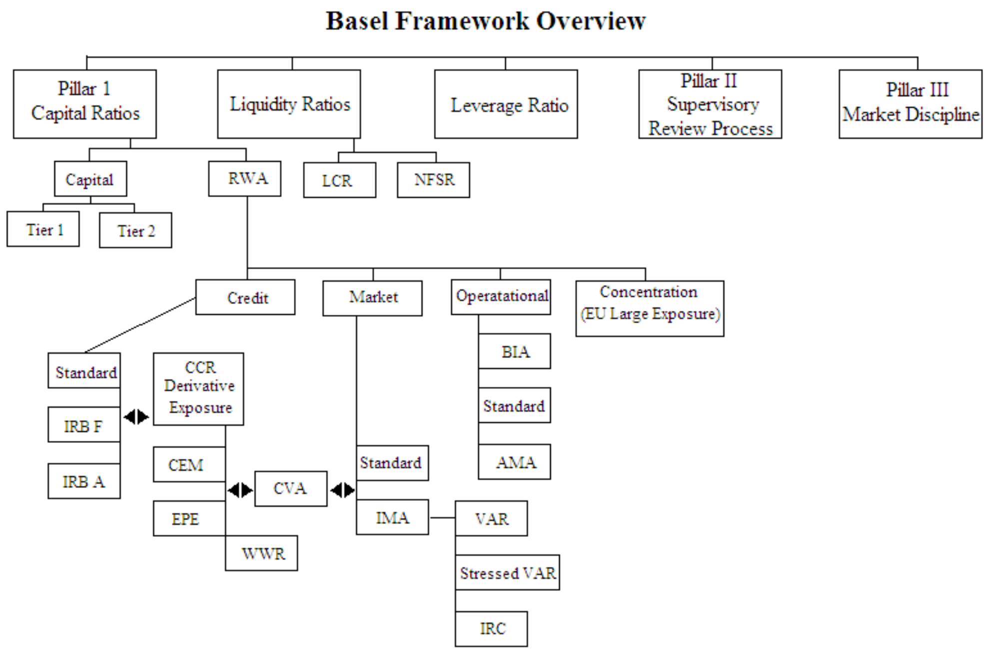


Figure 2: *Overview of the Basel regulatory framework[6].*

a bank must hold to meet the demands for a sound risk assessment, set out by the Basel Committee. In order to control whether banks have enough capital, clear definitions of what can be counted as regulatory capital must be made. The regulatory capital base of a bank is divided into two tiers, Tier 1 and Tier 2. Tier 1 is divided into Common Equity Tier 1 (CET 1) and Additional Tier 1. Common Equity Tier 1 mainly contains Shareholders' Equity, which is share capital (shares issued by the bank) and retained earnings[1]. Additional Tier 1 is mainly subordinated debt. Tier 2 capital is going-concern capital that is not incorporated into Tier 1. The precise definition of capital in Basel is rather complex and follow certain accounting standards.

Before defining what capital requirements the different Tiers will have to meet, an important concept, Risk-Weighted Assets (RWA's), is introduced. RWA is a way of weighting the different assets of a bank, where the weights reflect how risky the assets are (the creditworthiness of the counterparty, e.g. a government bond with high rating will give a low weight). The sum of the notional exposures[1] of the assets multiplied by the weighting coefficients gives the RWA.

[1]Exposure is the maximum amount that will be lost if the counterparty defaults, i.e. is unable to fulfill agreements, for example is unable to pay back a loan.

Common Equity Tier 1 is subject to the Common Equity Tier 1 Capital Ratio, and has to be a minimum of 4.5 % of the Risk-Weighted Assets by January 2015. The earlier minimum requirement in Basel II, 2 %, is replaced through a phase-in process by a requirement of 3.5% starting from January 2013. A threshold of 4% is introduced by January 2014. The Total Tier 1 Capital Ratio (Common Equity plus Additional Tier 1) will be, following phase-in requirements in the same manner, ending in a requirement of 6% by January 2015. Finally, the Total Capital Ratio (Tier 1+Tier 2) should be a minimum of 8 % of the Risk-Weighted Assets at all times, which is the same requirement as in both Basel I and II (see figure 3). In addition some assets will be given higher weights than in Basel II, which will increase the capital requirements.

Annex 1

Calibration of the capital framework

Calibration of the Capital Framework
Capital requirements and buffers (all numbers in percent)

	Common Equity Tier 1	Tier 1 Capital	Total Capital
Minimum	4.5	6.0	8.0
Conservation buffer	2.5		
Minimum plus conservation buffer	7.0	8.5	10.5
Countercyclical buffer range*	0 – 2.5		

Figure 3: *Capital requirements in Basel III[1].*

Certain changes to what can be considered as Common Equity Tier 1 are also introduced in Basel III, which also increase the capital requirements and the demand of high quality capital. Additionally, a capital conservation buffer is introduced, with a role of helping banks to absorb losses during periods of severe stress. This buffer should be built up during good times to prepare banks for recessions and stressful periods. This can for example be done by allocating a part of the retained earnings to the buffer or reducing the dividends pay-out at the end of the year. The minimum amount is 2.5% of RWA's and should be met exclusively with CET 1 capital, which means that a total requirement of 7 % of CET 1 will be active in 2019. Starting from 2015 this will be phased into the minimum requirements. Banks that don't meet these requirements will face restrictions on the usage of the retained earnings during the following year.

A countercyclical capital buffer is also introduced to capture certain macroeconomic factors that affect banks on a national level, i.e. it will *"reflect the geographic composition of its portfolio of credit exposures"*[1]. The buffer will vary between 0-2.5% of CET 1 and is in effect an extension to the capital conservation buffer.

2.3 Supervisory requirements under Basel III (Pillar 2)

The second Pillar under Basel III gives guidelines on how banks should operate in order to deal with the capital constraints in Basel III. There are four main principles involved in this[8]:

- Banks should have a process in place that assesses their overall capital adequacy with respect to their risk profile and a strategy for maintaining their capital levels.
- Supervisors should review banks' internal capital adequacy assessments and strategies, as well as their capability to monitor their regulatory capital ratios. If the results of the process do not meet relevant standards, necessary actions should be taken by supervisors.
- Supervisors should expect banks to keep levels above minimum regulatory capital ratios and be able to demand that banks hold capital above minimum levels.
- Supervisors should at an early stage consider actions necessary to prevent capital from falling below minimum levels required to support a particular bank's risk profile. If capital is not regained or maintained, supervisors should require rapid countermeasures by the bank.

These principles are closely linked to operationalization of risk appetite. Section 721 in Basel II[8] reads:

"The supervisory review process recognises the responsibility of bank management in developing an internal capital assessment process and setting capital targets that are commensurate with the bank's risk profile and control environment. In the Framework, bank management continues to bear responsibility for ensuring that the bank has adequate capital to support its risks beyond the core minimum requirements."

How the methodology for this looks like is to a large extent up to the bank, even though some minimum regulations are set. The process is often referred to as ICAAP (Internal Capital Adequacy Assessment Process) and the bank should have methods for calculating their credit risk, market risk, operational risk, interest rate risk and liquidity risk. Basel emphasizes that the ratios set out in Pillar 1 are minimum requirements, and that banks should strive for higher ratios in order to have a buffer against future crises. It also states that the complexity of the models used under a bank's ICAAP should reflect the size and risk acceptance of the bank. There are a variety of suggestions on how to deal with this in Basel III, ranging from crude estimates of the risk types to some quite advanced models. The bank should be able to monitor the level and trend of these risks and their effect on capital levels, as well as evaluating continuously if key underlying assumptions are correct. It also states that banks should be able to assess future capital requirements based on it's risk appetite and be able to see if strategic changes are needed in order to be in line with the required and desired risk[8].

Stress testing is an important tool in risk management and is used by banks as part of ICAAP. Stress testing is a way of testing how the bank behaves under extreme but plausible scenarios and evaluating if it has enough capital to cover those events. It should provide indications on how much capital is needed to absorb losses during recessions. While stress testing for market and interest rate risk has been done for several years, the credit risk involved in the banking book (assets intended to be held to maturity) has more recently come into focus.

Stress testing can differ a lot depending on the complexity and structure of the bank and the models used vary a lot. It can be done by constructing a tool that projects plausible future scenarios that are of interest to the bank, using data and statistical modeling. It addresses unexpected outcomes and relates these to the various risks. It should be an integrated part of the risk management structure of a bank and link to risk appetite in a clear way[11].

2.4 Risk Appetite

Risk Appetite, which is the level of desired risk for a firm, is very important to address for a bank. The weighting of risk versus return is one of the core questions to identify for a company. For banks this is an issue that has gathered a lot of attention over recent years, when the financial crisis showed huge deficiencies in several banks' ways of treating risk. The IIF(Institute of International Finance) defines risk appetite as:

"Risk appetite is the amount and type of risk that a company is able and willing to accept in pursuit of its business objectives."[4]

Risk appetite is not the same as risk capacity, although risk capacity serves as a regulation on how much risk a bank can or wants to take on. In other words, it serves as an upper boundary of the measure of risk appetite. Risk capacity is the amount of risk that a bank can bear given certain regulatory capital constraints (Basel III), liquidity and borrowing capacity. Essentially the bank has to determine which buffer it should hold, i.e. the difference between risk capacity and risk appetite.

The hard part is not to state which level of risk that is desired for the bank; it is how to link it to the business plan in an adequate way and to assess and incorporate it in a consistent way throughout an organization. The views need to be accounted for at a strategic, tactical and operational level. At the operational level, this includes answering the question: How should risk appetite be measured? This is a question that is often related to the specific business, since so called KRI's (Key Risk Indicators) are different across different companies. For a bank, a Key Risk Indicator could for example be the capital ratios that are defined in Basel, which could in case of a breach warn a bank that insufficient amounts of capital are held. Identifying KRI's involves a process of analyzing where in the organization certain risks are an issue, which often depends on the skills and goals of the different business lines. It also includes identifying which underlying risk factors or risk drivers contribute to the different areas of a bank. As stated earlier this is a part of a process called ICAAP, which is a procedure that includes identifying, measuring and aggregating risks across an institution, as well as following regulatory standards set by Basel III and having a risk management system that are meeting certain standards (also Basel, Pillar II)[7]. A part of this management system for banks includes handling assets and liabilities on the balance sheet, and projections (forecasts) of the balance sheet, with measures of risk incorporated, as a way of analyzing which future risks could arise from the current allocation of assets and liabilities, i.e. a way to operationalize risk appetite.

Risk appetite is a quantitative statement, and therefore it is important to define certain risk metrics that measures risk appetite in a good way. When considering which risk metrics to use, one should:

- Define at least one core metric that is covering all relevant risk types and business units
- Define metrics that are measurable and quantifiable
- Define metrics that provide the right measures, i.e. could be expressed as targets

The optimal risk profile is often expressed as the risk target. The so called risk limits are upper and lower bounds around the risk target, which is defined in such a way that a breach of the limits serves as a warning to the bank that some actions should be considered. The most risky approach of an upper bound is the regulatory requirements in Basel[7]. Risk limits are a way of defining what risk tolerance the bank has. Common risk metrics are Return on Equity and Value-at-Risk.

Another key issue is how the business plans and the risk monitoring processes are operationalized. This is a fundamental part of the risk appetite framework - risk appetite loses its value if it isn't connected to a robust and ongoing monitoring process where it is evaluated through appropriate measures and then is followed up if it breaches the risk appetite limits of the firm.

3 Relevant risks under Basel III

Basel III defines which different types of risk are critical to deal with and how the risk quantification processes should be approached. The framework is described in the sections below.

3.1 Credit risk under Basel III

Credit risk is the oldest risk type to be dealt with in terms of regulatory requirements for banks. It was the core risk type of Basel I and has continued to be so in the following versions. Credit risk is the risk of loss caused by a borrower or counterparty's failure to repay or meet a contractual obligation. When this is happening, it is said that the counterparty is defaulting on it's loan or contract. It can also be stated as the risk of a change in portfolio value due to changes in the creditworthiness or credit quality of one or several counterparties. The biggest difference between Basel II and III regarding credit risk is the CCR derivative exposure (counterparty credit risk derivative exposure) which adds a capital charge for default risks related to derivatives, e.g. CVA (credit valuation adjustment) which compensates for the cost of potential mark-to-market losses in credit quality migrations of counterparties. Another change is higher capital requirements for securitization products, which can be for example mortgage-backed securities or asset-backed securities.

The Basel Committee let banks choose between two methodologies for calculating capital requirements for credit risk. They are the standardized approach and the internal ratings-based approach.

The standardised approach divides assets into "risk weight buckets", reflecting the risks of the assets. How to allocate the assets to the different buckets is determined by some external rating, for example S&P or Moody's credit rating systems. In the cases where an external rating isn't available, the bank should estimate the risk-weight of the counterparty in question. The summation of exposures multiplied by risk weights then gives the RWA's that are used in calculating the capital requirements for credit risk.

The internal ratings-based approach (IRB) is the second approach and it is divided into F-IRB (foundation) and A-IRB (advanced). Under the foundation-based approach banks use own estimates of Probability of Default (PD), but use regulated values for Loss Given Default (LGD), determined by the Basel Committee. The advanced approach can be used by banks that derive their own Probability of Default (PD), Exposure At Default (EAD) and Loss Given Default (LGD) estimates of the assets in the portfolio. Sometimes also an effective maturity (M) needs to be determined. If the Probability of

Default is lower than 0.03%, the bank has to use 0.03% as the PD number. These estimates are then used as inputs to formulas specified in Basel to determine the credit risk capital charge. Depending on which asset class, like corporate, sovereign or banks, different formulas are applied. One example is

$$\begin{cases} \mathrm{R} = 0.12 \cdot \left(\frac{1-e^{-50 \cdot PD}}{1-e^{-50}}\right) + 0.24 \cdot \left(1 - \frac{1-e^{-50 \cdot PD}}{1-e^{-50}}\right) \\ \mathrm{b} = (0.11852 - 0.05478 \cdot \ln(\mathrm{PD}))^2 \\ \mathrm{K} = \left(\mathrm{LGD} \cdot \Phi\left((1-\mathrm{R})^{-0.5} \cdot \Phi^{-1}(\mathrm{PD}) + \left(\frac{\mathrm{R}}{1-\mathrm{R}}\right)^{0.5} \cdot \Phi^{-1}(0.999)\right) - \mathrm{PD} \cdot \mathrm{LGD}\right) \\ \cdot(1 - 1.5 \cdot \mathrm{b})^{-1} \cdot (1 + (\mathrm{M} - 2.5) \cdot \mathrm{b}) \\ \mathrm{RWA} = \mathrm{K} \cdot 12.5 \cdot \mathrm{EAD} \end{cases}$$

where the outputs are:

$$\begin{cases} \text{R - asset correlation,} \\ \text{b - maturity adjustment, in years} \\ \text{K - capital requirement} \\ \text{RWA - risk-weighted assets} \end{cases}$$

The origin of these formulas will not be explained in detail in this thesis, but they are based on an asymptotic single risk factor model, derived from a Merton/Vasicek model. Summing the results from the calculations for the different assets gives the total credit risk capital charge. The credit risk charge is applied to the banking book, i.e. for assets that are intended to be held to maturity. It is reflecting the risk of holding a portfolio for one year and at a 99.9 % confidence level.

3.2 Market risk under Basel III

The definition of market risk is "the risk of losses in on- and off-balance-sheet risk positions arising from movements in market prices"[9]. While the first Basel accord had a clear focus on credit risk, it was obvious to the Basel Committee that market risk had to be captured more thoroughly. Therefore, in 1996 in the so called Amendment to Basel I, two different methods for market risk capital charge calculation were introduced. The first one was a formula-based standardized model, and the second was referred to as an internal model (i.e. a model developed by the bank itself). The basis for measuring market risk in Basel is Value-at-Risk, a measure developed by JPMorgan in 1993. Value-at-Risk will be described in more detail later. There were not many changes in the Basel II framework compared to the Amendment.

At the time of the Amendment, most banks' trading books consisted of quite simple instruments that could be traded in liquid markets. Since then a rapid increase of more complex instruments with a larger degree of credit risk exposure has been seen and created many questions around the feasibility of the treatment of market risk in Basel. To deal with these shortcomings, an additional capital charge intended to capture default risk was introduced in the so called Basel 2.5, called IRC (Incremental Risk Charge). Also, a stressed VaR component was added to capture the risk under stress scenarios. The Basel Committee also advises banks to opt for using expected shortfall instead of Value-at-Risk[9].

By definition in Basel, the market risk capital charge is applied only to the trading portfolio. The trading portfolio consists of instruments that are intended to be traded or are used to hedge other assets that are trade intended.

Before describing the standardized and the internal methods, an introduction to Value-at-Risk follows below.

3.2.1 Value-at-Risk

Value-at-Risk has been used in a frequent manner in risk management ever since it was introduced in 1993. Since it plays a central part in the Basel accords, it needs to be explained in more detail.

Let's say it is of interest to study the potential losses of a portfolio of risky assets, and that a loss is denoted by L. The probability function for the loss, which can be denoted by $F_L(l) = P(L \leq l)$, is constructed for a predetermined time period. The Value-at-Risk of the portfolio is then, at confidence level $\alpha \in (0, 1)$, the smallest value l so that the probability of the loss L exceeding l is no larger than $(1 - \alpha)$. This can be expressed as

$$VaR_\alpha = inf\{l \in \mathbb{R} : P(L > l) \leq 1 - \alpha\} = inf\{l \in \mathbb{R} : F_L(l) \geq \alpha\}. \quad (1)$$

This can in words be expressed as "the maximum loss which is not exceeded with a given high probability"[10]. One serious drawback of this is that VaR doesn't say anything about the size of the losses beyond this threshold. It only states the probability of exceeding it. Another core point of Value-at-Risk is the question of coherency. VaR violates one of the properties that is required in order to be defined as a coherent risk measure. The property is the subadditivity principle, which says that if two portfolios are added, with $L = L_1 + L_2$, the Value-at-Risk for the new portfolio should be less than or equal to the sum of the VaR for the two old portfolios calculated separately, i.e. $VaR_{\alpha,L} \leq VaR_{\alpha,L_1} + VaR_{\alpha,L_2}$. The violation of this property creates a contradiction in terms of the diversification benefits when adding two portfolios.

3.2.2 Standardized method and internal model

Depending on the quality of the model used to quantify risks of the trading desk, a bank may or may not use an internal model. It is the supervisory authorities of the bank that make this decision. If the authorities judge that the model used by the bank doesn't assess and quantify the risks in a granular way, it will require the bank to use the standardized model. The four minimum requirements can be expressed as:

- A sound and integrated risk management system should be in place
- Sufficient number of skilled staff, not only in trading area but also in other areas of the bank
- A history of accurate risk measurements
- Stress tests are done on a regular basis

Basel states that a standardized model serves two purposes. First, for small banks it can be unnecessary to have a complex business model, and therefore the use of a standardized model is preferred. Second, if the model of a bank fails, the standardized model serves as a backup plan in order to calculate the capital charges.

The standardized model was revised in Basel 2.5 and suggests two different approaches: the partial risk factor approach and the fuller risk factor approach. The partial risk factor approach divides assets with similar risk attributes in the trading book into different buckets and applies a risk weight, that is determined by Basel, to the market value of the asset in question. In the fuller risk factor approach, assets are mapped to certain risk factors specified by the Basel Committee and then calculates the capital charge when risk factor shocks are applied. It requires the bank to use it's own pricing models when setting the market value of a specific instrument[9].

The minimum capital requirement consists of two separate charges, one called "specific risk", which involves risk factors related to the specific issuer of an instrument, and the other "general market risk", which captures market interest rate risk.

The total capital charges account for interest rate related assets and equities, plus FX and commodities risks, and those are independent of whether the asset is held in the trading book or the banking book.

The base for the internal models is Value-at-Risk, and therefore the internal models often are referred to as VaR-models. Before Basel 2.5, the minimum standard for market risk was (evaluated on a daily basis) to derive Value-at-Risk at a 99% one-tailed confidence interval, with a minimum holding period of ten days. The historical time period to sample from should be no less than one year. The market risk (MR) capital charge (RC) for the internal model (IM) is calculated as the higher of its previous day's VaR number and an average of daily VaR for the last 60 days, as

$$RC_{IM}^{t}(MR) = max\left(VaR_{0.99}^{t,10}\, , \frac{k}{60}\sum_{i=1}^{60} VaR_{0.99}^{t-i,10}\right) + C_{SR}, \tag{2}$$

where a multiplication factor, k, with a value between 3 and 4 is used. This factor reflects the quality of the internal VaR model, and is determined by backtesting the current model to see if it previously calculated VaR numbers reflect the loss at the 99th percentile (i.e. in average one exceedance over 100 days). The second term, C_{SR}, aims to capture specific risk. This formula still applies after Basel 2.5, but two additional charges have been developed, namely the stressed VaR component and the IRC component. The sum of the three gives the internal models total capital charge for market risk. The stressed VaR is calculated in the same manner as the regular VaR, but uses stressed market conditions as base for the calibration (the historical time period to sample from)[15].

The third capital charge component, IRC, is added as a way of capturing both default risk and credit migration risk within the trading book. It is calculated on a one-year horizon, with a 99.9% confidence level (consistent with formulas for the credit exposures in the banking book). The reason for adding this charge is mainly due to the fact that the other two charges do not capture liquidity risk in the trading book, which was a phenomenon observed during the financial crisis in 2008.

Under the internal model approach, banks may use whatever method they think is appropriate. The three most common methods are the variance-covariance method, historical simulations and Monte Carlo simulations.

3.3 Operational risk under Basel III

Operational risk was introduced in Basel II and has kept its original design in Basel III. In Basel, operational risk is defined as "the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events"[8]. In this definition legal risk is included but strategic and reputational risk are not. To give a historical example of a large operational loss, one can take the British bank Barings, that went bankrupt in 1995 due to a single trader, Nick Leeson, loosing $1.3Billion on a so called straddle. An overview of operational risk in Basel III can be seen in figure 4.

Operational Risk in Basel III

Event-Type Category (Level 1)	Definition	Categories (Level 2)
Internal fraud	Losses due to acts of a type intended to defraud, misappropriate property or circumvent regulations, the law or company policy, excluding diversity/ discrimination events, which involves at least one internal party	Unauthorised Activity
		Theft and Fraud
External fraud	Losses due to acts of a type intended to defraud, misappropriate property or circumvent the law, by a third party	Theft and Fraud
		Systems Security
Employment Practices and Workplace Safety	Losses arising from acts inconsistent with employment, health or safety laws or agreements, from payment of personal injury claims, or from diversity / discrimination events	Employee Relations
		Safe Environment
		Diversity & Discrimination
Clients, Products & Business Practices	Losses arising from an unintentional or negligent failure to meet a professional obligation to specific clients (including fiduciary and suitability requirements), or from the nature or design of a product.	Suitability, Disclosure & Fiduciary
		Improper Business or Market Practices
		Product Flaws
		Selection, Sponsorship & Exposure
		Advisory Activities
Damage to Physical Assets	Losses arising from loss or damage to physical assets from natural disaster or other events.	Disasters and other events
Business disruption and system failures	Losses arising from disruption of business or system failures	Systems
Execution, Delivery & Process Management	Losses from failed transaction processing or process management, from relations with trade counterparties and vendors	Transaction Capture, Execution & Maintenance
		Monitoring and Reporting
		Customer Intake and Documentation
		Customer / Client Account Management
		Trade Counterparties
		Vendors & Suppliers

Figure 4: *An overview of operational risk in Basel III[8]*

In Basel there are three approaches to measuring operational risk and they are the Basic Indicator Approach (BIA), The Standardized Approach

(TSA) and the Advanced Measurement Approaches (AMA).

3.3.1 The Basic Indicator Approach (BIA)

The Basic Indicator Approach is the most simple way of measuring operational risk in Basel. It requires banks to hold a fixed percentage, α, of the average of the last three years of (positive) annual gross income. Gross income is net interest income plus net non-interest income. Any negative income should be excluded when calculating the average. This creates a problem if a bank has three consecutive years of negative gross income (the denominator is zero), and the supervisors will then consider appropriate supervisory actions. The percentage (α) is decided by the Basel Committee and is equal to 15 %. This method gives a higher capital charge than the other approaches, to create an incentive for banks to move towards more advanced methods. The formula is

$$K_{BIA} = \frac{\sum_{i=1}^{3} \max(GI_i, 0) \cdot \alpha}{n} \tag{3}$$

where

$$\begin{cases} K_{BIA} = \text{the capital charge under the Basic Indicator Approach} \\ GI_i = \text{annual gross income for year i} \\ n = \text{number of previous three years for which gross income is positive} \\ \alpha = 15\% \end{cases}$$

3.3.2 The Standardized Approach (TSA)

Under The Standardized Approach, the bank is divided into eight business lines, which are corporate finance, retail banking, agency services, asset management, trading and sales, commercial banking, payment and settlement and retail brokerage. A capital charge is then calculated for each line individually and then a summation of these is done to get the overall operational capital charge. The method for calculating the individual charge for each line is similar to the Basic Indicator Approach. Different percentages are determined by the Basel Committee for different lines, and they range from 12 to 18 %. If the summation of the charges in one year is negative, it will be taken out of the calculation. The formula is

$$K_{TSA} = \left(\sum_{i=1}^{3} \max \left(\sum_{j=1}^{8} (GI_{i,j} \cdot \beta_j, 0 \right) \right) /3 \tag{4}$$

where

$$\begin{cases} K_{TSA} = \text{the capital charge under The Standardized Approach} \\ GI_{i,j} = \text{annual gross income for year i and business line j} \\ \beta_j = \text{fixed percentage for business line j} \end{cases}$$

3.3.3 The Advanced Measurement Approaches (AMA)

The AMA method involves a development of a bank's internal operational risk measurement system. This means that the bank uses its own model to estimate the operational risk charge. AMA is subject to supervisory approval. There are several requirements, as the use of both internal and external data in the model and the use of scenario analysis. The bank must be able to demonstrate that the model captures potential severe tail loss events. It also has to show that the output plays an integral part in the everyday risk management processes of the bank[8].

3.4 Liquidity risk under Basel III

During the financial crisis, it became clear that liquidity risk was a risk needed to be taken care of in a better way. Liquidity risk is stemming from the fact that banks tend to finance their long term lending by short term borrowing. For example, a bank may use commercial paper with a 30-day maturity from one company to fund a one-year loan to another corporation. When the 30-day commercial paper expires, the bank signs a new agreement in order to continue to fund the loan. The risk involved in this is if the bank starts experiencing financial trouble (or perhaps is just perceived as having it), it will have difficulties to get the needed funds, simply because the counterparty, in light of the worsening economic state of the bank, no longer has a willingness to make a lending agreement. During the crisis, banks could have no problem meeting its capital requirements, but still face issues with liquidity. This was what happened to Lehmann Brothers in the U.S. and Northern Rock in the U.K[28].

In order to deal with the shortcomings of the regulatory requirements in Basel II, two liquidity ratios were introduced in Basel III: the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). These will be tested during a period and they could be modified, depending on the evaluation of the trial period. LCR is planned to be implemented by 2015 and NSFR by 2018.

3.4.1 Liquidity Funding Ratio (LCR)

The main goal with LCR is to test if a bank has the needed assets to survive a 30-day period of severe liquidity dry-ups in the market. The period should involve several stress parameters affecting liquidity: credit rating downgrades by at least three steps, complete loss of wholesale funding, increased haircuts on secured funding and a severe loss of deposits. The ratio is defined as

$$\text{LCR} = \frac{\text{High Quality Liquid Assets}}{\text{Net Cash Outflows in a 30-day Period}} \tag{5}$$

and should be minimum 100 %.

3.4.2 Net Stable Funding Ratio (NSFR)

The Net Stable Funding Ratio is introduced to ensure that the bank has enough stable funding over a one-year period. It is defined as

$$\text{NSFR} = \frac{\text{Amount of Stable Funding}}{\text{Required Amount of Stable Funding}} \tag{6}$$

and should be 100 % minimum. The way of calculating the denominator is to apply weights to each asset, with higher weights for long term assets, assets in the banking book and assets with lower credit quality, and sum the weights multiplied by the exposures for all assets in the bank's portfolio. This will lower the ratio if the bank has less stable or less liquid assets. The way of calculating the numerator is to apply weights to the different liabilities (the funding of the bank) and in the same manner sum the weights multiplied by the corresponding funding amount. Deposits will have a higher weight than for example wholesale funding.

4 Balance sheet structure

This section describes the basics of how a balance sheet of a bank can be viewed and structured.

4.1 The balance sheet of a bank

The balance sheet of a bank can be described as a snap shot of the current financial situation. A typical example of a balance sheet statement is shown in figure 5. It is often divided into assets and liabilities (see figure 6), where the assets, according to Basel regulatory views, usually are divided into a banking book and a trading book. The banking book consists of loans and mortgages, giving interest income to the bank. The assets placed in the banking book are assets that are intended to be held to maturity. The trading book consists of financial instruments, i.e. bonds, equities and derivatives traded by the bank. Those assets are intended to be used for trading or as a hedge of a trading asset.

The liabilities are divided into two parts, one containing Shareholders' Equity, which includes share capital and retained earnings. The other part consist of funding, divided into deposits and wholesale funding. Deposits are seen as a stable source of funding, and involves paying interest to the customers that holds money in the bank (the depositors). Often the deposits aren't enough to cover the loans of the bank and/or the trading activity, and therefore a bank turn to wholesale funding, which can consist of borrowing from the interbank lending market, having repo agreements or borrowing from other financial investors. The distribution of deposits and wholesale funding often depends on how much deposits a bank can get.

4.2 Assets

4.2.1 Banking book

The banking book is the main source of income for a retail bank[2]. It consists of different loans; for example retail loans, corporate loans and retail mortgages. The interest rate determined for these loans are creating an income for the bank. Retail loans are loans to private customers, corporate loans are loans to larger firms, and retail mortgages are residential loans for private customers.

[2]A bank which relies heavily on private (retail) customers, i.e. retail loans and stable private deposits.

BALANCE SHEET STATEMENT

(DKK millions)	31 March 2013	31 Dec. 2012	31 March 2012
ASSETS			
Cash in hand and demand deposits with central banks	96.143	97.267	36.097
Due from credit institutions and central banks	186.097	200.646	208.466
Trading portfolio assets	831.669	812.927	869.047
Investment securities	113.643	107.724	108.282
Loans and advances at amortised cost	1.169.599	1.161.816	1.205.235
Loans at fair value	731.337	732.762	718.744
Assets under pooled schemes and unit-linked investment contracts	73.290	70.625	66.324
Assets under insurance contracts	241.838	241.343	234.295
Holdings in associates	1.173	1.118	1.045
Intangible assets	20.943	21.181	21.670
Investment property	4.126	4.131	4.612
Tangible assets	6.511	6.544	7.012
Current tax assets	195	147	395
Deferred tax assets	1.283	1.418	1.844
Other assets	23.151	25.300	18.350
Total assets	3.500.998	3.484.949	3.501.418
LIABILITIES			
Due to credit institutions and central banks	485.512	459.932	488.324
Trading portfolio liabilities	544.406	531.860	627.332
Deposits	899.050	929.092	854.520
Bonds issued by Realkredit Danmark	623.133	614.325	604.323
Deposits under pooled schemes and unit-linked investment contracts	82.260	78.741	73.874
Liabilities under insurance contracts	265.300	266.938	253.604
Other issued bonds	347.289	340.005	363.892
Current tax liabilities	586	575	331
Deferred tax liabilities	7.629	7.583	6.721
Other liabilities	42.704	50.109	36.877
Subordinated debt	63.561	67.785	64.033
Total liabilities	3.361.430	3.346.945	3.373.831
SHAREHOLDERS' EQUITY			
Share capital	10.086	10.086	9.317
Foreign currency translation reserve	-196	-195	-229
Reserve for available-for-sale financial assets	-1.199	-1.523	-1.772
Retained earnings	130.877	129.632	120.222
Proposed dividends	-	-	-
Shareholders of Danske Bank A/S (the Parent Company)	139.568	138.000	127.538
Non-controlling interests	-	4	49
Total shareholders' equity	139.568	138.004	127.587
Total liabilities and equity	3.500.998	3.484.949	3.501.418

Figure 5: *Example of a balance sheet statement[32].*

The risks involved in this part of the balance sheet are mainly credit risk and interest rate risk. Briefly, one can say that the credit risk is the risk that the counterparty of the specific loan will default (will be unable to pay back

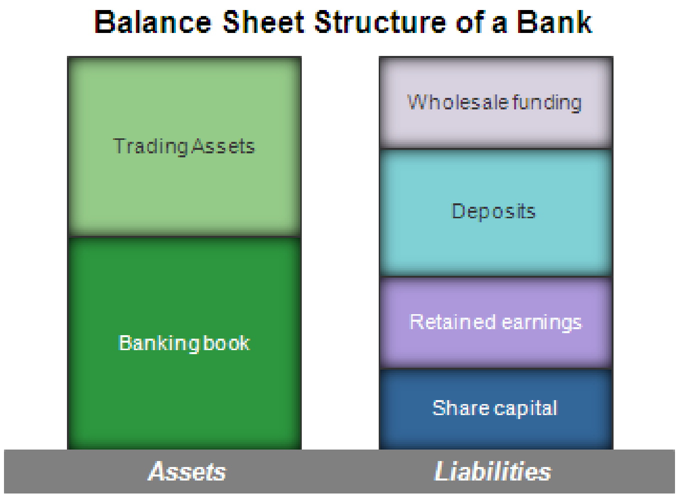


Figure 6: *A coarse illustration of assets and liabilities of a bank.*

the entire loan). The interest rate risk involves the risk of a reduction in the forecasted net interest income coming from the loans [3].

4.2.2 Trading book

The trading book consists of all the financial instruments held and traded by the bank. Typically, an investment bank has a greater focus on trading income than a retail bank, but most banks rely on trading assets to some extent (seeking higher returns and profits). The assets can be different bonds, like government, bank and corporate bonds, or equity and different types of derivatives. Equity can be interpreted as stocks traded by the bank. Derivatives consists of different contracts, like options and swaps, written on an underlying asset.

The market risk is a major risk type when it comes to the trading book. It is the risk of losses in the trading book affected by movements in various factors determined by the market. Examples of such factors can be yield curves, credit spreads and interest rates.

4.3 Liabilities

4.3.1 Shareholders' Equity

Shareholders' Equity can be viewed as the net worth of the bank. It is what can be claimed by the shareholders when all the debt payments are done.

Shareholders' Equity usually comes from two sources: share capital, which is capital invested in the company by shareholders, and the accumulated retained earnings. The formula for calculating Shareholders' Equity is

$$\text{Shareholders' Equity} = \text{Total Assets} - \text{Total Liabilities} \tag{7}$$

Accumulated retained earnings are the accumulated amount of net profit that has been made (when various costs, taxes and dividends have been taken care of). The accumulated retained earnings can both be negative and positive, depending on how the bank's business is doing. Net profits each year are added to the accumulated retained earnings. If net profits for one year are negative, no dividends are normally being paid out and net profits are equal to annual retained earnings. It could be the case that the bank still pays out dividends, since annual retained earnings are losses (or gains) for a single year. The bank can use the accumulated amount of retained earnings to pay out dividends. This is however not a sustainable strategy.

4.3.2 Deposits and Wholesale funding

The deposits of a bank are often seen as a quite stable source of funding. For a retail bank, deposits are the main funding base. It is different types of private savings accounts, where some have a fixed term before withdrawal can be made and some can be withdrew immediately. Deposits are a liability to the bank because it borrows the money from customers and pays an interest in return. The bank also provides services (debit cards, access to cash machines etc) in return for deposits, which have almost replaced the traditional deposit rate.

Retail deposits, made by both consumers and small to medium-sized enterprises, are the primary way of self-funding for most banks. The deposits are commonly insured by the government to a quite high level which lowers the risk of a bank-run[3]. A bank also relies on wholesale funding for various reasons, mainly because it can be hard to attract deposit customers.

Wholesale funding is a different way of obtaining cash (or cash equivalents) and is often used when the deposits do not cover the loans and the trades of the bank. It can be seen as a way of quickly raising liquidity. It is often divided into long term and short term funding, depending on the maturity of the loan, and these are in turn divided into secured and unsecured

[3]When financial instability occur and for example many retailers defaults on their loans, this can create a domino effect where depositors withdraw their money at the same time.

loans, depending on if collateral is used[4]. A secured loan can for example be repo agreements, where the bank sells securities together with an agreement to buy back the securities at a later point in time and pay interest during the time of the contract. Effectively the security works as a collateral, and the sale of the security as a cash loan. The collateral lowers the interest rate paid to the buyer of the contract. Haircuts are often applied, where the haircut reflects the riskiness, e.g. the price volatility of the collateral. For example, if the bank chooses to collaterize a loan with government bonds, which can be regarded as fairly safe, a high collateral, say 98%, is used. Then a 100 dollar worth of government bonds as collateral gives 98 dollars in return. Another way of obtaining wholesale funding is to lend from the interbank market, where banks borrow money from each other in a mutual funding market at a low cost. Other sources are covered bonds (long term bonds using mortgage loans or public sector loans as collateral) and commercial papers (short term funding without collateral, usually with maturity of 1-15 days)[5].

The type of risk that is the most crucial when it comes to wholesale funding is liquidity risk, i.e. the risk of running out of liquid assets. This can happen if too much of the assets are tied up as collateral in various funding agreements or if the bank has too big portion of long term illiquid assets such as retail loans, which would mean that those assets can't be used to cover losses under stressed market conditions. It can also happen when there is a shortage of funding available on the market. This was one major cause of the recent financial crisis.

4.4 Profit & Loss account

The Profit & Loss account keeps track of the income and expenses that have occurred during a time period, and is a way of accounting for where on the balance sheet money has been made (and lost). In other words, the retained earnings during one time period are derived from the P&L account. The earnings are added to the accumulated retained earnings, which are part of Shareholders' Equity, on the balance sheet. For example, if a loan is taken by the bank on the interbank lending market, the value of the loan is shown on the Liabilities side on the balance sheet, and the payments of interest are shown as an expense on the Profit & Loss account. An example of a P&L statement can be seen in figure 7.

[4] A collateral is working as a protection for the lender against the default risk of the borrower. In case of default, the lender receives the collateral. It is often used in mortgage loans, where the property serves as a collateral for the loan.

PROFIT AND LOSS STATEMENT

(DKK millions)	Q1 2013	Q1 2012	Full year 2012
Interest income	18.019	20.369	77.939
Interest expense	9.722	11.548	42.985
Net interest income	8.297	8.821	34.954
Fee income	3.117	3.041	12.168
Fee expenses	1.054	977	3.935
Net trading income	3.934	6.354	12.735
Other income	776	1.093	4.451
Net premiums	5.442	5.323	19.858
Net insurance benefits	9.776	10.916	31.089
Income from associates	-61	31	166
Profit on sale of associates and group undertakings	-	2	6
Staff costs and administrative expenses	5.866	6.064	24.554
Amortisation, depreciation and impairment charges	584	1.211	3.692
Profit before loan impairment charges	4.225	5.497	21.068
Loan impairment charges	2.009	3.922	12.529
Profit before tax	2.216	1.575	8.539
Tax	744	797	3.814
Net profit for the period	1.472	778	4.725

Portion attributable to			
shareholders of Danske Bank A/S (the Parent Company)	1.472	778	4.721
non-controlling interests	-	-	4
Net profit for the period	1.472	778	4.725
Earnings per share (DKK)	1,5	0,8	5,1
Diluted earnings per share (DKK)	1,5	0,8	5,1
Proposed dividend per share (DKK)	-	-	-

Figure 7: *Example of Profit & Loss statement[32].*

4.4.1 Structure

The structure of a Profit & Loss account can be done as following. First, two separate statements are done, one for income and one for expenses. Income is coming from the assets of the bank, for example interest rate payments from loan customers and dividends or coupon payments from equity and bonds.

Expenses are for example interest rate paid to depositors and lenders. The sum of these two will be the gross profit of the bank (assuming expenses are accounted as negative values). After deductions of other expenses, such as operating costs due to salaries and other costs for running the bank and losses due to defaulting counterparties, the income before paying taxes is calculated. If positive, a tax deduction is made, giving the net profit for the time period. Then, after deductions due to dividend payouts, the retained profits are obtained. This amount will then either be kept as cash or will be reinvested in financial instruments, depending on the current business strategy.

5 The projections

An important part of the ICAAP process is capital planning, which is a forward-looking analysis of the capital base and risks of a bank. It is a way of testing the bank's real capability to cover it's future risks and to analyze which risks are material[13]. This is done by projecting the balance sheet under different scenarios which should cover extreme, but plausible, events.

5.1 Projections - main purpose

In order to determine if a bank has the desired risk appetite in its portfolio and that it fulfills the capital requirements under different business plans and scenarios, certain risk factors and risk appetite measures are applied and incorporated into a capital planning tool where the balance sheet projections are made. The tool is implemented using Visual Basic for Applications (VBA) in Excel (see Appendix D). Projections are a way of assessing possible future risks involved in following a certain business plan. Then studies of how risk metrics behave under different scenarios are done. The main purpose behind the tool is not to give exact forecasts of the future but to investigate how different risk drivers affect the bank under different scenarios. The main idea is to be able to study so called "what if"-scenarios, where certain risk drivers are set to follow a deterministic path and then evaluate how the impact is on the bank for different scenarios. The scenarios are based on historical time periods that endured significant stress. This evaluation is made by studying the movements of the balance sheet and by looking at the measures of risk in the context of risk appetite limits. In order to determine a scenario which is relevant to study, certain assumptions about correlation between the risk drivers has to be made.

A simplified balance sheet of a bank described in section 5.3 will be used when doing the projections followed by an analysis of the sensitivity to certain risk factors, as for example the yield curve of bonds and the probability of default for retail loans.

The following questions are investigated:

- How should the outputs be defined, i.e. what risk appetite measures (risk metrics) are of interest?
- How should the inputs be defined, i.e. what risk factors should be considered?
- How can interesting/plausible scenarios be constructed and evaluated?

5.2 Risk metrics

Before looking at projections of a bank, it is crucial to define what the projections will be used for. The idea is to study certain business plans that the bank is considering, and evaluate if the risk appetite limits are breached in any of the proposed plans. Depending on what risk measures or KRI's that are of interest to the bank, it may require that the projections are modeled in a certain way so that the KRI's are able to be evaluated.

Since the main purpose of creating the tool is to operationalise risk appetite, it is therefore a natural first step to consider what type of risk metrics that are of interest for the bank, i.e. how the risk appetite should be measured. Also, it is of interest to define certain risk appetite targets and limits, where a breach of those limits would serve as a warning to the bank that the proposed business plan is too risky/risk averse and should be evaluated and maybe changed.

5.2.1 CET 1 Ratio

It is of great interest to have a metric that reflects if the bank is meeting its regulatory capital requirements set out by Basel. One way of doing this is to study the ratio of CET 1 instruments divided by the RWA's, and this defines the first metric and is (at time t):

$$\text{CET 1 Ratio(t)} = \frac{\text{CET 1(t)}}{\text{RWA(t)}}. \tag{8}$$

The formula for RWA in Basel is

$$\text{RWA} = \text{Credit risk} + 12.5 \cdot \text{Market risk} + 12.5 \cdot \text{Operational risk} \tag{9}$$

where 12.5 is the reciprocal of $\frac{1}{0.08}$, which comes from the fact that 8 % is the total minimum required capital (Tier 1+Tier 2) to hold for the bank. Credit risk does not have this factor because it is already incorporated into the credit risk formula (see section 3.1). It follows from this that the Risk-Weighted Assets need to be projected, which involves projections related to credit risk, market risk and operational risk. Also, the assets related to inclusion in CET 1 need to be projected, and those involve share capital and retained earnings.

The lowest possible limit for the bank to consider is of course the capital requirements set out in Basel, which are described in section 2.2. The upper limit is up to the bank to choose, depending on what the risk appetite of the bank is. The reason for having an upper boundary is that holding too much capital could mean that the bank misses investment opportunities that yield a higher return. The upper limit is set to 15 % and the target is set to 10.5 %. The lower limit is set to the Basel requirements.

5.2.2 Return on Equity (ROE)

The second risk appetite measure is capturing the appetite for large returns, namely Return on Equity, which can be seen as the ratio between net profits during a year and Shareholders' Equity. ROE shows how well a bank uses investment funds to generate growth. It is of great interest to have a measure that is focusing on returns, since it is desirable to have a sound balance between meeting the capital requirements and achieving good profit. Since the projections are made on a quarterly basis the annualized ROE at time t is calculated as

$$\text{ROE(t)} = 4 \cdot \frac{\text{Net profits(t)}}{\text{Shareholders' Equity(t)}}. \tag{10}$$

Net profits at time t are in the formula defined as the net profits made during the previous quarter. Shareholders' Equity is calculated as the average of the value at the current time and the value a quarter of a year ago. The limits are not regulated by Basel and should reflect the true appetite of the bank. Typical target values are in the area of 15-20 %. An upper limit breach could serve as a warning to the bank that it may have a too risky approach (high returns are related to high risk). A lower limit breach should serve as a warning to the bank that it is not making enough profit (or is losing money) and should consider another business plan.

The bank (see section 5.3) will aim for a target of 17 % and will have a lower and upper limit of 5 % and 29 %. The lower limit is motivated by the fact that a bank would aim for positive earnings. The upper limit is an estimate of what a bank could consider as returns that might imply excessive risk taking, which would mean that the bank would need to evaluate other risk metrics in order to determine if that is the case.

ROE cannot be used as a single risk metric, since it is dependent on the leverage that the bank is exposed to. Increased debt and decreased equity will increase ROE, and therefore it needs to be looked at together with a risk metric that captures this. This is done by using the Leverage ratio.

5.2.3 Leverage ratio

One reason for the crisis in 2008 was banks' build-up of excessive on- and off-balance sheet leverage. Many banks were building up excessive leverages that didn't affect the capital ratios, thus this leverage effect wasn't captured by Basel II. Therefore a new ratio requirement was incorporated into Basel III, which requires banks to have a minimum leverage ratio of 3%. It can be seen as a measure of how dependent a bank is on debt financing compared to equity financing. The way of defining the leverage ratio in Basel III is:

$$\text{Leverage ratio} = \frac{\text{Tier 1 Capital}}{\text{Total Assets}}. \tag{11}$$

The leverage ratio will be tested during a run period from 2013 to 2017 before being fully established. The lowest possible limit is defined by Basel (3 %) but a more risk averse bank would choose a higher limit (relying more on own capital). An upper limit would serve as an indication of the bank being to careful in its investment strategy. The target level for the bank presented in the next section is set to 8 % and the lower and upper limit are set to 3 and 15 % respectively.

5.2.4 NSFR

The Net Stable Funding Ratio is implemented as a way of capturing the stability of the current funding compared to the asset structure. It is presented in section 3.4.2. The lowest limit possible according to Basel is 100 % and the upper limit could be set to what the bank thinks is a too risk averse level. The target for the bank (presented in the next section) is set to 115 % and the upper limit is set to 135 %. The lower limit is set to the Basel requirements.

5.3 Constructing balance sheet for a simple bank

A somewhat simplified balance sheet is constructed in order to study the risk appetite and balance sheet projections of a bank. The bank, called Bank J, has the structure below (see figure 8). It is considered to be a bank with only transactions within the country and a local customer base, eliminating (to a certain extent) foreign exchange risk. The bank is situated in USA, and the reason for this is mostly due to data availability. More details about the assets and the projections of them will be explained in section 5.5. Before doing that, a discussion of the risk factors involved in the projections will be done.

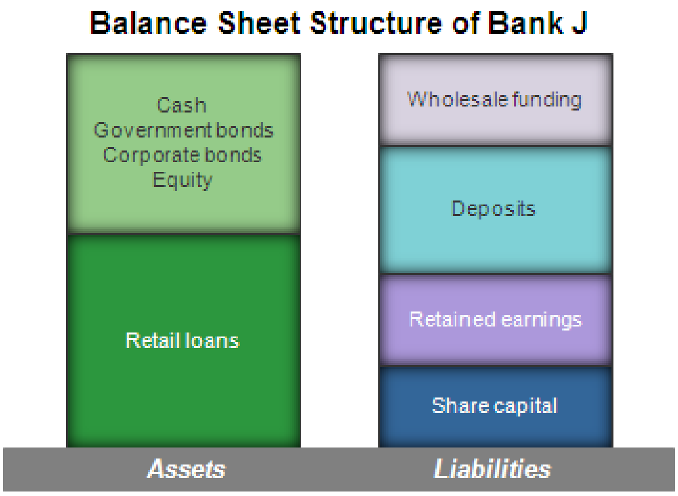


Figure 8: *Assets and Liabilities of Bank J.*

5.4 Relevant risk factors

A change in a risk factor for a certain asset or asset group is something that will affect the market price change of the asset in question. In other words, the risk factors are determining the prices of the assets in the portfolio and will therefore be used as inputs to the projections. They are a subset of market variables that capture the risks of the portfolio. The risk factors described in the following sections are incorporated into the model. Since the scenarios will reflect historical periods, data for the risk factors involved in these is also discussed. Due to proprietary reasons data is not available for all risk factors. In these cases generic market data has been used instead.

5.4.1 The yield curve

The yield curve is one of the most essential risk factors to consider for the portfolio. The yield curve describes the relationship between a particular redemption yield and a bond's maturity. If the bond yields are plotted for the different maturities the yield curve is constructed. It is important that just one type of bonds is used when constructing the yield curve; for example Treasury bonds. If assets traded at par are used, the yield curve is then referred to as a par yield curve. If a bond is trading at par it is paying coupons that make the market price of the bond equal to the face value (the amount received at maturity). In the model it will be involved in the pricing of both corporate and government bonds.

There are several yield curves to consider, for example the spot yield curve and the yield to maturity (YTM) yield curve. The difference between them is that the spot yield curve consists of yields for zero coupon bonds and the YTM yield curve consists of yields for bonds with several coupons. This difference mean that the YTM yield curve assumes that the coupons received will be reinvested, thus introducing reinvestment risk[17]. The spot curve doesn't account for this risk as it only looks at bonds with one final payment (for different maturities). The spot curve is also known as the term structure of interest rates. It can be derived from the YTM yield curve and is then called the theoretical spot yield curve. The yield curve is very interesting as it holds information of the market expectation of future interest rates.

Historically there have been three typical shapes of the yield curve; upward, downward and hump shape. The upward structure is the most typical shape of the yield curve can be seen in figure 9. This is a quite intuitive shape as an investor would expect to receive a higher yield for longer maturity compensating for future inflation risk and the uncertainty of future events. When the market predicts a recession the yield curve typically is decreasing for the future period (downward shape) expected to have an economic slowdown, and an example of this can be seen in figure 10, which shows the average yield curve for U.S. Treasury bonds for the first quarter in 2007, and it shows indications of a recession from 6 months to 2 years. The reason for this is that the market expects future interest rates to drop, which is often the case during recessions, where a decline in credit demand drives rates down[27].

The data used for the scenarios is the U.S. Treasury yield curve derived on a daily basis for maturities 1 month, 3 months, 6 months, 1 year, 2 years, 3 years, 5 years, 7 years, 10 years, 20 years and 30 years between the years 1990 to 2013 by the U.S. Department of the Treasury[33]. They use a cubic spline model to estimate the at par yield curve for U.S. Treasuries using bid

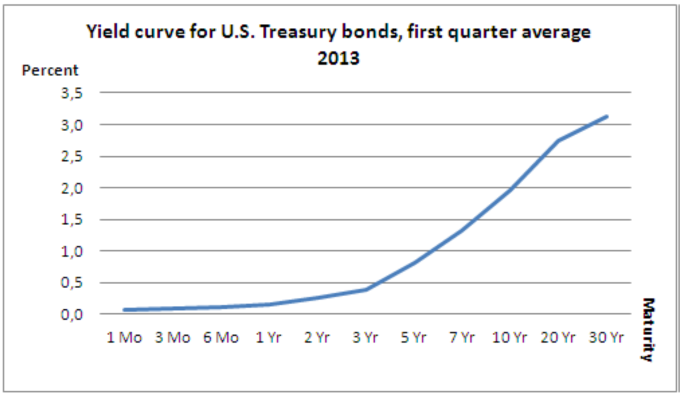


Figure 9: *Yield curve for U.S. Treasury bonds, first quarter (average) 2013.*

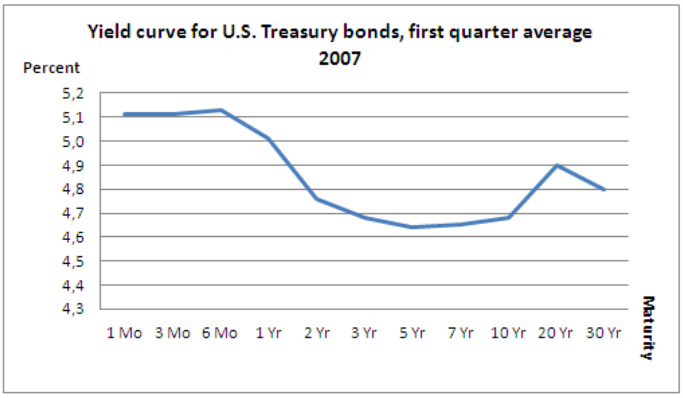


Figure 10: *Yield curve for U.S. Treasury bonds, first quarter (average) 2007.*

prices for U.S. government on-the-run securities. Quarterly averages of these are formed to fit the projections. This yield curve is used as the risk-free yield curve, which is based on the assumption that U.S. Treasury securities have a low probability of default.

5.4.2 Credit spread of bonds

The credit spread of bonds is the extra risk that is involved in holding bonds that have a probability of default. In addition to default risk, components like liquidity risk and added tax obligations could affect the size of the spread. There are several ways of defining the credit spread for bonds. The credit spread is here defined to be the additional amount of interest paid by a risky asset over the yield of a risk-free investment[18]. Primarily due to data availability this choice is option-adjusted spread (OAS). It is the percentage that the fair value Treasury spot yield curve is shifted in order to match the present value of discounted cash flows to the price of the bond[19]. A illustration of the concept can be seen in figure 11. OAS is assumed to be constant for all maturities, which is not often the case in reality.

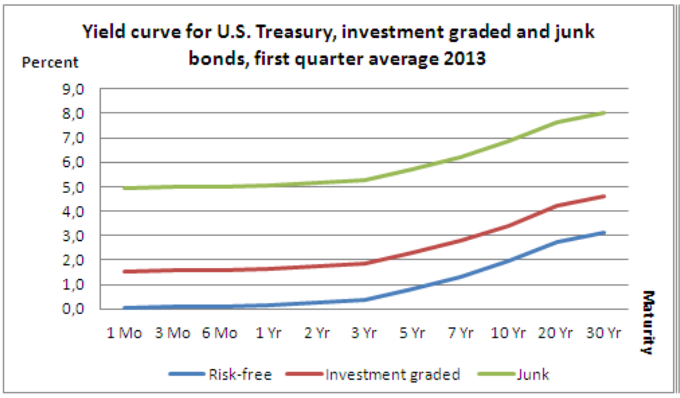


Figure 11: *Yield curve for U.S. Treasury, investment grade and junk bonds, first quarter (average) 2013.*

The OAS data is fetched from calibrations made by Bank of America and Merrill Lynch for both U.S. investment grade[34] and junk bonds[35]. The calibration method that is used is the Nelson-Siegel method[29], which is a four-parameter formula that is updated iteratively through minimizing the sum of squares of the price of the bonds and the fitted curve. The data is on a daily basis ranging from years 1996 to 2013 and has been averaged quarterly to fit the projection time periods.

5.4.3 Probability of Default

The Probability of Default (PD) is another important risk factor to consider, and it will be described by both credit migration probabilities, which is the probability of moving between certain pre-specified credit ratings, which reflects the credit quality of the issuer, and the probability of moving directly into a defaulting state. The definition is stated in section 3.1. The default probabilities and transition probabilities will be modeled by using Markov matrices for both corporate bonds and retail loans.

The credit quality of the corporate bonds are modeled using credit ratings provided by Standard & Poor's (S&P). These ratings are divided into seven different buckets ranging from AAA to CCC. Bonds are usually grouped as investment grade bonds, which are considered to be more safe and ranges from AAA to BBB- and non investment grade bonds or junk bonds, which are less safe and ranges from BB+ to CCC[20]. Depending on different factors, as for example the current financial stability of the issuer of the bond, different ratings are applied. The probabilities for the bond migrations will be estimated using yearly data 1981-2011[36], which estimates the probability of moving between investment grade and junk bonds and default state or a withdrawal rating state. The withdrawal state means that the bond no longer has a rating, but is not in default.

The estimation uses historical data of bonds to calculate the probability of migrating or defaulting every year. To calculate the annual default rate for the investment grade and the junk bonds, S&P divides the number of defaulted bonds within a group during a year with the total number of bonds in the same group. To get the credit migration probability, the end state is compared to the starting state for each bond (for bonds with similar starting state), and a summation of all transitions that has occurred is done and then divided by the total number of bonds within the starting state group. For example, to get the migration probability for one year for investment grade bonds to junk bonds, the number of transitions (investment grade at start of year and junk bond at end of year) from investment grade to junk bonds is divided by the number of investment grade bonds at the start of the year. Note that the estimation does not take into account if a bond has migrated several times during a year; only the starting state and the ending state matters. For example, an investment grade bond could migrate to a junk bond at the beginning of the year, and then migrate back before the end of the year. This will not be incorporated when calculating the transition probabilities[22]. The method is called the cohort method and is the most basic one when estimating transition matrices.

The transition matrix is adjusted by excluding bonds that have migrated to a withdrawal state multiplied by a factor 0.5. For rating class i, it is calculated as

$$H_i = D_i/(N_i - 0.5 \cdot W_i) \tag{12}$$

where H_i is the probability of default, D_i is the number of defaulting bonds during the period, N_i is number of bonds at the start of the period, and W_i is the number of withdrawals during the period. This factor, 0.5, represents the fact that a bond that has gone into withdrawal state at the end of the year would probably have almost zero default risk. Thus, a factor of 1 would reflect a pessimistic view of the default probabilities. This method is used by Moody's[23] in their transition matrices. An example of a transition matrix used by S&P is shown in figure 12.

The matrix needs to be adjusted to fit quarterly time periods, and therefore a method for calculating the 4th square root of the matrix is applied. The method is called Denman-Beavers iteration[24]. For further details regarding this method, see literature.

Average Multiyear Global Corporate Transition Matrix (1981-2011)

(%)	--One-year transition rates--								
From/to	**AAA**	**AA**	**A**	**BBB**	**BB**	**B**	**CCC/C**	**D**	**NR**
AAA	87.19	8.69	0.54	0.05	0.08	0.03	0.05	0.00	3.37
	(9.11)	(9.10)	(0.87)	(0.31)	(0.25)	(0.20)	(0.40)	(0.00)	(2.58)
AA	0.56	86.32	8.30	0.54	0.06	0.08	0.02	0.02	4.09
	(0.55)	(4.94)	(4.01)	(0.73)	(0.25)	(0.25)	(0.07)	(0.07)	(1.92)
A	0.04	1.91	87.27	5.44	0.38	0.16	0.02	0.08	4.72
	(0.13)	(1.15)	(3.49)	(2.10)	(0.49)	(0.36)	(0.07)	(0.11)	(1.92)
BBB	0.01	0.12	3.64	84.87	3.91	0.64	0.15	0.24	6.42
	(0.07)	(0.23)	(2.31)	(4.64)	(1.84)	(1.03)	(0.24)	(0.27)	(1.82)
BB	0.02	0.04	0.16	5.24	75.87	7.19	0.75	0.90	9.84
	(0.06)	(0.16)	(0.39)	(2.37)	(4.97)	(4.70)	(0.92)	(1.05)	(2.85)
B	0.00	0.04	0.13	0.22	5.57	73.42	4.42	4.48	11.72
	(0.00)	(0.13)	(0.38)	(0.34)	(2.52)	(5.30)	(2.57)	(3.32)	(3.02)
CCC/C	0.00	0.00	0.17	0.26	0.78	13.67	43.93	26.82	14.37
	(0.00)	(0.00)	(0.71)	(1.02)	(1.30)	(8.59)	(12.79)	(12.68)	(7.32)

Note: Numbers in parentheses are standard deviations. Sources: Standard & Poor's Global Fixed Income Research and Standard & Poor's CreditPro®.

Figure 12: *Credit migration matrix from Standard & Poor's. It shows the average one-year transition probabilities during 1981-2011[36].*

The retail loan portfolio is divided into high quality (low risk) customers and low quality (high risk) customers. These groups can, in a way, be thought of as investment grade bonds and junk bonds. The transition matrix is describing the probabilities of migrating between the different customer rating classes and the probability of default. Difficulties arise in how to estimate these probabilities, and banks often have their own assessment on the credit quality of their private borrowers.

The probabilities will be based on industry benchmarks, provided by EY, and a number of rating classes for different credit qualities will be divided into two buckets, with approximately equal amount of customers in each group. The estimated probabilities (on a quarter of a year basis) are shown in Eq. 13. When simulating the effect of a recession, the probability of default and the downward migration probabilities will be doubled, as a way of stressing the portfolio. The probability of staying in the same rating will be adjusted so that the sum of each row is equal to 1.

$$Q = \begin{pmatrix} 98.7\% & 1.0\% & 0.3\% \\ 1.1\% & 97.6\% & 1.3\% \\ 0 & 0 & 100\% \end{pmatrix} \tag{13}$$

5.4.4 Equity Index

The equity portfolio of Bank J is assumed to be a well-diversified portfolio with similar characteristics as S&P 500 equity index. The index corresponds to 500 leading firms in various industries of the U.S. economy and is containing 75 % of U.S. equities[14]. Data describing the daily index values is fetched from Federal Reserve of St. Louis[37] and contains data from 1957 to 2013. The quarterly changes (using quarterly averages) in value of the equity index are assumed to describe a corresponding value change of the equity portfolio for the bank. A sudden drop in market value of the index would be considered as being a risk for the bank. The index using the quarterly averages is shown in figure 13.

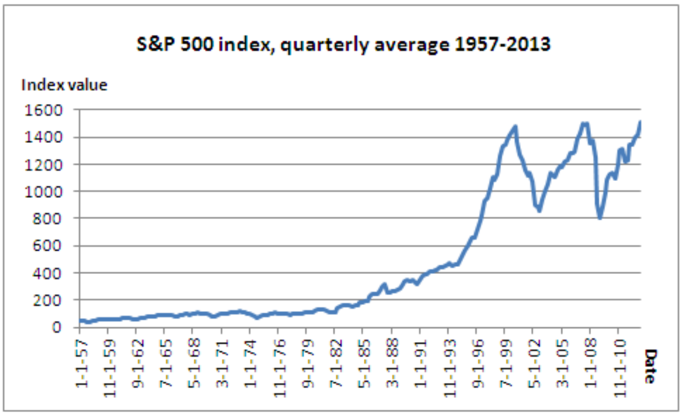


Figure 13: *Quarterly average of the S&P 500 equity index 1957-2013.*

The dividend payout coming from the equities is set to 2 % (yearly dividend yield) for all scenarios, due to the fact that the dividend yield has been quite stable in the two-percent area during the last ten years.

5.4.5 Exposure, volatility and correlation of yield curve, credit spreads and equity

The volatility and correlation of all risk factors are important when modelling the risks of a portfolio. However, since the market risk charge in Basel III, used as a part of the CET 1 ratio, is the only one of the projected risk metrics that uses these inputs, it will be sufficient to model the volatility and correlation of the risk factors involved in the pricing of the trading assets.

Since the market risk charge requires one year of historical data when calibrations are done, a rolling one year sample of the data sets (containing daily samples) of the Treasury yield[33], the credit spreads[34][35] and the equity index[37] is used. The yield curve volatility and correlation is estimated by using the 3-month Treasury rate and the Treasury rate for a common longer maturity, called target maturity (these two maturities are used for the bond portfolio, see section 5.6.1). Since the model that is used for the market risk charge will be the delta normal method (see section 5.8.1), which assumes normality and a linear relationship between risk factors, the data for the risk factors needs to be converted to a normal distributed form with zero mean and constant dispersion. By assuming stationarity, one can do this by constructing new vectors of risk factor changes, specifying the daily returns for stocks and daily changes in yields and spreads. By introducing notations $y_{3m}(t)$, $y_{\text{target}}(t)$, $c_1(t)$, $c_2(t)$ and $S(t)$ for the 3 month Treasury yield, a Treasury yield for longer maturity, the credit spread for investment grade bonds, the credit spread for junk bonds and the equity index respectively, these are defined as

$$\begin{cases} \Delta y_{3m}(t) = y_{3m}(t) - y_{3m}(t-1) \\ \Delta y_{\text{target}}(t) = y_{\text{target}}(t) - y_{\text{target}}(t-1) \\ \Delta c_1(t) = c_1(t) - c_1(t-1) \\ \Delta c_2(t) = c_2(t) - c_2(t-1) \\ \Delta S(t) = \ln(S_t/S_{t-1}) \end{cases}$$

where Δ is defined as one day. The volatility and the correlations are then calculated every quarter (spanning from 1996 to 2013, due to data availability), using the standard deviation during the last year and the Pearson correlation (linear correlation) for the same period. This is a backward-looking estimate of the volatility and the correlation and the estimation gives equal weights to each sample during the last year[5].

In order to derive Value-at-Risk for the portfolio the risk factors are mapped to an exposure equal to the market value of the assets subject to the risk factor. This is straightforward when it comes to the equity portfolio, since the changes in market value of the portfolio has a one-to-one relationship with daily returns. However, it is not as straightforward how a one-percent change in yields affect the market value change of a bond. To

[5]For details on the estimated values, see Appendix A

estimate this, the concept of modified duration is introduced. Modified duration is the sensitivity in price as a function of the yield[28]. For a yield y and a market value V, it is defined as

$$ModD(y) = -\frac{\partial \ln(V)}{\partial y}.$$

In other words, a positive shift in the yield curve would correspond to a negative shift in market value multiplied by a factor corresponding to the modified duration. This linear approach is used for both corporate bonds and government bonds. This means all risk factor changes affecting the price of these assets; yields and credit spreads. The modified duration can be expressed in terms of Macaulay duration, which is the average maturity until cash flows are received. The Macaulay duration will be slightly smaller than the maturity of a bond. This is because coupons are paid out before the maturity date, thus giving a lower value of the average maturity of cash flows compared to the maturity of the bond. The relationship between Modified duration and Macaulay duration for bonds paying coupons k times a year is[30]:

$$ModD(y) = \frac{MacD(y)}{1 + y/k}$$

This will be used when calculating the Value-at-Risk for the exposures (the value of the bonds) regarding changes in the yield curve and the credit spreads. The target maturity is set to 10 years. The typical procedure would be to map all cash flows to the corresponding maturity, as for example the 10-year bond would have payments every quarter. Then a separate risk factor would be present for each payment. To simplify things, all exposure related to 10-year bonds will be mapped to the 10-year yield maturity risk factor. For the 3-month bonds only one risk factor is needed from the yield curve.

5.4.6 Loss Given Default (LGD)

Loss Given Default (LGD) is defined as the percentage of remaining debt when default occurs that is expected to be lost. Since the assets exposed to a probability of default in the model is the corporate bonds and the retail loans, and these are divided into two risk buckets respectively, four different LGD parameters are applied for these assets.

Industry benchmarks suggests that an average exposure-weighted LGD is around 30 %[6], which is used as input when market conditions are assumed to be normal. In a stressed scenario an LGD of 50 % is applied and that is motivated by industry experience.

5.4.7 Loan rate

The loan rate is the rate at which banks offers loans to customers. Depending on the credit quality of the customer, the length of the loan, the amount (exposure) of the loan, if the loan is covered by collateral and if the loan rate is fixed or floating different loan rates are applied. The loan rate can also be linked to the strategy of the bank. For example, if the bank wants to attract customers it may lower the rates as a strategic action (to win market shares). If the bank feel that it is possible to gain more money by raising/lowering the loan rate (optimal supply and demand), it will probably do so. There is also an upper limit for how much the bank can charge its customers, since there are rules and laws (e.g. Truth in Lending Act in the U.S.) that specify what is considered to be a fair rate.

The bank using the tool is considered to be a small bank without any significant impact on the market. The bank will therefore adjust its loan rate to the current market conditions. The loans will be fixed-rate loans without collateral. The loan rate for fixed-rate loans is affected by the current interest rates. If the interest rate is low, the bank will probably offer loans with a higher loan rate than for floating rate loans, since it is likely that the interest rates will rise in the future. If not, this would imply a potential loss for the bank, since the customer will have a lower loan rate than what the market is offering in the future.

The value of the loans will be calculated by discounting the future known cash flows of the loans (more about this in section 5.6.4). The discount factor will be different for the different customer groups (described in section 5.4.3), with higher discount factors for loans with lower credit quality. It will be part both of calculating the value of the loans and when determining the loan rate. The discount factor that will be used is the spread between the prime loan rate and the federal funds rate. The federal funds rate is the rate which banks borrow money from each other held at the Federal Reserve (the central bank in the U.S.), typically overnight. The Federal Reserve controls the federal funds rate by adjusting the level of Treasury bills that are issued. The prime loan rate is an indicator of the interest rate at which banks are lending to high quality customers[21] and is around 3 % above the federal

[6]Numbers are based on expert judgement using input from EY.

funds rate. The prime loan rate is the base for other loans, such as credit card loans, where for example a typical way of setting the interest rate for a credit card loan is prime loan rate+x %.

The loan rate for high quality customers will consist of two parts, the federal funds rate and the additional spread between the federal funds rate and the prime loan rate. Effectively, the high rate customers will have a loan rate that is the prime loan rate. The loan rate, r_{high}, is:

$$r_{high} = \text{federal funds rate} + \underbrace{(\text{prime loan rate} - \text{federal funds rate})}_{\text{discount factor}}$$

The low quality customers will be treated as credit card loan takers, because this type of loan often is associated with more risky customers. Using that the average spread between all credit card loan rates issued by commercial banks and the federal funds rate between 1995 and 2012 is around 10 %, gives a proxy for the discount factor that will be used for low quality customers.

The loan rate will be the same for all maturities, but the effective interest rate will be higher for loans with higher maturity. To see the logic behind this, see section 5.6.4.

Data for the federal funds rate[38], the prime rate[39] and the credit card rates[40] is fetched from the Board of Governors of the Federal Reserve System, which is the board of the central bank (Federal Reserve System) in the United States. The historical data for the federal funds rate is plotted in figure 14.

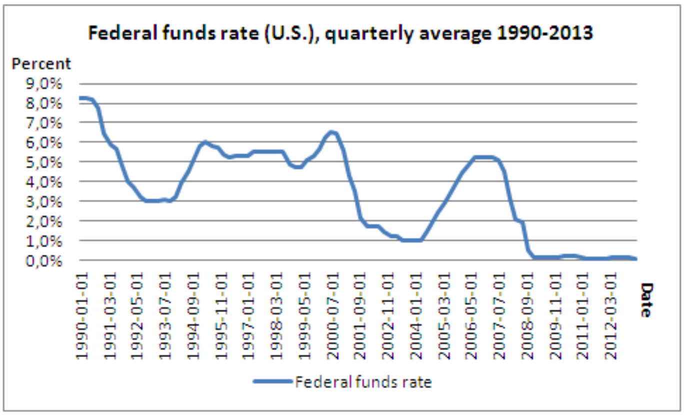


Figure 14: *Quarterly average of the federal funds rate in the United States 1990-2013.*

5.4.8 Cost of wholesale funding

The cost of wholesale funding is the cost that banks is exposed to in order to finance their business when core deposits is not enough (see section 4.3.2). The wholesale funding for Bank J will be modeled as being funding received from the interbank market, where banks borrow money from each other at a low cost. This kind of funding is often short term (typically overnight or three months) and there is no collateral protecting the bank.

The cost of funding depends on many factors, such as the current amount of liquid funding available on the market, the maturity of the funding, the current credit rating of the bank and the current credit rating of the country. In the U.S. banks borrow from each other at the federal funds rate through the Federal Reserve. It is also possible to borrow directly from the Federal Reserve at a slightly higher rate.

When looking at funding costs the question of how to quantify liquidity risk, resulting in a liquidity crisis similar to the one that happened during the financial crisis, is an issue. Using historical values for the effective federal funds rate, which decreased significantly before and during the crisis in 2008 due to attempts to stimulate the economy (lower rates creates incentives to borrow money and invest) and cushion the fall, will not reflect a liquidity crisis under a severe scenario. The actual funding cost under a severe scenario is a difficult problem, due to both data availability and many different factors affecting each other in an complex way[25]. The solution is to add a shock parameter, based on the TED spread, which is the difference in percent between the 3-month LIBOR and the 3-month Treasury yield. The TED spread is a common indicator of the credit availability in the U.S. economy and tends to rise when liquidity is an issue. The TED spread has historically been on a level between 0.1 and 0.5 %, except in times of financial stress.

By applying a second spread, reflecting the current credit rating of the bank, one could also simulate a potential downgrade as a consequence of a stressed scenario such as the recent financial crisis. This spread is added to the federal funds rate and is fetched from "The U.K. Financial Sector Assessment Program"[16], which is a guidance document for stress testing programs for banks. The spread is based on empirical estimates. Although this document is for U.K. banks primarily, it is assumed that funding cost spreads can be applied for an American bank as well. The applied spread can be studied in Appendix B.

5.4.9 Deposit rate and growth of deposits

The deposit rate is the rate that banks pay to there customers in return for keeping money in the bank. The deposit accounts are assumed to be stable and renewed on a short term basis. No risk for a bank run is considered, as it is assumed that the customers are secured against a default of the bank. The rate will be set to an annual percentage of 0.1-0.5 %, reflecting the low deposit rate that has been paid out during recent years. The number is estimated on the basis of expert judgement, provided by EY.

The growth of the deposits is set to follow the historical GDP (Growth Domestic Product) in the U.S., motivated by research made on European banks (Lakštutienė, 2008) that show a strong correlation between deposits and GDP for well developed countries such as United Kingdom and Germany[26]. The bank is assumed to maximize the amount of deposits possible under all business plans, due to the desired stability and low cost of the funding source.

5.5 Mechanics of the projections

This section describes the mathematical concepts behind the deterministic model used for the projections of the assets and liabilities.

5.5.1 Time horizon

The time horizon for the projections are τ years, and it is a discrete horizon with $\Delta = \tau/N$, where N is the number of time steps, assumed to be a multiple of τ, $N = h \cdot \tau, h \in \mathbb{Z}^+$. Then h is the number of time steps taken each year. The horizon is therefore $[0, \tau]$ with increments $[t, t + \Delta]$, where $0 \leq t \leq \tau - \Delta$. One increment will be referred to as one time period. The model is looking at the risk factors that directly affects the market values of the assets, and doesn't look at macroeconomic influences. The following sections will describe the projection process of one time period. The same process is then done in the same way for all time periods. For the capital planning tool, τ is equal to five years and the time steps Δ are set to a quarter of a year.

5.6 Assets

5.6.1 Corporate bonds

The risk factors directly involved in the market values of corporate bonds in the model are:

- Probability of Default
- Loss Given Default
- Exposure At Default
- Changes and volatility of the risk-free yield curve
- Changes and volatility of credit spreads

The main idea behind the corporate bond projections is based on credit migration techniques, with inspiration from the Jarrow-Lando-Turnbull model[12]. The main similarity is the matrix concept and the difference is that JLT converts the probabilities into risk-neutral probabilities using the credit spread. In this approach each firm is assigned to a credit-rating category at $t = 0$. The rating categories are finite and ordered by credit quality. Transition matrices that describe the probability of moving between different ratings over a fixed time period are constructed. Credit transition matrices are provided by rating agencies, for example Moody's or Standard & Poor's (S&P) and they are based on historical data of defaulting companies. The transition matrix, called P(t), that is used describes the probability of jumping between three states (investment grade bond, junk bond and default) during the discrete time period $[t, t+\Delta]$. It is assumed that the credit migration process follows a time-discrete Markov Chain and that the transition matrix can vary through time. The default state is an absorbing state. Let X_t define the credit rating of a bond at time t and $X = \{X_t, t = 0, \Delta, 2\Delta, ...\}$. The matrix is defined as

$$P(t) = \begin{pmatrix} p_{11}(t) & p_{12}(t) & p_{13}(t) \\ p_{21}(t) & p_{22}(t) & p_{23}(t) \\ 0 & 0 & 1 \end{pmatrix} \tag{14}$$

with $p_{ij}(t) = P(X_{t+\Delta} = j | X_t = i)$.

The yield curve of a default-free zero-coupon bond is assumed to be entirely described by $y(t, T)$, where t is the current time and T is the time to maturity. When valuing a risky bond, such as a corporate bond, the price must be lower because the investor wants to be compensated for taking a higher risk. This is referred to as the risk premium or the credit spread, and it is assumed to be entirely described by $c_i(t, T)$ for company i. The recovery rate is assumed not to affect the current market value of the bonds. If the coupon payments are assumed to be taking place at every discrete time-point and are denoted D_i, and the face value paid out at maturity is denoted f_i, then the present value of the bond is $(T_i > 0)$[10]:

$$v_i(t, T_i, D_i, f_i) = \left(\sum_{j=1}^{h \cdot T_i} \frac{D_i}{(1 + y(t, j/h) + c_i(t, j/h))^{j/h}} \right) + \frac{f_i}{(1 + y(t, T_i) + c_i(t, T_i))^{T_i}}. \tag{15}$$

This formula is the standard way of receiving the fair value of an asset through discounting promised payments. T_i is updated for every time step, where an increase in t corresponds to an equally large decrease in T_i. The yield curve and the credit spread (the parameters affecting the discount rate) are calibrated to match the price of the bond. The bonds in the model will be assumed to be traded at par. Using the par yield curve and the OAS data (described in sections 5.4.1 and 5.4.2) we can set the value equal to the face value, and then solve the equation for D_i, which gives the coupon rate for the bond when it is traded at par.

Let's say we have ω investment grade bonds and ξ junk bonds at time t, and that m=$\omega+\xi$, with a pre-determined distribution of different maturities and coupons/face values for all bonds, reflecting the investment strategy of the bank. For Bank J, this distribution will partly be one-period zero coupon bonds, and bonds with longer maturity. The bonds with longer maturity will be bucketed as bonds with one average maturity (called target maturity), and an average coupon and principle payment. This assumption is made to simplify the projections.

During the time period some bonds will migrate to a different credit rating or default. For example, if an investment grade bond migrates to a junk bond over one time period Δ, it will have the same coupon payment, but will be discounted at a higher rate (with a different credit spread), thus lowering the value of the bond as would be expected. It is also assumed that no bonds are secured.

It is also important to model how to allocate cash (retained earnings during the time period) to invest in new bonds at the start of the next time period. For this reason it is important to track all cash flows that are coming from the bonds during the time period. The cash flows are the pay-off coming from coupons and principals, and the lost value from defaulted bonds. The coupons and the lost value from defaulted bonds will be placed in the Profit & Loss account. The principal payments are transfered directly to the cash account, since this is not seen as profit or loss: it is just a cash flow (from bonds to cash). The reason for this is that the increased amount of cash from the principal equals the decreased value of the bond.

The lost value from defaults equals the exposure (EAD) multiplied by the Loss Given Default (LGD), denoted $\delta_i(t)$ for $[t, t+\Delta]$, and the total percentage of defaulted bonds. Each bond is mapped to an indicator function $Y_i(t)$, which will be 1 if default has occurred during the time period $[t, t+\Delta]$ and 0 otherwise. It should be noted that for many bonds, it holds that

$$\frac{\sum_{i=1}^{m} Y_i(t)}{m} \approx p_{13}(t) + p_{23}(t) \tag{16}$$

which will be used in the tool, due to its deterministic nature. If the lost value is denoted R_d it can then be expressed as:

$$R_d(t+\Delta) = \sum_{i=1}^{m} Y_i(t)\delta_i(t)v_i(t+\Delta, T_i-\Delta, D_i, f_i). \tag{17}$$

By constructing sub-portfolios for investment grade bonds and junk bonds, with values denoted $v_I(t)$ and $v_J(t)$, and corresponding LGD of $\delta_I(t)$ and $\delta_J(t)$, the lost value can then be expressed as:

$$R_d(t+\Delta) = p_{13}(t)\delta_I(t)v_I(t+\Delta) + p_{23}(t)\delta_J(t)v_J(t+\Delta) \tag{18}$$

The values of these portfolios is easily calculated as (assuming bonds have been ordered with all investment grade bonds first):

$$\begin{cases} v_I(t) = \sum_{i=1}^{\omega} v_i(t, T_i, D_i, f_i) \\ v_J(t) = \sum_{j=\omega+1}^{m} v_j(t, T_j, D_j, f_j) \end{cases} \tag{19}$$

In reality, due to legal issues and other practicalities, it is not the case that the recovered value from a defaulted counterparty can be obtained without certain delays, but for simplicity this is assumed to be the case in the model. Note that the market value of the bond in case of no default is used in Eq. 17, which is needed since the value at the present time step is 0. This method, called RMV, to estimate default exposure are suggested by Duffie and Singleton[31]. If the bond would have matured at this time point, the expected market value is set to the value of the principal f_i plus the final coupon payment D_i.

The total value accounted for on the P&L, denoted R_{PL}, is then

$$R_{PL}(t+\Delta) = \left(\sum_{i=1}^{m}(1-Y_i)D_i\right) - R_d(t+\Delta). \tag{20}$$

The bonds that have not matured are assumed to be liquid and can therefore be traded at market price. They are valued according to Eq. 15. The value of the bonds together with cash flows from principals and retained earnings will be reallocated at the start of the next time period. The allocation follows the chosen business plan. No trading costs are assumed.

5.6.2 Government bonds

The government bonds traded by Bank J are assumed to be high quality bonds with practically no risk of default. This is a simplifying assumption that could easily be altered, for example by applying the same model that is used for the corporate bonds, with certain probabilities of ending up in a defaulting state. The bonds therefore have a credit spread $c_i(t,T) = 0$ at all times, and the cash flows will be discounted only by the risk-free yield curve, $y(t,T)$. One could look at it as if the government bonds are assigned to a credit rating that is slightly better than the investment grade bonds, and that they are in an absorbing state. This will give the same formula as Eq. 15 when calculating the market value. In the same manner as for the corporate bonds, the government bonds will be either zero coupon bonds maturing at the end of the time period, or bonds with a target maturity. The distribution of these is set to follow the chosen business plan by Bank J.

However, there are still several risks involved in holding the government bonds. The biggest risk is drops in market value of the bonds due to rising interest rates, i.e. a positive shift in the yield curve would decrease the market value of the bonds (now having less attractive coupon payments).

The allocation of cash-flows will be coupons and principal payments, and the coupons are accounted for on the Profit & Loss account. This amount is, if the number of government bonds are n and the coupon payments are D_j, equal to

$$R_{PL}(t+\Delta) = \sum_{j=1}^{n} D_j. \tag{21}$$

The bonds are, just as the corporate bonds, assumed to be liquid and possible to trade at market price. The bonds, principals and coupons are reallocated or reinvested at the start of the next time period.

5.6.3 Equity

The biggest risk in the equity portfolio is the volatility in the market value changes. The market value of the equity portfolio is set to follow a deterministic historical path (see section 5.4.4) that is reasonable considering the scenario that is constructed. The growth of the portfolio will be determined by the current business plan. The dividend yield is set to a constant percentage of the market value of the portfolio. The dividend yield will be accounted for on the P&L account. The market value of the equity portfolio and dividends will be reallocated at the start of the next time period, as it is assumed that the equity portfolio is highly liquid.

5.6.4 Retail loans

The risk factors directly involved in the market values of retail loans in the model are:

- Probability of Default
- Loss Given Default

- Exposure At Default
- Duration of loans
- Migrations in customer quality

The retail loan portfolio can conceptually be thought of as the portfolio of corporate bonds, with some differences. When modeling the loans, it is for example not as easy to trade private customer loans as corporate bonds, which will make the retail loan portfolio more static in its behavior. This characteristic also makes it more complex to keep track of all the cash flows, since the loan portfolio cannot simply be re-financed at the end of each time-step as the corporate bond portfolio is assumed to be.

The retail loans are for practical reasons divided into two different parts, existing (old) loans and new loans. They are all assumed to be unsecured, i.e. no collateral is protecting the bank against default. The loans vary in maturity dates, with a possibility of demanding higher loan rates for loans with longer terms. This is for compensating for inflation risk (value of payments vulnerable), interest rate risk, i.e. the risk of rising interest rates, making the loans losing value. Also, the probability of default (not being fully re-paid) rises when the term is longer. A long term loan is also making the bank vulnerable to liquidity risks; for example if the bank is not able to get enough short term funding, or quick decreases in the deposit base, to cover long term loans. Pre-payment risk, i.e. the risk of a customer re-paying the loan earlier than agreed (leading to future losses in income) is not incorporated into the model for simplifying reasons. The calibration for Bank J (see section 5.4.7) suggests a flat loan rate curve, but this assumption can easily be altered in the model.

The loans offered by Bank J will be structured as two types of loans; short term loans and long term loans. The short term loans will have maturity T_s years and the long term loans will have maturity T_l years, where $T_l > T_s$. T_l will be set to 10 years and T_s to 2 years for the bank. The customer base is divided into high quality customers and low quality customers. Compensating for the extra risk induced by lending to low quality customers will result in higher loan rates to these customers. The customer distribution at t=0 will be consisting of γ high quality customer loans and ϕ low quality customer loans, with total time period payments $L_{s,\gamma}$, $L_{l,\gamma}$, $L_{s,\phi}$ and $L_{l,\phi}$. The loans are normalized so that $\gamma + \phi = 1$. In a similar fashion as for the bonds, the retail loans will have a probability of defaulting, and also to shift between the two rating classes. Let W_t define the credit rating of a loan at time t and $W = \{W_t, t = 0, \Delta, 2\Delta, ...\}$. The Markov matrix describing the credit migrations is then defined as:

$$Q(t) = \begin{pmatrix} q_{11}(t) & q_{12}(t) & q_{13}(t) \\ q_{21}(t) & q_{22}(t) & q_{23}(t) \\ 0 & 0 & 1 \end{pmatrix} \tag{22}$$

with $q_{ij}(t) = P(W_{t+\Delta} = j | W_t = i)$.

The behavior of the customers, in terms of credit quality, is assumed to be time-dependent, but not dependent on the maturity of the loan or the time that has elapsed since the loan was issued. As described in section 5.4.7 the loan rate will be fixed (which means that the rate will be held for the remainder of the loans) and determined at each time point for new loans. It will consist of the federal funds rate $F(t)$ and a credit spread (spread between the fed funds rate and prime loan rate/credit card loan spread) reflecting the credit quality of the customer taking the loan ($b_\gamma(t,T)$ and $b_\phi(t,T)$). In total, if a short term loan worth N is granted to for example a high quality customer, the following will be solved for $L_{s,\gamma}$:

$$N = \sum_{i=1}^{h \cdot T_s} \frac{L_{s,\gamma}}{(1 + F(t) + b_\gamma(t, i/h))^{i/h}} \tag{23}$$

which will give the payment that will be made during each period (until maturity). To get the effective interest that is paid it is just a matter of subtracting the payment amount ($L_{s,\gamma}$) multiplied by the number of payments ($h \cdot T_s$) by the total amount of the loan (N). To get the rate in percentage it is just a question of dividing this number by N.

The effective interest rate will be higher for longer maturities, since the same (or higher) interest rate will be applied (see section 5.4.7) for a higher number of payments and on a longer basis. For example, consider a loan N=100, that is considered for either one period (one payment) and two periods (two payments). If the loan rate is 5 %, this will give a effective interest rate for one period of $r = (1.05^{1/4} \cdot 100 - 100)/100 = 1.2\%$. For two periods, it will be $r = (2(\frac{1}{(1/1.05^{1/4} + 1/1.05^{2/4})} \cdot 100) - 100)/100 = 1.8\%$, which illustrates that the loan with longer term will have a higher effective interest rate even for a flat loan rate curve.

Because of the fact that a customer that has migrated will have the same loan rate, but a different credit quality, means that for valuation purposes (see next section) it is needed to keep track of the credit quality when the loan was issued. This means that the high quality customers will be divided into two buckets, one that was considered high quality when the loan was issued and one that has migrated into low quality after the loan initially was set. The same holds for the low quality customers, giving four types of customers in total. It is, however, not affecting the transition matrix, since it is assumed that a customer that has migrated to a specific rating will have the same probabilities that a customer who initially were in the same rating bucket. Otherwise this would have violated the Markov properties of the matrix, which assumes that the probability of moving to a different state is only dependent of the current state.

5.6.5 Old loans

The loans already existing in the portfolio will have known payments, and these cash flows will be discounted by the future discount rates related to a certain scenario to get the current market value. The whole portfolio of old loans will have the same payments (within each group) for simplifying reasons. The maturity dates are equally distributed among the old loans[7]. This portfolio will be further divided into the four groups described in the previous section. The notation will be done in the following manner: The part of the loans that is currently low quality, but was high quality when it was initiated, will be described by $\phi_{t,\gamma}$. Consider the short term portfolio, with initial distribution of loans:

$$\begin{pmatrix} \text{High quality customers (high when initiated)} \\ \text{High quality customers (low when initiated)} \\ \text{Low quality customers (high when initiated)} \\ \text{Low quality customers (low when initiated)} \end{pmatrix} = \begin{pmatrix} \gamma_{t,\gamma} \\ \gamma_{t,\phi} \\ \phi_{t,\gamma} \\ \phi_{t,\phi} \end{pmatrix}$$

These loans will follow the Markov matrix Q. The value of this portfolio can then be expressed as:

$$V_s(t) = \mathbb{1}(t < T_s)\frac{1}{(T_s - t)h} \sum_{i=1}^{(T_s-t)h} \sum_{j=1}^{i} \left(\frac{L_{s,\gamma}\gamma_{t,\gamma} + L_{s,\phi}\gamma_{t,\phi}}{(1 + b_\gamma(t, i/h))^{i/h}} + \frac{L_{s,\phi}\phi_{t,\phi} + L_{s,\gamma}\phi_{t,\gamma}}{(1 + b_\phi(t, i/h))^{i/h}} \right) \quad (24)$$

where the indicator function tells that no old loans will be left when $t = T_s$. The second term normalizes the amount of loans left by excluding matured loans. The double summation works as follows: one part has one period left with one payment and is discounted once, one part has two periods left with two payments and is discounted twice, and so on. The payments are calculated for the whole portfolio, i.e. they are the payments summed for each group.

[7]For example, if the short term old loan portfolio consists of 2-year loans, and each payment is made quarterly, 1/8 of the loans will just have one period to maturity, 1/8 will have two periods and so on.

During every time period $[t, t+\Delta]$, a portion of the loans will end and a portion of the loans will default or migrate to a different credit rating. The distribution of loans will be updated according to this (after the allocation of interest payments and default losses on the P&L account). If a loan has defaulted in the time period $[t, t+\Delta]$, an LGD of $\kappa_\gamma(t)$ or $\kappa_\phi(t)$ of the total value of the loan will be lost at $t+\Delta$, depending on the credit quality at time t.

To calculate the default losses the retail loan portfolio is divided into two parts: one that is high quality at time t and one that is low quality at time t. As seen in (22), the probabilities of these two groups defaulting is $q_{13}(t)$ and $q_{23}(t)$ (independent of initial state). The value of these two portfolios is denoted $V_{s,\gamma}(t)$ and $V_{s,\phi}(t)$. These can be extracted from (24). The total lost value, R_d, at the end of the time period is then

$$R_d(t+\Delta) = q_{13}(t)\kappa_\gamma(t)V_{s,\gamma}(t) + q_{23}(t)\kappa_\phi(t)V_{s,\phi}(t) \tag{25}$$

To calculate the interest payments received at the end of the period, it will use the distribution of loans that have not defaulted. The interest payment part of the loan is equal to the actual payments minus the total amount of the loan (N) divided by the number of payments ($T_s h$) and is, for loans that were high quality as initial state, denoted:

$$R_{s,\gamma} = L_{s,\gamma} - \frac{N}{T_s h} \tag{26}$$

The distribution of loans will be updated as

$$\begin{cases} \gamma_{t+\Delta,\gamma} = \gamma_{t,\gamma}(1 - q_{13}(t) - q_{12}(t)) \\ \gamma_{t+\Delta,\phi} = \gamma_{t,\phi}(1 - q_{13}(t) - q_{12}(t)) \\ \phi_{t+\Delta,\gamma} = \phi_{t,\gamma}(1 - q_{23}(t) - q_{21}(t)) \\ \phi_{t+\Delta,\phi} = \phi_{t,\phi}(1 - q_{23}(t) - q_{21}(t)) \end{cases} \tag{27}$$

The total payments from the whole short term loan portfolio, denoted R_p, can then be expressed as

$$R_p(t+\Delta) = \mathbb{1}(t < T_s)\frac{h \cdot (T_s - t)}{h \cdot T_s}\left((\gamma_{t+\Delta,\gamma} + \phi_{t+\Delta,\gamma})R_{s,\gamma} + (\phi_{t+\Delta,\phi} + \gamma_{t+\Delta,\phi})R_{s,\phi}\right) \tag{28}$$

The indicator function again tells that no old loans will be left when $t = T_s$. The second term tells how many of the equally large parts of the old loans that has not matured. The P&L account will have interest payments (the other part of the payment is just cash flows) on the plus side and lost value of defaulted loans on the minus side at the end of each period, in total (for the short term loans):

$$R_{PL}(t+\Delta) = R_p(t+\Delta) - R_d(t+\Delta) \tag{29}$$

After this the distribution of loans will be normalized so that the sum is equal to one. The same procedure as described above is then taking place during the next time step. The long term portfolio will be treated in a similar way, only with maturity time T_l instead. The amount of old loans in the portfolio will be calibrated to the specific balance sheet that is studied.

5.6.6 New loans

New loans will be initiated at the beginning of each time period, both short term and long term, with a predetermined distribution of the quality of the loans. This distribution will be affected by the risk profile and strategy of the bank. A total value of N is allocated to the loans, and the payments are then calculated using the current federal funds rate and discount rates (see Eq. 23). Since the short term and the long term loans will have a similar behavior, it is enough to describe the short term loans. They will have a structure similar to the old loans, with market value (for loans starting at time point τ):

$$V_\tau(t) = \mathbb{1}(t < \tau + T_s) \sum_{i=1}^{(\tau+T_s-t)h} \left(\frac{L_{s,\gamma}\gamma_{t,\gamma} + L_{s,\phi}\gamma_{t,\phi}}{(1+b_\gamma(t,i/h))^{i/h}} + \frac{L_{s,\phi}\phi_{t,\phi} + L_{s,\gamma}\phi_{t,\gamma}}{(1+b_\phi(t,i/h))^{i/h}} \right) \tag{30}$$

The difference from the old loans is that the distribution will not be normalized at each time step. It will just be updated in a similar fashion as Eq. 27. The cash flows will also be similar to the formula for the old loans. To get the overall market value of the loan portfolio, the values of all sub-portfolios of both old and new loans are summed.

5.7 Liabilities

5.7.1 Deposits

The deposits are modeled as a stable source of funding, consisting only of retail deposits. The risk involved is the volatility of the deposit rate and the risk of rising deposit rates, which can be triggered by many factors, e.g. the competition for retail consumers which has significantly increased since the crisis, or a rising inflation rate which would force the bank to raise the deposit rates.

The value of the deposits are set to increase or decrease by a percentage each time period, reflecting the current scenario. The deposit rate are in the same manner set to capture the existing scenario. The deposit rate multiplied by the present value of the deposits will be accounted for as a cost on the Profit & Loss account.

5.7.2 Wholesale funding

Wholesale funding is modeled as Bank J borrowing money from the interbank market. The amount of wholesale funding needed is projected as the gap between assets and liabilities (including Shareholders' Equity) at the beginning of each time step, making the two books to match. In other words, the bank will raise the required amount of wholesale funding in order to finance loans and trading assets at each time step.

The risk factor considered for wholesale funding is the risk of a liquidity crisis, similar to the one during the financial crisis in 2008. The way of capturing this risk is by raising the projected interest rate paid to investors, thus making wholesale funding more costly. This will make a negative impact on the Profit & Loss account, since the total amount of wholesale funding multiplied by the cost of wholesale funding is registered as a loss there.

5.7.3 Share capital

Share capital is projected as an input parameter set by the bank, reflecting the current business strategy under consideration. Under all plans the share capital will be held constant, since it is assumed that the bank would not consider issuing more shares. The reason for this is that it is considered to be a big decision and something that would not be part of a regular business plan.

5.7.4 Retained earnings (Profit & Loss account)

Retained earnings for one period are projected by using the final result from the Profit & Loss account. The P&L account will include interest income from loans and coupon payments from corporate and government bonds. It will also consist of dividend payouts from the equity portfolio.

The total defaulted value of loans and bonds will also be registered on the P&L account. The recovered value of these bonds and loans will be put there as well.

The expenses from paying interest to depositors and investors through wholesale funding will also be accounted for.

After the deduction of operating costs (salaries, rent for buildings, other operating expenses) the bank will get the gross income for the period. The operating costs will be modeled as an increasing function of the total value of the assets, since it is reasonable to assume that the bank will get higher costs when expanding their business. The operating costs will be based on values from Profit & Loss statements, and will increase or decrease by a small percentage relative to the change in size of the assets. This reflect the fact that a doubling in size of the assets is not equal to a doubling in operating costs (many fixed costs will not change).

Then, taxes will be charged from the gross income, and the number used (30 % if positive gross income, 0 otherwise) is taken from the balance sheet data for the American bank that is the base for the projections (see section 6.1). After tax deductions, the net income is received.

Then the bank pays out dividends to its shareholders (zero if negative net profit), which will be treated using recommendations in Basel III[1](see figure 15), which use the CET 1 ratio as input parameter, combined with a strategy decision from the bank (a maximum set to 70 %). The resulting figure is the retained earnings for one time period, which are added to the accumulated retained earnings. This sum will be allocated as cash or in assets, which is a decision dependent on the strategy of the bank.

Individual bank minimum capital conservation standards	
Common Equity Tier 1 Ratio	Minimum Capital Conservation Ratios (expressed as a percentage of earnings)
4.5% - 5.125%	100%
>5.125% - 5.75%	80%
>5.75% - 6.375%	60%
>6.375% - 7.0%	40%
> 7.0%	0%

Figure 15: *Dividend payout rules in Basel III. The maximum dividend corresponds to the complement of the number in the second column (100%-x)[1].*

5.7.5 Reallocating assets/retained earnings at end of each period

After each time period trading assets and retained earnings will be reinvested in assets, cash or redistributed as retail loans. Also, the bank may choose to raise additional funds to buy more bonds/equity or lend more money to retail customers. This will be managed in the tool as input parameters, where the chosen inputs will reflect the business plan that is considered for Bank J.

5.7.6 Default state

The bankruptcy state for the bank will be defined as

$$\text{Share capital} + \text{Accumulated retained earnings} < 0. \tag{31}$$

This is because of the fact that the part of the liability side that is own capital is Share capital and accumulated retained earnings. If own capital becomes negative, the bank is in a defaulting state.

5.8 Risk-weighted assets

Before considering which business plans to stress test through scenario analysis, the risk-weighted assets used in the CET 1 ratio need to be projected. The three risk charges used for calculating the risk-weighted assets are market risk, credit risk and operational risk.

5.8.1 Market risk for Bank J

The capital charge for market risk for Bank J is calculated by using an internal method (VaR) approach. The assets that are subject to the market risk charge are the trading assets, which are the corporate bonds, government bonds, equity and cash. Since cash can be considered to have almost zero risk it will not be part of the model. The model will be based on the delta-normal method, which is described below.

The delta-normal method (also called covariance-variance method) is the simplest VaR approach and assumes that the risk factor changes are linear, stationary and multivariate normally distributed. These assumptions are often not fulfilled in practice[10], but it is assumed that the relatively simple portfolio of the bank can be described by this model in an accurate way. It uses the volatility of the different risk factor changes (yield curve, credit spreads, equity index) and the correlations between them. The volatility and correlation are calculated as described in section 5.4.5. The volatility vector is scaled from 1-day to 10-day volatilities (required time horizon in Basel) by multiplying with the square root of ten[8]. A matrix multiplication generates the covariance matrix from the volatility vector and the correlation matrix, denoted $\sum$. Multiplying this with the vector of exposures $\mathbf{x}$ (which has been multiplied by the Modified duration for bonds) gives the variance,

[8]The standard way of transforming a volatility to another time horizon is to multiply by the square root of the relative time factor. For example, a 2-day volatility would be translated into a 10-day by $\sigma_{10} = \sigma_2 \cdot \sqrt{\frac{10}{2}}$.

$\sigma^2 = \mathbf{x'} \sum \mathbf{x}$. The square root of this value gives the standard deviation, σ. Multiplying this value with 2.32, which is the 99 % quantile for the normal distribution, gives the VaR for the portfolio.

This should then be compared to the average VaR of the last 60 days, calculated in the same manner for each day and multiplied with a bank-specific factor called k, which is set to 3(see Eq. 2). The larger of these two should be applied as the market risk charge. To simplify things, the calculated VaR number is used as the average VaR as well. An additional stressed market risk charge is added as well, using data from the financial crisis in 2008 as a stressed calibration period. Since the IRC charge deals with assets exposed to liquidity risk, and the assets in the portfolio are assumed to be highly liquid, no IRC charge is incorporated into the calculation.

Finally, a specific risk charge, C_{SR}, is calculated using the standardized method, which applies risk weights to the various assets in the portfolio (specified by Basel). The bank can choose a combination of the internal method approach and the standardized approach, or the supervisors can impose such demands if parts of the internal model does not capture risks in a sufficient way. The investment grade bonds receive a percentage weight of 0.25-1.6 % depending on the maturity of the bonds. The junk bonds receive a risk weight of 8 % for all maturities. The equity portfolio gets a risk weight of 8 % and the government bonds get a risk weight of zero, due to the low risk associated with those assets. The market value of each group is then multiplied with the corresponding risk weight and summed, which gives the total specific risk charge.

The sum of the two VaR components and the specific risk charge gives the total market risk charge for Bank J.

5.8.2 Credit risk for Bank J

The credit risk charge is applied to the assets in the banking book, which for Bank J are the retail loans. The bank uses the advanced internal ratings-based approach (A-IRB) and is assumed to estimate its own PD, LGD and EAD numbers under certain scenarios and business plans. These numbers differ for the high quality customers and the low quality customers and the capital charges are therefore calculated and treated separately, giving two charges for two portfolios, one for customers that are currently high quality and one for customers that are currently low quality. These charges are then added, which gives the total credit risk charge. The exposures (EAD) are treated as being the current market value of the loans, as explained in section 5.6.4. The PD and LGD values are estimated as described in sections 5.4.6 and 5.4.3. The formula is

$$\begin{cases} \mathrm{R} = 0.03 \cdot \left(\frac{1-e^{-35 \cdot PD}}{1-e^{-35}}\right) + 0.16 \cdot \left(1 - \frac{1-e^{-35 \cdot PD}}{1-e^{-35}}\right) \\ \mathrm{K} = \left(\mathrm{LGD} \cdot \Phi\left((1-\mathrm{R})^{-0.5} \cdot \Phi^{-1}(\mathrm{PD}) + \left(\frac{\mathrm{R}}{1-\mathrm{R}}\right)^{0.5} \cdot \Phi^{-1}(0.999)\right) - \mathrm{PD} \cdot \mathrm{LGD}\right) \\ \mathrm{RWA} = \mathrm{K} \cdot 12.5 \cdot \mathrm{EAD} \end{cases}$$

where the outputs are:

$$\begin{cases} \text{R - asset correlation,} \\ \text{K - capital requirement} \\ \text{RWA - risk-weighted assets} \end{cases}$$

5.8.3 Operational risk for Bank J

Operational risk is calculated by using the Basic Indicator Approach (BIA, see section 3.3.1), which uses the average annual gross income for the last three years. In order to avoid distorted values, due to no positive income in the last three years, a charge equal to the credit risk charge is applied if this is the case.

6 Testing business plans under different scenarios

6.1 Initial portfolio of Bank J

The portfolio described in the previous section needs to be initiated with a distribution of bonds, equity and loans. For this purpose, balance sheet data from a U.S. bank called Wells Fargo is used. Annual statements of banks are publicly available and free to use. Since the balance sheet data (see Appendix C) consists of more asset classes than Bank J, the various assets are grouped within the existing asset classes in the portfolio. The rules applied for this can be studied in Appendix C. The resulting portfolio is seen in table 1. The bank was rated A+ by S&P at the end of 2012, which will be Bank J's initial rating in the scenarios.

Table 1: Balance sheet of Bank J (B$)

Assets	Value	%
Government bonds	184	12.9
Corporate bonds	140	9.9
Equity	57	4.0
Cash	102	7.2
Retail loans	939	66.0
Liabilities	**Value**	**%**
Deposits	1002	70.5
Wholesale funding	262	18.4
Share capital	81	5.7
Retained earnings	77	5.4

6.2 Business plans

In the following subsections four different business plans considered for the bank are presented. The plans describe different ways of allocating assets in the portfolio for the next five years. Under all business plans, the distribution between short term and long term bonds will be 50 % and the target maturity is set to 10 years. The loans will be divided equally into short term and long term loans as well. This is to enable a more robust discussion of the results. All plans except Plan 2 will have an equal number of high quality and low quality customers for the retail loans.

6.2.1 Plan 1 - Keeping current portfolio structure

Under the first plan, the bank simply holds its current portfolio allocation and aims at keeping it constant in size. This will be referred to as Plan 1.

6.2.2 Plan 2 - Increasing trading portfolio

Under this suggested plan, the bank increases its trading portfolio by approximately 15% annually during the 5 year horizon and is targeting a constant size in value of the retail loan portfolio, making the loans less important and going in a direction towards an investment bank portfolio. An annual increase of 15 % corresponds to approximately a doubling in size of the trading portfolio over five years. Also, the bank will move towards riskier assets (more junk bonds and equity). The bank will increase its corporate bond portfolio from 10 % to around 25 % and allocate 90 % of this to junk bonds. It will also increase the equity portfolio from 4 % to 14 %. The bank will target more low quality customers (around 60 % of retail loans) in order to reach higher returns. To achieve this expansion, the bank will raise more wholesale funding during the time period.

6.2.3 Plan 3 - Increasing retail loan portfolio

Under this plan the bank instead relies more on retail loans and expands its retail loan portfolio by around 15 % on an annual basis during the 5 year horizon, targeting a structure closer to a retail bank portfolio. The trading portfolio will be kept constant and is focusing on safer assets, such as government bonds. The retail portfolio will go from initial 66 % to around 80 % and the government bonds will be more than 50 % of the trading portfolio. This plan also involves a more aggressive approach on the interbank market.

6.2.4 Plan 4 - Aggressive growth agenda

Under this approach the bank is increasing the whole portfolio by around 15 % annually, targeting a total expansion of around 100 % for the five year plan. The reason for this is to win market shares in order to get a bigger influence on the level of loan rates and funding costs. The distribution of assets will be the same as for Plan 1, and the size of the portfolio is the changing parameter.

6.3 Scenarios

Stress testing under ICAAP involves evaluating the impact of extreme, but plausible, scenarios. Therefore, a key issue is how to select these scenarios, since it often involves a certain degree of subjectivity. Stress testing can be done by stressing individual variables, as a sudden decrease in equity index or a 100-basis-point shift in the yield curve. It can also involve stressing several risk factors at once, since this often is the case in reality. When one risk factor makes a sudden change, it is very likely that other risk factors will do as well. Another option is to let management construct scenarios, involving expert judgement to a large extent.

The scenarios can also be based on historical periods of significant stress. This is the approach in the construction of scenarios in this thesis. The nature of this challenge lies in the fact that history never repeats itself exactly. For example, people involved in trading try to avoid making the same mistakes as those causing earlier recessions and huge losses. The solution to this is to base the scenarios on past events, but to include some key aspects of the current financial situation. The objective is to capture the spirit of historical downturns, and still keep it consistent with the world we see today.

One of the biggest issues with stress testing and "what if"-scenarios is the problem of assessing a probability to a certain scenario. Even if the model that projects the assets and liabilities is calibrated in a good way, it is still not telling us anything about the probability of occurrence of the event. The solution is often to use expert judgement to estimate this probability.

Three 5-year scenarios will be constructed; one base case scenario, which is treated as how the future could possibly evolve under normal market conditions where no stresses occurs, and two historical time periods. The first one captures the climate of the period 2000-2004, under which the dot-com bubble in 2000 and events like the 9/11 attacks made significant impacts on the U.S. market in 2002 and 2003. The second one uses historical data from the period 2005-2009, which involves the financial crisis in 2008.

All three periods will use market conditions as today as a starting point and then evolve differently over time.

6.3.1 Scenario 1 - Base Case Scenario

The Base Case Scenario will be treated as if the current financial climate is continuing in the same manner for the next five years. The short term Treasury rate will continue to be low (it has been around 0.1 % the last 4 years). The yield curve between 2009 and 2013 can be seen in figure 16. The credit spreads will, as during the last 4 years, vary between 1.5 and 2.5 %

for investment grade bonds and 5 to 7 % for junk bonds (see figure 17).

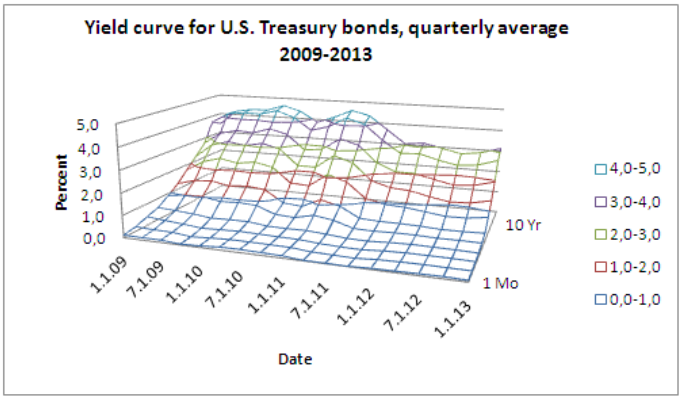


Figure 16: *Yield curve for U.S. Treasury bonds on a quarterly average basis between 2009 and 2013. As can be seen, the yield curve has kept a similar shape with low rates for short maturities.*

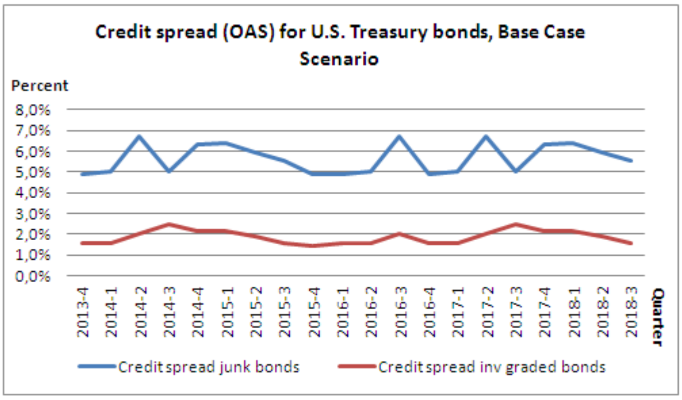


Figure 17: *Credit spread for U.S. Treasury bonds for Base Case Scenario.*

The funding costs for wholesale funding will be low, around 0.2-0.3 % yearly, and the deposit rate is set to a constant value of 0.1 %. The bank is assumed to keep its current credit rating (A+) throughout the period. The credit quality of the corporate bonds will be described by a migration matrix that has low Probability of Default for both investment grade and junk bonds (see Eq. 32 for quarterly averages). The probabilities are based on historical observations under normal market conditions. The matrix will move with low variability around these numbers during the scenario.

$$P = \begin{pmatrix} 99.55\% & 0.4\% & 0.005\% \\ 0.9\% & 98.7\% & 0.4\% \\ 0 & 0 & 100\% \end{pmatrix} \tag{32}$$

Loss Given Default is set to 30 % for both retail loans and corporate bonds. The annual discount rate is around 3 % for high quality customers and 10 % for low quality customers, and the loan rates slightly above those numbers, with a margin equal to the federal funds rate. The migration matrix will be set to a constant matrix (see Eq. 13), as described in section 5.4.3.

The volatilities and correlations involved in the market risk charge will be set to numbers similar to those observed under normal market conditions.

6.3.2 Scenario 2 - Early 2000's Recession (2000-2004)

The second scenario deals with the period from 2000 to 2004, which involves the burst of the Dot-com bubble in 2000 and the recession that followed. The scenario will focus on the things that happened after the bubble. This scenario simulates the effects of a similar recession in the near future.

In 2000 the yields on bonds were high; for example the yield on 3-month U.S. T-bills were around 5-6 %. The yields declined during the recession, and in 2004 the 3-month yield on the same type of bond was around 1 %. The yields on short term U.S. T-bills are today close to zero. To create a scenario that would be consider plausible, but yet extreme, a burn-in period of one year is introduced, where the yields rises quickly and reaches a level of around 4-5 %. Then they follow the historical data points from the period 2001-2004. The historical yield levels are plotted in figure 18. The credit spreads had a similar level back in 2000 compared to today, and will be set to values given from historical data. They varied between 1-2 % for investment grade bonds and between 3-10 % for junk bonds (see figure 19).

The Probability of Default was high (close to 3 % quarterly) for junk bonds during 2001 and 2002, which reflects the significant stress that was endured. In 2003 and 2004 the probabilities declined as a result of the economy recovering from the recession. The probability of default for investment grade bonds were quite low (0.01-0.06 %) during the whole period, but the migration probabilities from investment grade to junk bonds more than doubled (from 0.5 % to 1.1 % quarterly) from 2000 to 2002. They decreased during 2003 and 2004, just as the default probabilities for junk bonds did. The PD values in the scenario are set to the same numbers as the historical values. Loss Given Default in this particular scenario is, for both bonds and

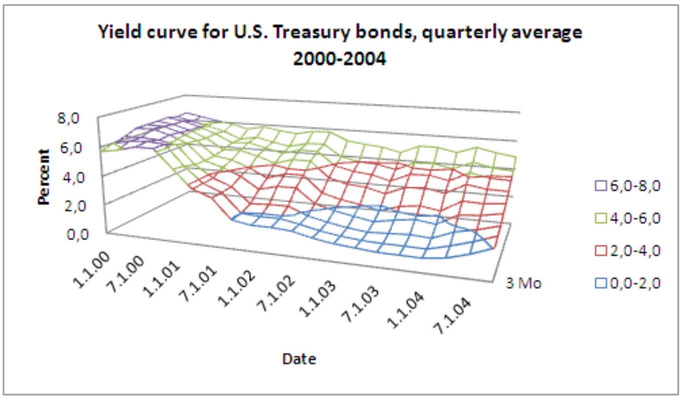


Figure 18: *Yield curve for U.S. Treasury bonds on a quarterly average basis between 2000 and 2004. As can be seen, the yield curve went from a quite flat shape with high interest for low maturities to a more steeper shape from 2002 and forward.*

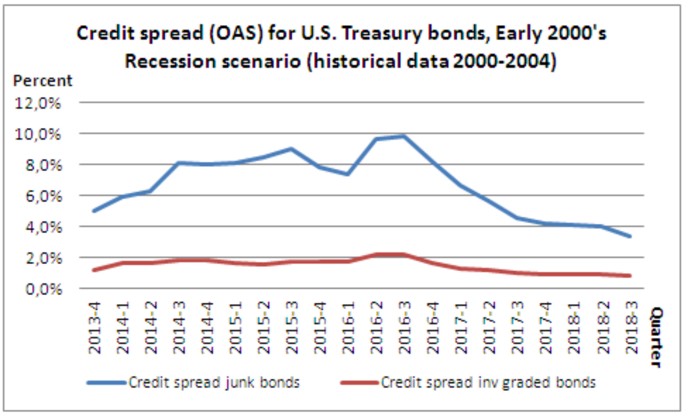


Figure 19: *Credit spread for U.S. Treasury bonds for Early 2000's Recession scenario.*

retail customers, set to 30 % in the first year, then an increase to 50 % in year 2 and 3, and ending in 30 % during the 4th and 5th year.

The discount factor for retail loans is just as in the Base Case Scenario set to 3 % for high quality customers (the spread between the prime rate and the federal funds rate during 2000-2004) and 10 % for low quality customers (average credit card rate over federal funds rate). Probability of Default will be the same as under the Base Case Scenario, but with a doubled PD under the second and third year, which are the stressed years in the scenario. The second component of the loan rate, which is the federal funds rate, was at a significantly higher level in 2000 than it is today, which should be adjusted in a similar fashion as the yield curve. The reason for this is that they are closely related. The federal funds rate can be viewed as the target lending rate set by the government, and the yield curve as the borrowing rate (U.S. Treasuries are issued to raise funds). Therefore, the federal funds rate will be raised to historical levels during a one-year burn-in period. Regarding the actual probability of the U.S. Federal Reserve quitting the zero-interest rate policy that has been the strategy since the crisis, no investigations are made. This could perhaps eliminate the scenario as a plausible one, but that is a question to be evaluated by management and experts. Let's make the assumption that the scenario is in fact plausible, but extreme.

The federal funds rate is then increased during the first year, to 4 %, and then follows historical values of a steady decline during a recession down to 1 % in three years followed by an increase in the 5th year. The credit rating of the bank will migrate to BBB+ in year 2 and 3, but advance in rating to a final score of A in year 5. The total funding costs for the scenario are plotted in figure 20. The deposit rate is around 0.5 % on an annual basis.

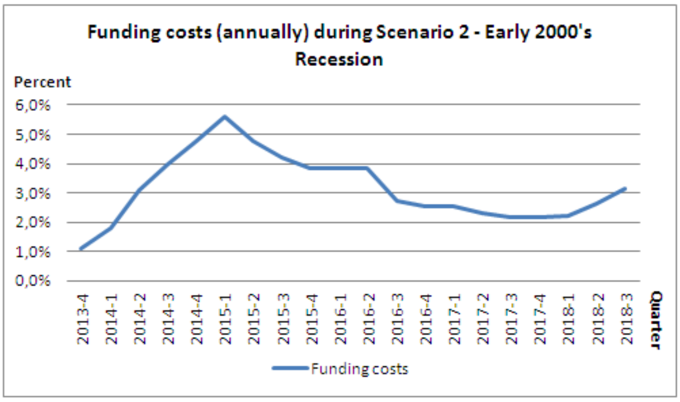


Figure 20: *Annual funding cost rate for Bank J under Scenario 2 - Early 2000's Recession.*

The volatilities and correlations of assets in the trading portfolio are following historical estimates (see Appendix A). The equity portfolio will move like the historical data shows in figure 13, with a rapid decrease in the first two to three years, and then a growth when the market recovers from the recession.

6.3.3 Scenario 3 - Financial Crisis (2005-2009)

The third scenario uses historical inputs from the years leading up to the financial crisis in 2008 and the aftermath in 2009. This involves the housing bubble (including subprime-mortgage crisis) that escalated in 2007 and the following financial crisis that affected the whole economy. Another cause of the crisis was the increased leverage that financial institutions took on as credit was easy to obtain. An increase in off-balance sheet leveraging, which is a way of banks to move assets of the balance sheet in order to meet capital requirements, enabled banks to keep this heavy leveraging process in place. Also, the creation and misuse of complex financial assets such as CDO's, which contained low quality mortgages, and CDS's, which is an insurance contract that protects the lender against default of the borrower, led to further degeneration of the stability of the economy. The decreased trust among banks led to a unwillingness to lend, which created major liquidity issues during the crisis.

The yield curve during the years leading up to the crisis shows an interesting shape (see figure 21). There is a hump in the curve during 2006 and 2007, which usually is an indicator of a recession. As can be seen, there is a big drop in the curve during 2008 and 2009 for low maturities when the crisis peaked. This can be interpreted as a typical flight to quality-response by the market. When market volatilities rise a search for safer and more liquid assets is regarded as expected. The increased demand, and price, for these kinds of assets leads to a decrease in yields. Another explanation for the structure of the yield curve for short term bonds is the connection to the federal funds rate, which increased and decreased in a similar manner during the same period, which can be seen in figure 14.

The yield curve is, just as for Scenario 2, adjusted in the beginning to fit the current yield curve. The credit spreads show a significant increase during the crisis (see figure 22), but have initial values that can be considered reasonable. The bond default probabilities increase from 0 % to 0.05 % for investment grade bonds during the scenario and from 0.4 % to 2.8 % for junk bonds (aligned with historical data). LGD for both corporate bonds and government bonds are set to 30 % during the first three years and then stressed to 50 % during the last two.

The retail loan customers have a spread of 3 % and 10 %, just as in the other scenarios. This is in line with historical data. Probability of Default will be doubled during the stressed years and is therefore raised from 0.3 % to 0.6 % for high quality customers and 1.3 % to 2.6 % for low quality customers. The migration probability from high to low quality is doubled as well, from 1 % to 2 %. The federal funds rate will grow fast in the beginning

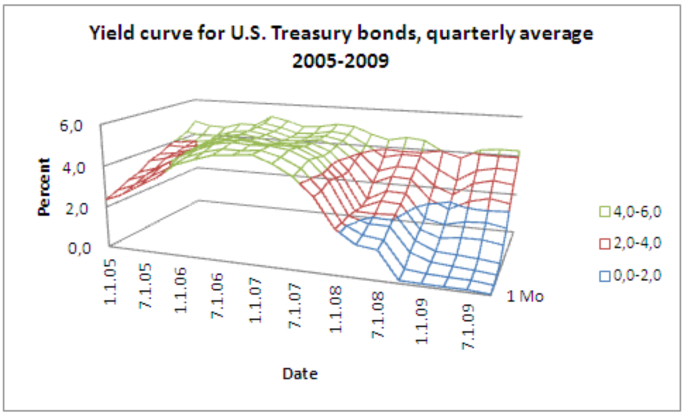


Figure 21: *Yield curve for U.S. Treasury bonds on a quarterly average basis between 2005 and 2009. The yield curve has a hump in its shape during 2006 and 2007, indicating a future recession.*

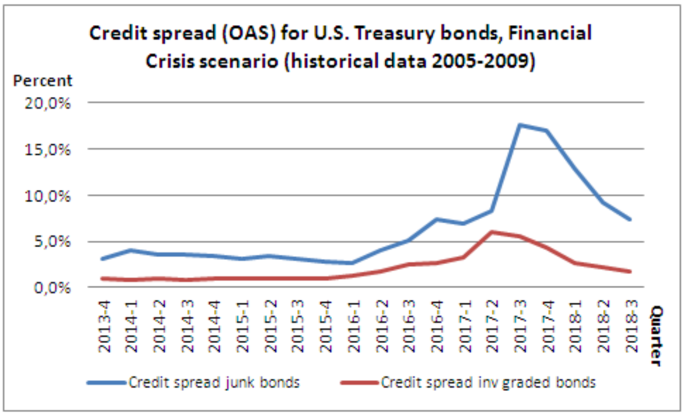


Figure 22: *Credit spread for U.S. Treasury bonds for Financial Crisis scenario.*

and then decline during the crisis, with an added peak during autumn 2008 (increased TED spread) as a way of capturing the liquidity crisis. The bank will migrate from A+ to BBB gradually during the scenario, which will also increase the funding costs. The funding costs can be seen in figure 23. The deposit rate is around 0.5 % annually.

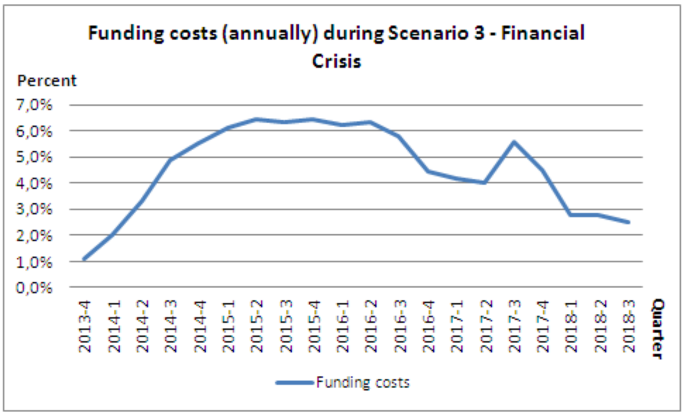


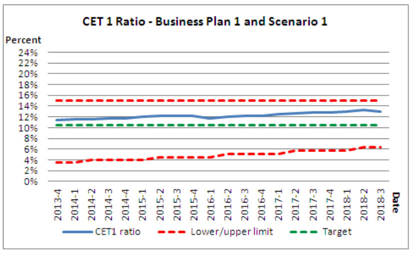
Figure 23: *Annual funding cost rate for Bank J under Scenario 3 - Financial Crisis.*

7 Results

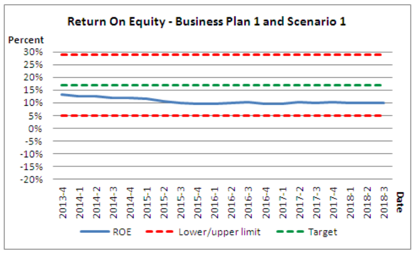
The results show the risk metrics under the three scenarios and the four business plans.

7.1 Scenario 1 - Base Case Scenario

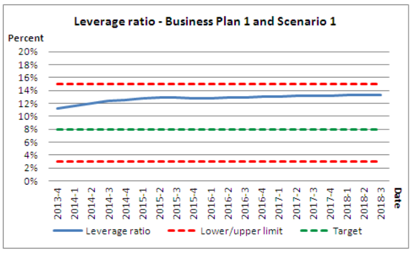
The risk metrics for the Base Case Scenario should confirm that the bank has a viable structure under at least some of the proposed business plans. The risk metrics for the first business plan - to keep the current structure of the portfolio and a constant size - are shown in figure 24. It shows that all risk metrics are performing well with no breaches. The CET 1 ratio is close to the upper limit at the end, indicating that the approach may be too risk averse.



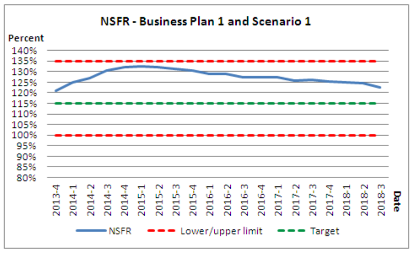
(a) *CET 1 ratio*



(b) *Return on Equity*



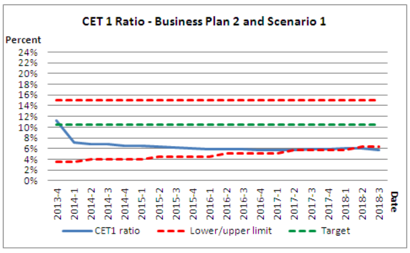
(c) *Leverage ratio*



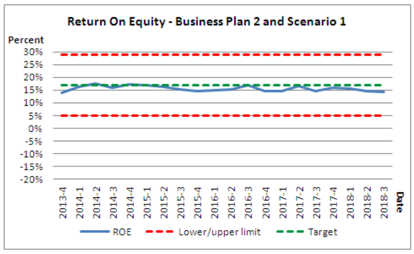
(d) *NSFR*

Figure 24: *The risk metrics under Scenario 1 - Base Case Scenario and Business Plan 1 show that all four risk metrics are within limits.*

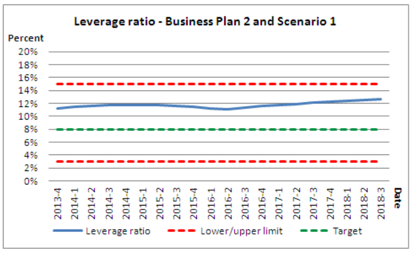
The second business plan - to double the size of the trading portfolio during a 5-year horizon - shows the resulting risk metrics in figure 25. Since the trading assets are shifting towards more risky assets (especially equity), this will have an impact both on returns and on the CET 1 ratio. The projected returns are higher than for Business Plan 1 and the CET 1 ratio is lower.



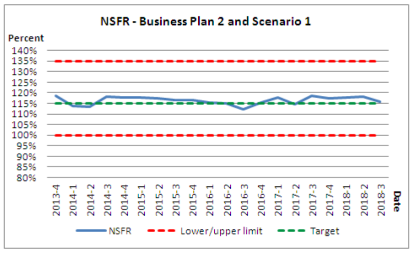
(a) *CET 1 Ratio*



(b) *Return on Equity*

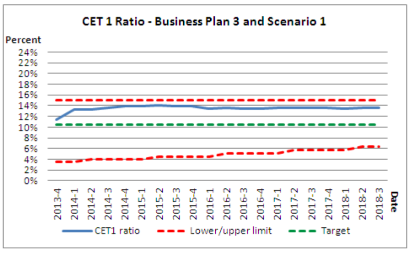


(c) *Leverage ratio*

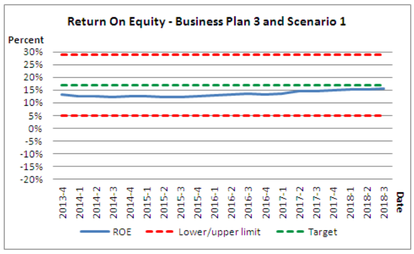


(d) *NSFR*

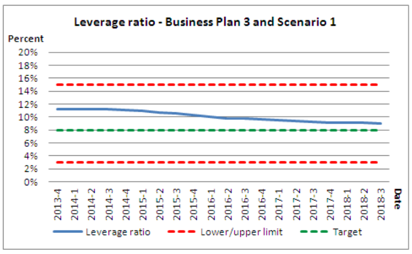
Figure 25: *The risk metrics under Scenario 1 - Base Case Scenario and Business Plan 2 show that three out of four risk metrics are within limits. Only one is below, which is the CET 1 ratio, and it is just breaching the lower limit at the end of the scenario.*



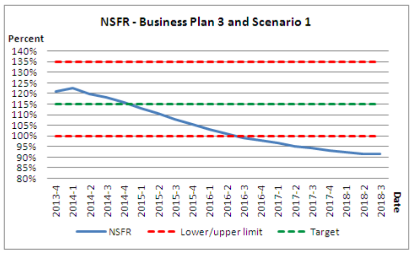
(a) *CET 1 Ratio*



(b) *Return on Equity*



(c) *Leverage ratio*

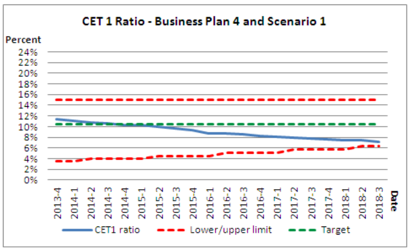


(d) *NSFR*

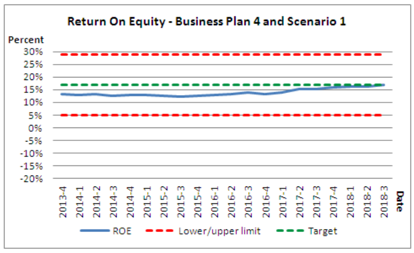
Figure 26: *The risk metrics under Scenario 1 - Base Case Scenario and Business Plan 3 show that three out of four risk metrics are within limits. The only metric that is outside limits is the NSFR, which is breaching the lower limit.*

The third plan - to double the retail loan portfolio during the 5-year projection period - is shown in figure 26. It shows that the NSFR is breached at the end of the period, and this is due to the high weight that is applied for retail loans (85-100 %). The plan will, however, give good results when it comes to capital adequacy. This can be concluded from the CET 1 ratio, which is close to the upper limit and is showing values around 14 %.

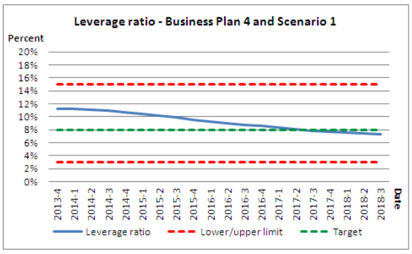
The fourth plan is the aggressive growth agenda, which aims at doubling the size of the whole portfolio during a 5-year time horizon. The resulting risk metrics can be seen in figure 27. ROE shows a positive trend, but the other three risk metrics decreases during the scenario. This is to expect, as a quick increase in growth often implies a bigger reliance on debt.



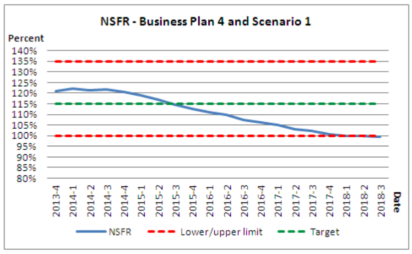
(a) *CET 1 Ratio*



(b) *Return on Equity*



(c) *Leverage ratio*

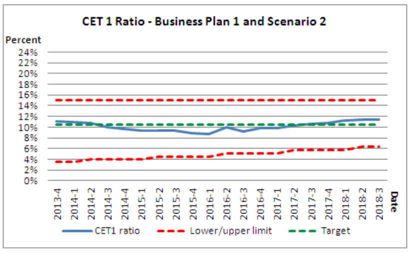


(d) *NSFR*

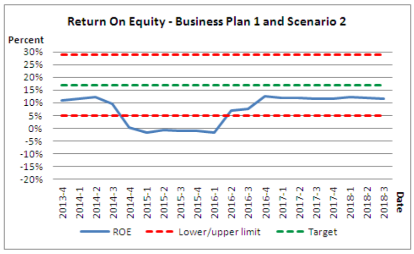
Figure 27: *The risk metrics under Scenario 1 - Base Case Scenario and Business Plan 4 show that all four risk metrics are within limits. Return on Equity shows a good trend but the CET 1 ratio and the NSFR are decreasing and are close to the lower limit and the end of the period.*

7.2 Scenario 2 - Early 2000's Recession

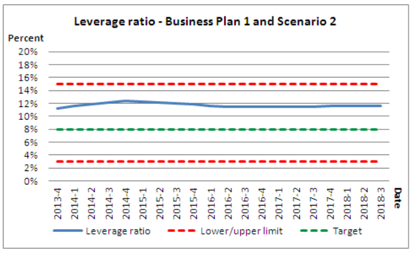
The risk metrics for Scenario 2, Early 2000's Recession, is presented below. The resulting risk metrics for the first business plan can be seen in figure 28. There is a breach of the ROE metric and this is during the stressed period similar to the years 2001 and 2002. The other three risk metrics are within limits during the whole period.



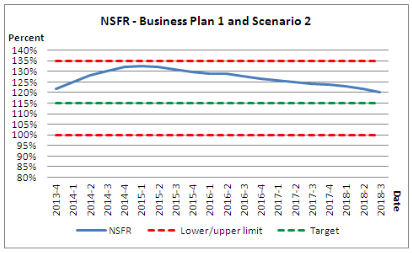
(a) *CET 1 ratio*



(b) *Return on Equity*

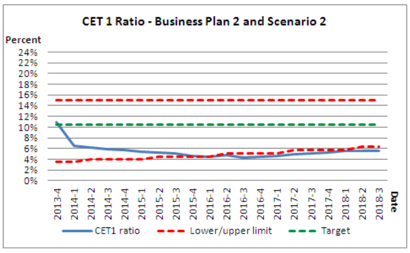


(c) *Leverage ratio*

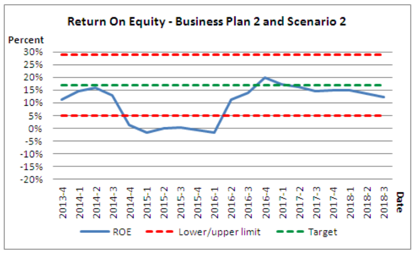


(d) *NSFR*

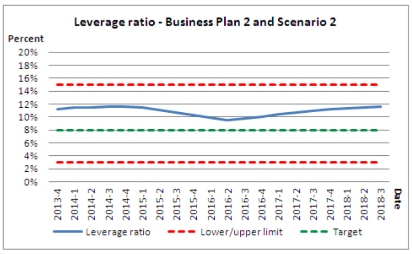
Figure 28: *The risk metrics under Scenario 2 - Early 2000's Recession - and Business Plan 1 show that three out of four risk metrics are within limits. The only breach is for ROE, which goes below the lower limit during the second and third year.*



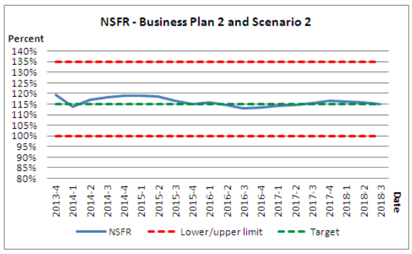
(a) *CET 1 Ratio*



(b) *Return on Equity*



(c) *Leverage ratio*

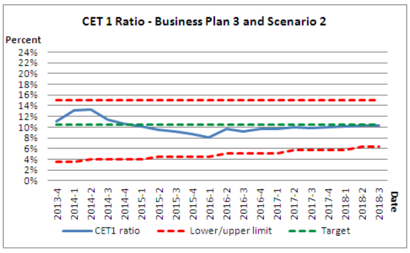


(d) *NSFR*

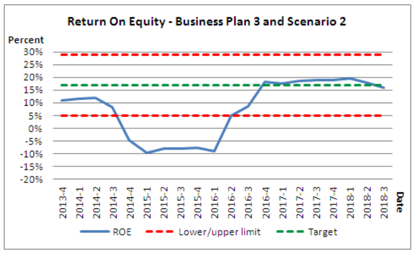
Figure 29: *The risk metrics under Scenario 2 - Early 2000's Recession - and Business Plan 2 show that two out of four are within limits. ROE is breached during years 2-3, but the values are just below zero. The CET 1 ratio is being breached during years 3-5.*

The second business plan shows the resulting risk metrics in figure 29. The CET 1 ratio goes slightly below the lower limit during years 3 to 5, due to a significant increase in the market risk charge. The ROE is breached; however it is close to keeping a positive return during every quarter for the whole period. The Leverage ratio and the NSFR are within limits during the entire 5-year period.

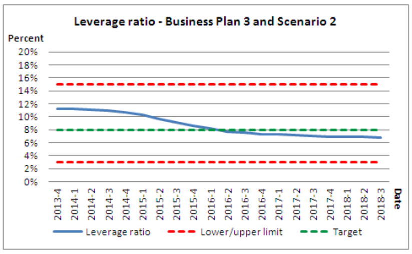
In figure 30 we can see the results from the third plan; to increase retail loans by 100 % in five years. It shows that the portfolio endures significant stress in terms of ROE and NSFR. The proposed plan could potentially lead to negative income during year 2 and 3, but a good revenue during year 4 and 5.



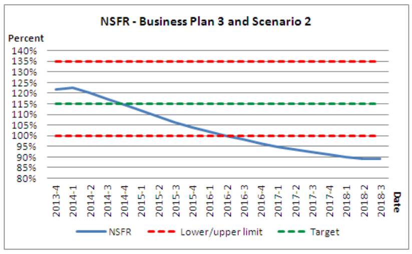
(a) *CET 1 Ratio*



(b) *Return on Equity*



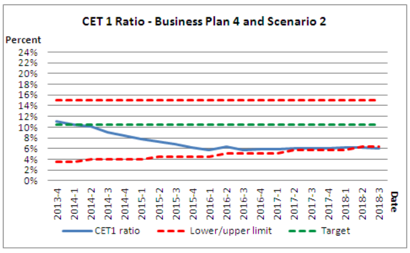
(c) *Leverage ratio*



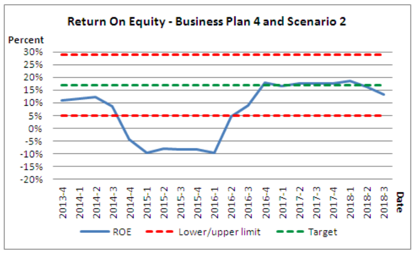
(d) *NSFR*

Figure 30: *The risk metrics under Scenario 2 - Early 2000's Recession - and Business Plan 3 show that two out of four risk metrics are within limits. ROE reaches values around -10 % during the stressed years and NSFR is around 90 % at the end of the period, which is due to the expansion of retail loans, affecting the ratio negatively. The CET 1 ratio is above target at the beginning of the scenario.*

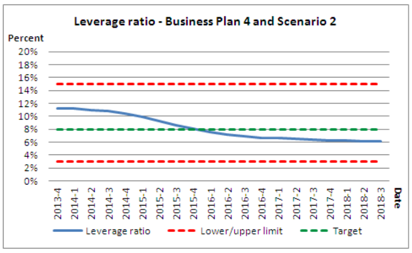
The fourth plan, the aggressive growth agenda approach, is shown in figure 31. ROE is similar to the results for Business Plan 3, but the CET 1 ratio is significantly more stressed under this plan. The Leverage ratio reaches values below target and is down at 6 %, but the bank still meets its regulatory requirements. NSFR shows a decreasing trend and is below the lower limit at the end of the period.



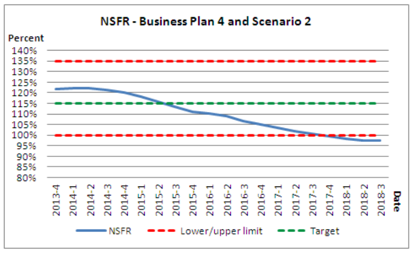
(a) *CET 1 Ratio*



(b) *Return on Equity*



(c) *Leverage ratio*



(d) *NSFR*

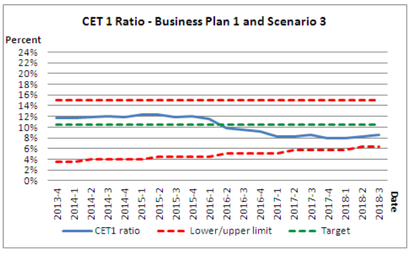
Figure 31: *The risk metrics under Scenario 2 - Early 2000s recession - and Business Plan 4 show that two out of four risk metrics are within limits. ROE is far below its lower limit during year 2 and 3 but goes above target during year 4 and 5. CET 1 ratio and Leverage ratio start above target but both go below and are close to the lower boundary at the end of the period. NSFR breaches its lower limit at the end of the period.*

7.3 Scenario 3 - Financial Crisis

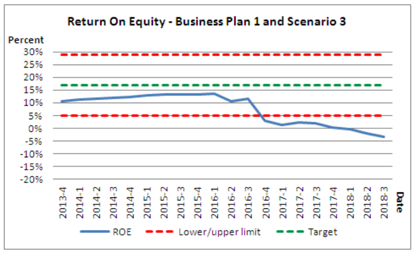
The risk metrics for Scenario 3, Financial Crisis, are presented below. The risk metric results for Business Plan 1 are shown in figure 32. The only risk metric limit that is breached is the lower limit for ROE. This corresponds to the stressed part of the scenario, namely the years corresponding to 2008 and 2009.

The second business plan - to increase the trading portfolio and go into a direction of more risky assets - shows the resulting risk metrics in figure 33. The CET 1 ratio is breached during the last two years, due to the larger share of risky assets and riskier retail loan customers, which affects the market risk charge and the credit risk charge in a negative way. ROE is breached at the end of the period, but is making good revenue during the crisis. The Leverage ratio is above target and the NSFR is above or just below target during the 5-year horizon.

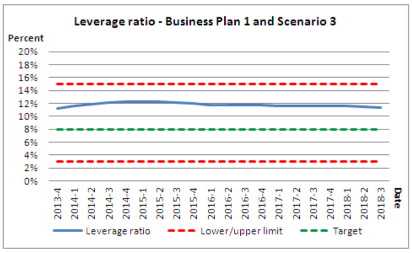
The third plan, which involves an expansion of the banking book as well as more investments in safer assets such as government bonds, can be seen in figure 34. It shows that the portfolio is exposed to big losses, with ROE



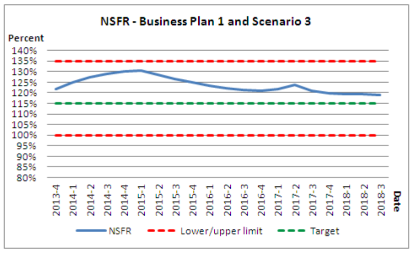
(a) *CET 1 ratio*



(b) *Return on Equity*

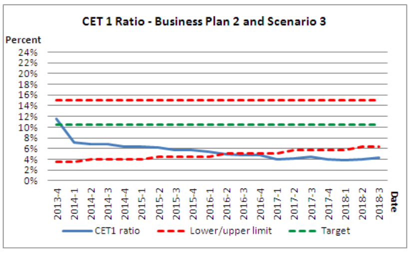


(c) *Leverage ratio*

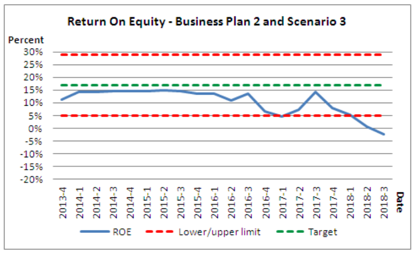


(d) *NSFR*

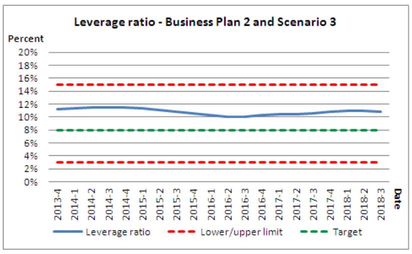
Figure 32: *The risk metrics under Scenario 3 - Financial Crisis - and Business Plan 1 show that three out of four are within limits. ROE is breached at the end of the period, which is when the stressed part of the scenario is taking place.*



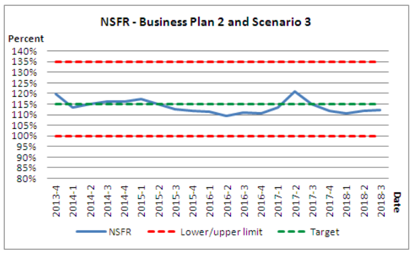
(a) *CET 1 Ratio*



(b) *Return on Equity*



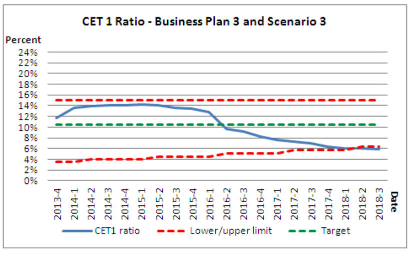
(c) *Leverage ratio*



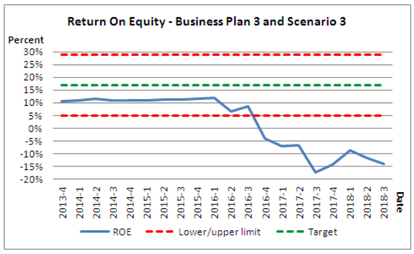
(d) *NSFR*

Figure 33: *The risk metrics under Scenario 3 - Financial Crisis - and Business Plan 2 show that two out of four are within limits. ROE is breached in year 5, but is making good revenue during year 4. The CET 1 ratio is breached during years 4 to 5.*

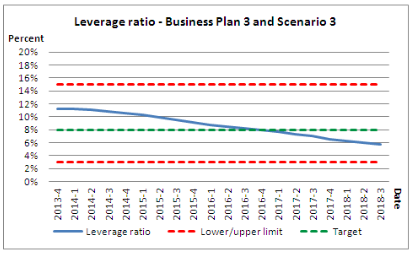
values close to -20 %. One explanation to this could be that the increased amount of retail loans, increased funding costs (the retail loan portfolio is 66 % of the portfolio and a 100 % increase leads to a significant increase in wholesale funding) and increased probabilities of default of retail customers together make a huge impact on the P&L account.



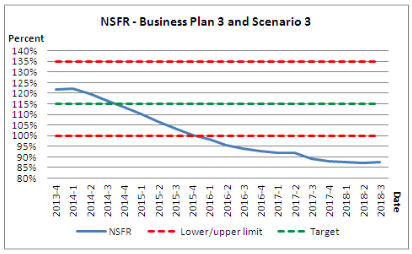
(a) *CET 1 Ratio*



(b) *Return on Equity*



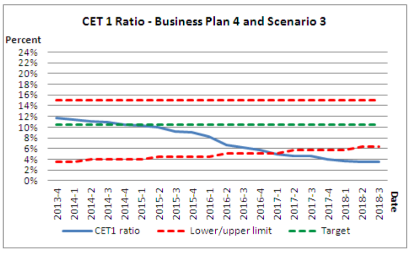
(c) *Leverage ratio*



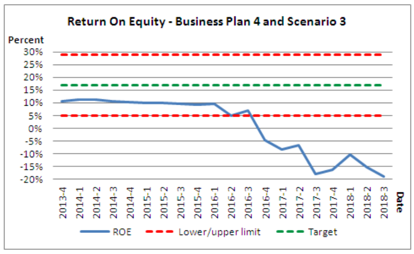
(d) *NSFR*

Figure 34: *The risk metrics under Scenario 3 - Financial Crisis - and Business Plan 3 show that one out of four is within limits. ROE reaches values near -20 % at the peak of the crisis and NSFR is around 85-90 % at the end of the scenario. The CET 1 ratio is close to the upper limit at initial years, but just below the lower limit at the end of the period.*

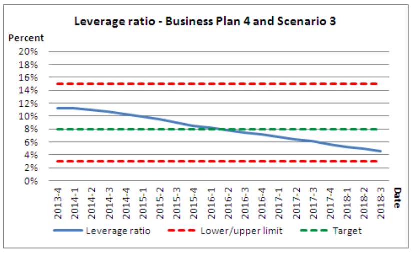
Business Plan 4 - Aggressive Growth Agenda - is shown in figure 35. This plan fails to meet the lower limits in three out of four metrics, and is under 5 % for the Leverage ratio, which is close to the minimum requirements of 3 % in Basel. Return on Equity is showing large negative returns during the end of the period. NSFR maintain values above the lower limit during year 4, but fail to meet its limits during year 5. The CET ratio breaches its lower limit after the third year. This approach would be considered as too risky under the Financial Crisis scenario.



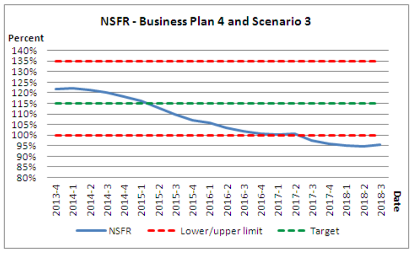
(a) *CET 1 Ratio*



(b) *Return on Equity*



(c) *Leverage ratio*



(d) *NSFR*

Figure 35: *The risk metrics under Scenario 3 - Financial Crisis - and Business Plan 4 show that just one out of four is within limits and all four are below target. There is significant losses in ROE during year 4 and 5. The Leverage ratio is above the lower limit, although quite close to a breach at the end of the scenario.*

8 Conclusions

The scenarios demonstrate a differentiation for different business plans, and the risk metrics could together serve as a good indicator base for identifying potential excessive risk taking. One is focusing on capital adequacy, one on returns, one on amount of non self-financed debt and one on stability of debt. These take into account many of the risks relevant to a domestic bank.

8.1 Scenario 1 - Base Case Scenario

The first scenario, the Base Case Scenario, is just as expected not breaching the lower limits of the the risk metrics to a large extent under any of the proposed business plans. It shows a potentially too risk averse approach for Plan 1. This is to expect since Plan 1 is the most modest plan with no aim of growth or reallocations towards riskier assets.

For Plan 2, it is projecting good returns but is also challenging the capital requirements. This is in line with what could be expected for a more investment focused portfolio under normal market conditions.

The third plan, to increase retail loans, is projecting good returns as well as very good CET 1 ratios. This is the result from a low credit risk charge under normal market conditions. The amount of stable funding (NSFR) decreases due to the rapid growth of wholesale funding under this scenario and the high weight applied for retail loans when calculating the NSFR. The weight is high due to the illiquid nature of retail loans.

Business Plan 4 shows a decrease in the Leverage ratio and NSFR, and this is also due to an aggressive growth of wholesale funding. Deposits are assumed to follow GDP, which makes relatively small changes, and therefore it is wholesale funding that is the growing part of the liabilities. However, the more diversified approach with an increase of both trading assets and the banking book, can be interpreted as an explanation to why all risk metrics are within limits. All four plans are fulfilling the Leverage ratio requirements, which confirms that the positive ROE trend is complemented by a sound distribution of equity and debt. This is also a sign that the bank has good expanding possibilities based on its current liability structure.

8.2 Scenario 2 - Early 2000's Recession

The second scenario, Early 2000's Recession, shows some interesting results. All four plans have a similar shape when it comes to ROE, but Plan 1 and Plan 2 are absorbing losses in a better way during the stressed years. Business Plan 1 also manages to keep the other three risk metrics within limits, and can therefore be considered the most suitable plan to follow under this scenario. Plan 2 also displays good results with better returns than Plan 1 and just a small breach of the CET 1 ratio. The lower ROE for Plan 1 is due to the fact that the portfolio consists of less risky assets, but this pays off in terms of the other three risk metrics, with more stable funding and lower amount of Risk-Weighted Assets (RWA).

Plan 3 has a breach in ROE and NSFR. For ROE, this could be explained by the high probability of default for both high quality and low quality customers, leading to large default losses, in combination with increased funding costs due to a greater reliance on wholesale funding. As far as NSFR is concerned, it is quite intuitive that this ratio is breached. A bank that doubles its retail loans, with an illiquid nature with long maturities, and at the same time raises large amounts of wholesale funding, which is considered as less stable than deposits, is most certainly affecting its NSFR in a significant way.

Plan 4 demonstrates a larger stress of the Leverage ratio than under the Base Case Scenario, which is due to losses in retained earnings, affecting the self-financing part of the liabilities. It exhibits more balanced results in terms of the CET 1 ratio and the NSFR than Plan 2 and 3. This can be attributed to the diversification of the portfolio. Also, the market risk charge is affecting the CET 1 ratio to a larger extent.

8.3 Scenario 3 - Financial Crisis

The third scenario, Financial Crisis, is also presenting some quite interesting results. Plan 1 is not stressed at all when it comes to the Leverage ratio and NSFR, which is to be expected when no growth is taking place. The funding base, with stable deposits as core source, keeps the NSFR at a stable level and the size of the assets combined with quite stable accumulated retained earnings keeps the Leverage ratio at a constant and stable level as well. The CET 1 ratio is not stressed but is lowered a bit, due to increased probability of default for retail loans (affecting the credit risk charge) and increased volatilities and correlations in the trading book (affecting the market risk charge). ROE is negative during the end of the stressed period, but compared to Plan 3 and 4, it shows no significant losses.

Plan 2 is breaching the CET 1 ratio during the end of the period, due to high volatilities and exposures for equity and junk bonds, affecting the market risk charge. At the same time quite good, but varying, ROE numbers are recorded. The primary reason for this is the increased returns on junk bonds during the crisis, with huge credit spreads. A delay in losses due to defaults at the same time could explain why this is the case. It can also be explained by a potentially large liquidity premium in the credit spreads, which is not captured in the default probabilities.

Both Plan 3 and 4 show significant losses during the stressed period that corresponds to 2008 and 2009. The main reason for this is the huge losses that stems from the increasing default probabilities of retail loans and the increased funding costs, just as for Scenario 2. Opposed to the case with junk bonds, no extra spread is applied in the model to compensate for an increase in PD. This is motivated by the potential difficulty of quickly raising the spread, which might offset customers and lead to a decrease in the customer base. The significant losses also lead to a decrease in own equity, which has a negative impact on the Leverage ratio. The same conclusions about NSFR made under Scenario 2 hold for Scenario 3.

8.4 Final conclusions

The scenarios support Plan 1 and 2 to a greater extent than 3 and 4. The results do however support a diversified business plan with both trading and lending activities. The model is capturing downturns in the scenarios in a good way, but in order to validate if the quantification of the losses are realistic, one would need more data and an adaptation to operations of a real bank. The results could inspire the management of the bank to investigate a set of new business plans, and then test them in a similar procedure. The framework presented in this thesis should work as an iterative process, where both the results from the risk metrics and the choice of risk metrics itself are discussed and developed on a daily basis. The models should be validated through backtesting and by using internal data from the bank.

The obvious risk in using risk metrics that follow regulatory standards is that they may create incentives for banks to build their strategies in a certain way in order to meet requirements. This could lead to a gaming environment, where banks find ways of maximizing the ratios through various loopholes or special ways of grouping or labeling assets. If banks do this in a similar way, the regulation itself could create a risk of similar movements among banks on the market.

Another risk with regulatory risk metrics is that banks estimate the parameters themselves. This could lead to biases in the estimation of important regulatory parameters, such as PD or LGD. This is where it is important that supervisors make thorough controls of the internal models in Basel.

9 Discussion of improvements

One of the central parts of building scenarios based on the model is the calibration of the many input parameters, such as PD, LGD, EAD, funding costs etc. The assumptions made for some of these parameters when constructing the scenarios are appropriate for an average bank, but may not reflect any specific bank in reality. When using the model in a real bank, such parameters can be estimated in a better way, and then also help validating the model and find out what to improve or change. Due to the use of generic market data for many important parameters, such as the discount rate and probability of default for retail customers, the possibility of validating the results in a good way are quite hard. This makes the model to be mainly a theoretical one, but with further development and calibration it could serve as a helping tool when evaluating business plans at a bank.

The model is deterministic, which could be seen as focusing on a few possible paths in a Monte Carlo simulation. To make it more dynamic, a natural continuation would be to develop a stochastic model based on the same structure and principles. One way of doing this could be to fit distributions, with a possible correlation structure, to the different parameters, based on data from the bank, and then let them be based on some macroeconomical parameters that describe the current financial situation.

Another improvement could be to investigate other risk metrics, to see if they can capture other risks involved in the business plans of the bank. It could also be interesting to build some kind of optimization scheme, which finds the optimal business plan that stays within limits during all scenarios.

The VaR model that is applied is the Delta-Normal method. In practice this is a quite weak approach for several reasons. It is for example often the case that the distribution of the risk factors are more heavy-tailed than the normal distribution. An improvement could be to try to fit other distributions to the risk factor changes. An improvement could also be to investigate other, more forward-looking, approaches to measuring Value-at-Risk. This could for example involve the development of a GARCH-model.

Appendices

A Volatility and correlation in trading book

A.1 Volatility of risk factors in trading book

Table 2: Daily volatility in percent (every quarter) 1998-2012 using 1-year rolling historical data window for S&P 500 index, 3-month and 10 year U.S. Treasury yield and OAS credit spreads for U.S. investment grade bonds and junk bonds.

Quarter	Equity	Credit spread inv	Credit spread junk	Yield 3m	Yield 10yr
1998 - 1	1.12%	0.02%	0.04%	0.04%	0.05%
1998 - 2	1.10%	0.01%	0.04%	0.04%	0.05%
1998 - 3	1.05%	0.01%	0.04%	0.04%	0.05%
1998 - 4	1.31%	0.02%	0.06%	0.05%	0.05%
1999 - 1	1.22%	0.03%	0.07%	0.06%	0.05%
1999 - 2	1.31%	0.03%	0.07%	0.06%	0.06%
1999 - 3	1.36%	0.03%	0.07%	0.06%	0.06%
1999 - 4	1.13%	0.03%	0.06%	0.06%	0.06%
2000 - 1	1.13%	0.02%	0.05%	0.05%	0.06%
2000 - 2	1.19%	0.02%	0.05%	0.05%	0.06%
2000 - 3	1.31%	0.02%	0.05%	0.06%	0.06%
2000 - 4	1.25%	0.02%	0.05%	0.05%	0.05%
2001 - 1	1.38%	0.01%	0.07%	0.07%	0.05%
2001 - 2	1.35%	0.02%	0.08%	0.07%	0.05%
2001 - 3	1.31%	0.02%	0.09%	0.07%	0.05%
2001 - 4	1.38%	0.03%	0.12%	0.08%	0.06%
2002 - 1	1.25%	0.03%	0.13%	0.06%	0.07%
2002 - 2	1.10%	0.03%	0.13%	0.05%	0.07%
2002 - 3	1.30%	0.03%	0.13%	0.05%	0.07%
2002 - 4	1.55%	0.03%	0.12%	0.03%	0.07%
2003 - 1	1.62%	0.03%	0.12%	0.02%	0.07%
2003 - 2	1.68%	0.03%	0.12%	0.02%	0.07%
2003 - 3	1.48%	0.02%	0.10%	0.03%	0.07%
2003 - 4	1.14%	0.02%	0.09%	0.02%	0.07%
2004 - 1	0.97%	0.01%	0.08%	0.02%	0.07%
2004 - 2	0.79%	0.01%	0.08%	0.02%	0.07%
2004 - 3	0.70%	0.01%	0.07%	0.02%	0.06%
2004 - 4	0.69%	0.01%	0.06%	0.02%	0.06%
2005 - 1	0.68%	0.01%	0.05%	0.02%	0.05%
2005 - 2	0.66%	0.01%	0.06%	0.03%	0.05%
2005 - 3	0.65%	0.01%	0.06%	0.03%	0.05%
2005 - 4	0.65%	0.01%	0.06%	0.03%	0.04%
2006 - 1	0.63%	0.01%	0.06%	0.03%	0.04%
2006 - 2	0.58%	0.01%	0.05%	0.03%	0.04%
2006 - 3	0.66%	0.01%	0.04%	0.03%	0.04%
2006 - 4	0.61%	0.01%	0.04%	0.02%	0.04%
2007 - 1	0.59%	0.01%	0.04%	0.02%	0.04%
2007 - 2	0.65%	0.01%	0.04%	0.02%	0.04%
2007 - 3	0.71%	0.01%	0.06%	0.03%	0.04%
2007 - 4	0.88%	0.01%	0.07%	0.10%	0.04%
2008 - 1	1.09%	0.02%	0.09%	0.11%	0.06%
2008 - 2	1.22%	0.02%	0.11%	0.13%	0.07%
2008 - 3	1.28%	0.02%	0.11%	0.12%	0.07%
2008 - 4	2.27%	0.06%	0.20%	0.13%	0.08%
2009 - 1	2.58%	0.07%	0.24%	0.12%	0.09%
2009 - 2	2.75%	0.07%	0.26%	0.11%	0.09%
2009 - 3	2.75%	0.08%	0.27%	0.11%	0.10%
2009 - 4	1.90%	0.04%	0.19%	0.02%	0.09%
2010 - 1	1.49%	0.03%	0.15%	0.01%	0.08%
2010 - 2	1.10%	0.02%	0.10%	0.01%	0.07%
2010 - 3	1.14%	0.02%	0.09%	0.01%	0.06%
2010 - 4	1.10%	0.02%	0.09%	0.01%	0.06%
2011 - 1	1.06%	0.02%	0.09%	0.01%	0.06%
2011 - 2	0.93%	0.01%	0.07%	0.01%	0.06%
2011 - 3	1.14%	0.02%	0.09%	0.01%	0.07%
2011 - 4	1.37%	0.03%	0.11%	0.01%	0.07%
2012 - 1	1.43%	0.03%	0.11%	0.01%	0.06%

A.2 Correlation between risk factors in trading book

Table 3: Linear correlation coefficient 1998-2012 (every quarter) using 1-year rolling historical data window for S&P 500 index, 3-month and 10 year U.S. Treasury yield and OAS credit spreads for U.S. investment grade/junk bonds.

Quarter	Equity - Yield 3m	Cred inv - Yield 3m	Cred junk - Yield 3m	Cred inv - cred junk	Equity - Cred inv	Equity - Cred junk	Equity - Yield 10yr	Cred inv - Yield 10yr	Cred junk - Yield 10yr	Yield 3m - Yield 10yr
1998 - 1	0.11	0.15	-0.21	0.27	0.03	0.01	-0.25	0.04	-0.71	0.3
1998 - 2	0.17	0.09	-0.22	0.21	0.01	-0.03	-0.16	0	-0.76	0.29
1998 - 3	0.23	0.07	-0.32	0.21	0.01	-0.13	-0.04	-0.01	-0.76	0.35
1998 - 4	0.27	0.03	-0.33	0.41	-0.29	-0.46	0.3	-0.06	-0.71	0.43
1999 - 1	0.21	0.06	-0.27	0.22	-0.2	-0.4	0.26	-0.09	-0.63	0.28
1999 - 2	0.19	0.07	-0.25	0.25	-0.21	-0.38	0.24	-0.11	-0.65	0.27
1999 - 3	0.15	0.06	-0.24	0.25	-0.19	-0.3	0.15	-0.12	-0.68	0.26
1999 - 4	0.1	0.08	-0.23	0.07	0.01	0.01	-0.14	-0.06	-0.68	0.21
2000 - 1	-0.07	0.02	-0.21	0.37	-0.1	0.12	-0.26	-0.03	-0.77	0.28
2000 - 2	-0.11	0.01	-0.23	0.38	-0.02	0.12	-0.22	-0.04	-0.75	0.31
2000 - 3	0.01	-0.02	-0.15	0.33	-0.08	-0.05	-0.04	-0.05	-0.71	0.23
2000 - 4	0.02	0.02	-0.06	0.35	-0.05	-0.08	0.06	-0.09	-0.68	0.18
2001 - 1	0.06	0.01	-0.11	0.39	0.01	-0.13	0.16	-0.2	-0.62	0.17
2001 - 2	0.1	0.03	-0.11	0.41	-0.12	-0.28	0.3	-0.2	-0.63	0.18
2001 - 3	0.04	0.02	-0.19	0.31	0	-0.27	0.27	-0.1	-0.56	0.27
2001 - 4	0.13	-0.18	-0.42	0.46	-0.04	-0.3	0.34	-0.16	-0.59	0.37
2002 - 1	0.17	-0.24	-0.52	0.45	-0.06	-0.3	0.26	-0.21	-0.63	0.41
2002 - 2	0.19	-0.28	-0.57	0.46	-0.06	-0.27	0.2	-0.26	-0.63	0.41
2002 - 3	0.24	-0.27	-0.56	0.5	-0.13	-0.25	0.28	-0.29	-0.63	0.39
2002 - 4	0.14	-0.05	-0.28	0.5	-0.13	-0.23	0.36	-0.22	-0.6	0.37
2003 - 1	0.22	0.02	-0.24	0.57	-0.2	-0.36	0.56	-0.21	-0.57	0.38
2003 - 2	0.22	0	-0.23	0.59	-0.21	-0.41	0.63	-0.22	-0.56	0.37
2003 - 3	0.23	-0.03	-0.24	0.68	-0.22	-0.48	0.59	-0.22	-0.63	0.39
2003 - 4	0.18	-0.05	-0.25	0.63	-0.29	-0.48	0.47	-0.27	-0.68	0.35
2004 - 1	0.11	-0.19	-0.25	0.57	-0.19	-0.36	0.35	-0.3	-0.75	0.32
2004 - 2	0.02	-0.1	-0.23	0.51	-0.08	-0.23	0.16	-0.24	-0.75	0.3
2004 - 3	-0.15	-0.05	-0.16	0.49	-0.09	-0.14	0.05	-0.24	-0.75	0.25
2004 - 4	-0.06	-0.11	-0.19	0.45	-0.14	-0.22	0.18	-0.26	-0.77	0.28
2005 - 1	-0.06	-0.12	-0.21	0.44	-0.19	-0.19	0.09	-0.25	-0.73	0.29
2005 - 2	-0.04	-0.12	-0.22	0.47	-0.28	-0.19	0.03	-0.21	-0.7	0.26
2005 - 3	0.02	-0.16	-0.21	0.4	-0.21	-0.2	0.12	-0.17	-0.67	0.26
2005 - 4	-0.01	-0.14	-0.21	0.41	-0.18	-0.18	0.02	-0.16	-0.67	0.26
2006 - 1	0.08	-0.18	-0.23	0.45	-0.14	-0.15	-0.01	-0.18	-0.67	0.29
2006 - 2	0.1	-0.18	-0.22	0.36	-0.11	-0.17	0.07	-0.2	-0.69	0.31
2006 - 3	0.05	-0.19	-0.27	0.4	-0.12	-0.08	-0.03	-0.24	-0.73	0.29
2006 - 4	0.03	-0.17	-0.27	0.39	-0.12	-0.06	-0.07	-0.23	-0.7	0.29
2007 - 1	-0.11	-0.08	-0.2	0.34	-0.13	-0.03	-0.1	-0.24	-0.74	0.24
2007 - 2	-0.06	-0.11	-0.24	0.63	-0.15	-0.14	-0.01	-0.4	-0.75	0.27
2007 - 3	-0.07	-0.15	-0.23	0.63	-0.15	-0.21	-0.02	-0.39	-0.74	0.24
2007 - 4	0.11	-0.29	-0.27	0.72	-0.29	-0.43	0.3	-0.47	-0.71	0.15
2008 - 1	0.15	-0.33	-0.31	0.73	-0.31	-0.5	0.44	-0.47	-0.72	0.22
2008 - 2	0.2	-0.37	-0.34	0.7	-0.31	-0.49	0.51	-0.43	-0.74	0.32
2008 - 3	0.22	-0.36	-0.35	0.71	-0.31	-0.51	0.57	-0.41	-0.74	0.32
2008 - 4	0.36	-0.45	-0.45	0.62	-0.23	-0.48	0.57	-0.3	-0.72	0.39
2009 - 1	0.26	-0.37	-0.32	0.73	-0.18	-0.38	0.46	-0.23	-0.4	0.3
2009 - 2	0.24	-0.37	-0.31	0.73	-0.15	-0.33	0.4	-0.2	-0.36	0.24
2009 - 3	0.22	-0.36	-0.26	0.73	-0.16	-0.31	0.36	-0.2	-0.36	0.18
2009 - 4	0.18	-0.24	-0.22	0.75	-0.15	-0.29	0.33	-0.16	-0.35	0.12
2010 - 1	0.06	-0.1	-0.14	0.65	-0.13	-0.22	0.26	-0.12	-0.43	0.13
2010 - 2	0.02	-0.02	-0.01	0.63	-0.2	-0.25	0.23	-0.21	-0.56	0.13
2010 - 3	0.17	-0.05	-0.08	0.72	-0.42	-0.49	0.49	-0.33	-0.64	0.17
2010 - 4	0.15	-0.07	-0.09	0.77	-0.44	-0.59	0.57	-0.4	-0.72	0.15
2011 - 1	0.12	-0.09	-0.09	0.75	-0.45	-0.58	0.53	-0.37	-0.71	0.12
2011 - 2	0.14	-0.09	-0.11	0.76	-0.45	-0.59	0.49	-0.39	-0.75	0.11
2011 - 3	0.01	0.04	0.01	0.69	-0.35	-0.53	0.43	-0.38	-0.77	0.02
2011 - 4	-0.02	0.11	0.02	0.76	-0.33	-0.47	0.42	-0.34	-0.72	0.06
2012 - 1	-0.02	0.07	0	0.84	-0.38	-0.52	0.57	-0.41	-0.7	0.08

B Spread for cost of wholesale funding

Spread added to funding costs with respect to credit rating. As can be seen, the spread is added to the T-bill rate. The federal funds rate and the T-bill rate are relatively close in value, which makes it a reasonable assumption to be able to add it to the federal funds rate as well.

Appendix Table 3. Minimum Funding Cost: Empirical Estimation of Non-Linear Change

Rating Scale (Moody's)	Rating (S&P, Fitch)	One Year PDs	Funding costs (Spread above t-bills, bps)	Economic capital ratio (Basel II (quasi-IRB)	Change of Funding spread (CAR Elasticitity)
Aaa	AAA	0.004%	**8.73**	0.281	
Aa1	AA+	0.006%	**8.74**	0.273	0.00%
Aa2	AA	0.008%	**8.74**	0.262	0.00%
Aa3	AA-	0.010%	**8.9**	0.212	0.00%
A1	A+	0.012%	**9.0**	0.197	0.00%
A	A	0.026%	**11.9**	0.143	0.01%
A2	A-	0.060%	**12.7**	0.139	0.02%
Baa1	BBB+	0.135%	**21.0**	0.117	0.04%
Baa2	BBB	0.200%	**25.9**	0.111	0.08%
Baa3	BBB-	0.291%	**44.6**	0.099	0.15%
Ba1	BB+	0.682%	**92.7**	0.085	0.35%
Ba2	BB	0.728%	**98.4**	0.084	0.57%
Ba3	BB-	1.791%	**229.4**	0.071	1.03%
B1	B+	2.450%	**310.5**	0.067	2.01%
B2	B	3.827%	**480.2**	0.062	3.16%
B3	B-	7.666%	**953.1**	0.054	6.37%
Caa1	CCC+	9.150%	**1135.9**	0.053	10.74%
Caa2	CCC	16.388%	**2027.6**	0.048	17.69%
Caa3	CCC-	24.806%	**n.a.**	n.a.	24.63%
Ca/C	C/CC	32.949%	**n.a.**	n.a.	31.58%

Note: Funding cost exclude the cost of equity. The economic capital ratio includes a capital buffer above the hurdle rate of 2.5 percentage points.

Figure 36: *Empirical spread added to funding costs based on credit rating[16].*

C Balance sheet data and mapping rules

The balance sheet data used is fetched from the annual statements from Wells Fargo & Company (see figure 37). The rules applied for grouping assets are the following:

- Government bonds: Federal funds sold
- Corporate bonds: Other assets
- Equity: Trading Assets
- Cash: Cash and due from banks, Premises and equipment, net and Goodwill
- Retail loans: Mortgages held for sale, Loans held for sale, Mortgage servicing rights
- Deposits: Total deposits
- Wholesale funding: short term borrowings, Accrued expenses and other liabilities, Long term debt
- Share capital: Equity (minus retained earnings)
- Retained earnings: Retained earnings

Securities available for sale are technically not part of neither the banking book nor the trading book and is therefore spread as 2/5 to retail loans, 1/5 to cash, 1/5 to government bonds and 1/5 to corporate bonds (chosen arbitrarily).

Wells Fargo & Company and Subsidiaries

Consolidated Balance Sheet

		December 31,
(in millions, except shares)	2012	2011
Assets		
Cash and due from banks	$ 21,860	19,440
Federal funds sold, securities purchased under resale agreements and other short-term investments	137,313	44,367
Trading assets	57,482	77,814
Securities available for sale	235,199	222,613
Mortgages held for sale (includes $42,305 and $44,791 carried at fair value)	47,149	48,357
Loans held for sale (includes $6 and $1,176 carried at fair value)	110	1,338
Loans (includes $6,206 and $5,916 carried at fair value)	799,574	769,631
Allowance for loan losses	(17,060)	(19,372)
Net loans	782,514	750,259
Mortgage servicing rights:		
Measured at fair value	11,538	12,603
Amortized	1,160	1,408
Premises and equipment, net	9,428	9,531
Goodwill	25,637	25,115
Other assets	93,578	101,022
Total assets (1)	$ 1,422,968	1,313,867
Liabilities		
Noninterest-bearing deposits	$ 288,207	244,003
Interest-bearing deposits	714,628	676,067
Total deposits	1,002,835	920,070
Short-term borrowings	57,175	49,091
Accrued expenses and other liabilities	76,668	77,665
Long-term debt (includes $1 and $0 carried at fair value)	127,379	125,354
Total liabilities (2)	1,264,057	1,172,180
Equity		
Wells Fargo stockholders' equity:		
Preferred stock	12,883	11,431
Common stock – $1-2/3 par value, authorized 9,000,000,000 shares; issued 5,481,811,474 shares and 5,358,522,061 shares	9,136	8,931
Additional paid-in capital	59,802	55,957
Retained earnings	77,679	64,385
Cumulative other comprehensive income	5,650	3,207
Treasury stock – 215,497,298 shares and 95,910,425 shares	(6,610)	(2,744)
Unearned ESOP shares	(986)	(926)
Total Wells Fargo stockholders' equity	157,554	140,241
Noncontrolling interests	1,357	1,446
Total equity	158,911	141,687
Total liabilities and equity	$ 1,422,968	1,313,867

(1) Our consolidated assets at December 31, 2012 and December 31, 2011, include the following assets of certain variable interest entities (VIEs) that can only be used to settle the liabilities of those VIEs: Cash and due from banks, $260 million and $321 million; Trading assets, $114 million and $293 million; Securities available for sale, $2.8 billion and $3.3 billion; Mortgages held for sale, $469 million and $444 million; Net loans, $10.6 billion and $12.0 billion; Other assets, $457 million and $1.9 billion, and Total assets, $14.6 billion and $18.2 billion, respectively.

(2) Our consolidated liabilities at December 31, 2012 and December 31, 2011, include the following VIE liabilities for which the VIE creditors do not have recourse to Wells Fargo: Short-term borrowings, $0 and $24 million; Accrued expenses and other liabilities, $134 million and $175 million; Long-term debt, $3.5 billion and $4.9 billion; and Total liabilities, $3.6 billion and $5.1 billion, respectively.

The accompanying notes are an integral part of these statements.

Figure 37: *Balance sheet data for Wells Fargo[41].*

D Capital Planning Tool

In this section a short description of the Capital Planning Tool developed in Excel/VBA is done, with some screen shots of the tool.

The tool enables the user to control the scenarios and the business plans through two input sheets, where risk factors involved in the scenarios are defined (see figure 38) and the various strategy decisions in the business plans are defined. A third sheet is then used as a terminal where it is easy to switch between business plans and scenarios, and also to apply specific risk factor shocks, as a shift in the yield curve or a change in the credit spread (see figure 39).

The overall development of the balance sheet and the value of the assets and liabilities can be studied in two separate sheets, which capture the situation at the start of each time period and at the end of each time period. A screen shot of the start period sheet can be seen in figure 40. The end period sheet is needed to be able to structure the reallocation process regarding funding allocation and the reallocation of trading assets. The end period sheet is also used as input to the calculation of some of the risk metrics. A separate sheet is describing the P&L account, which also is used in the risk metric calculations. An example of the P&L sheet can be seen in figure 41.

All asset and liability groups have a separate sheet for their projections, and the risk charges have separate sheets as well. The details regarding these projections can be studied in section 5.5.

Risk appetite is treated in a separate sheet, where limits and targets for the risk appetite measures are defined by the user. In the same sheet the output from the risk metrics is shown and plotted with the limits and targets. One example can be seen in figure 42.

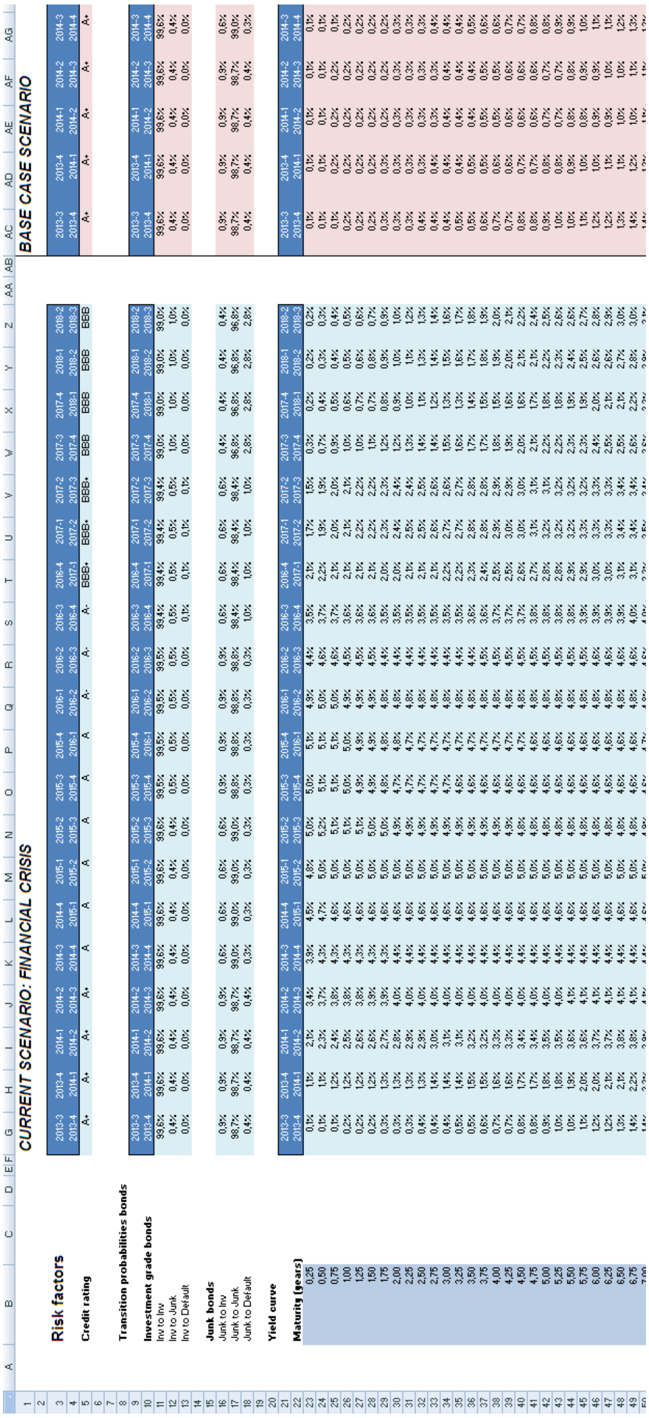


Figure 38: *Screen shot of the risk factor input sheet.*

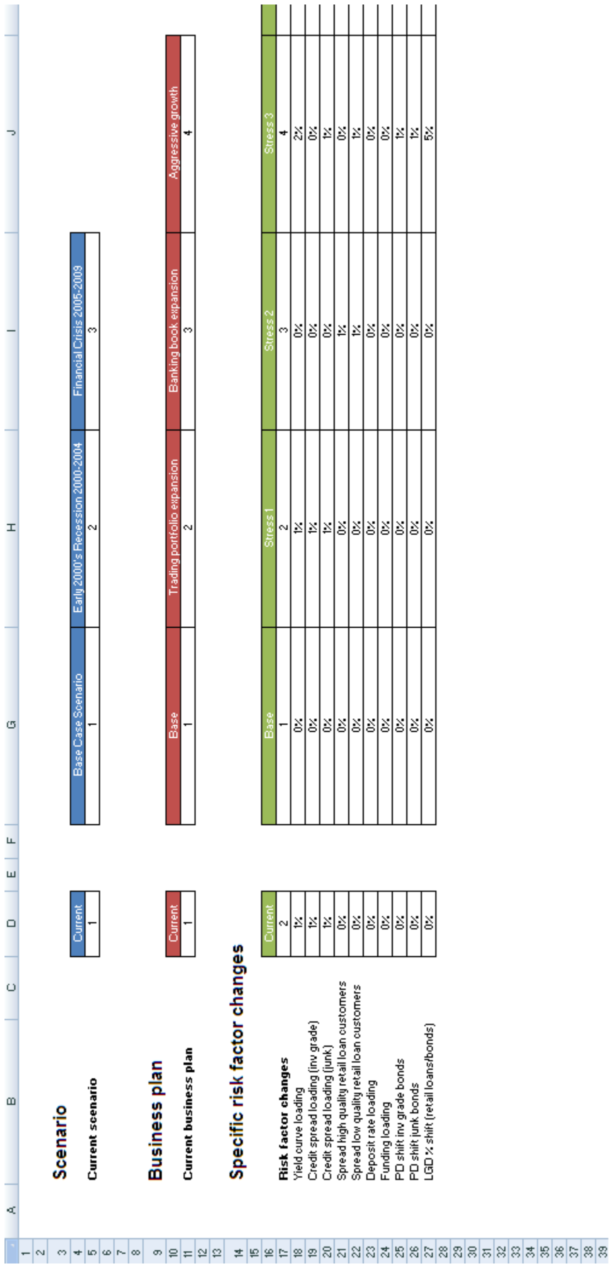


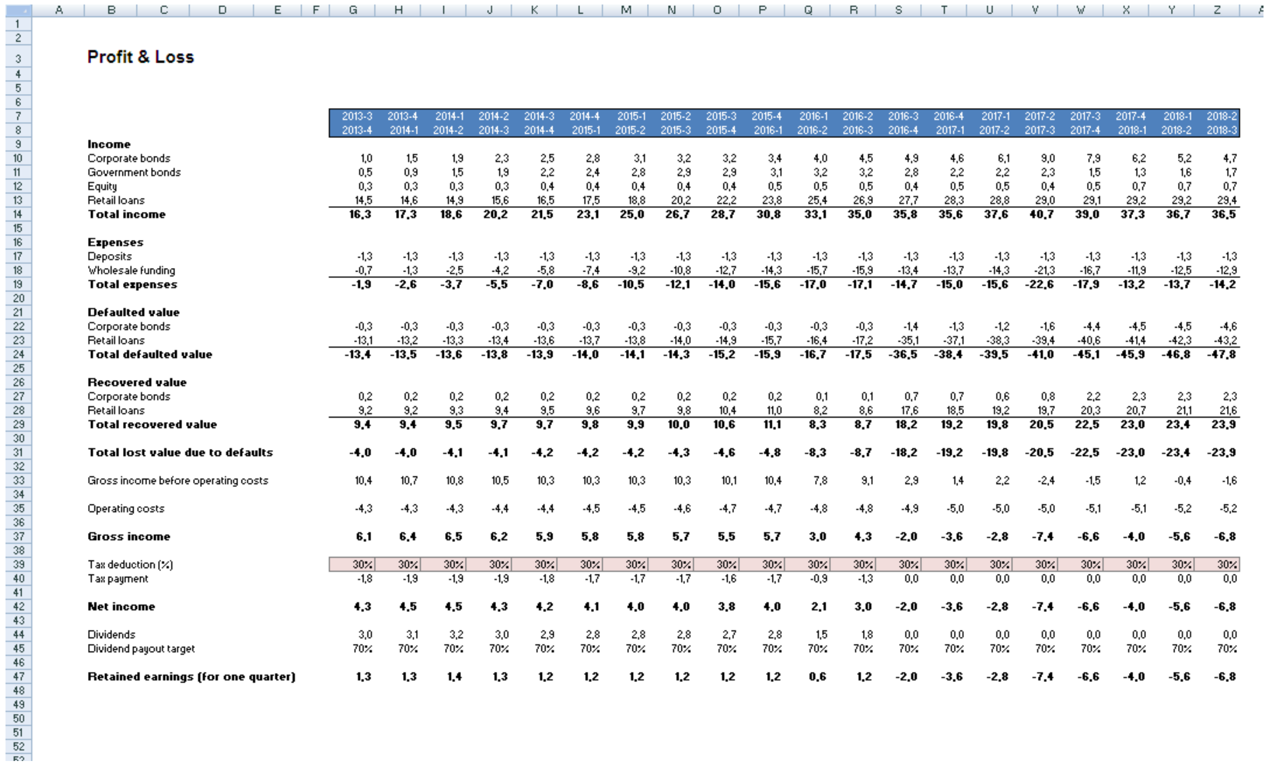
Figure 39: *Screen shot of terminal sheet where scenarios, business plans and specific risk factor changes are controlled.*

Balance Sheet
Start of period

	2013-3 2013-4	2013-4 2014-1	2014-1 2014-2	2014-2 2014-3	2014-3 2014-4	2014-4 2015-1	2015-1 2015-2	2015-2 2015-3	2015-3 2015-4	2015-4 2016-1
Assets										
Cash	102	106	107	109	110	110	110	110	111	111
Corporate bonds	140	148	149	151	152	153	154	154	155	155
Government bonds	184	194	196	198	200	202	203	203	204	205
Equity	57	60	61	62	62	62	62	62	62	63
Retail loans	939	881	855	840	833	841	857	882	915	949
Total Assets	**1422**	**1391**	**1368**	**1359**	**1358**	**1369**	**1386**	**1411**	**1447**	**1483**
Liabilities	2013-3 2013-4	2013-4 2014-1	2014-1 2014-2	2014-2 2014-3	2014-3 2014-4	2014-4 2015-1	2015-1 2015-2	2015-2 2015-3	2015-3 2015-4	2015-4 2016-1
Deposits	1002	1005	1006	1008	1009	1012	1013	1013	1015	1015
Wholesale funding	262	227	202	189	185	191	206	229	261	295
Share capital	81	81	81	81	81	81	81	81	81	81
Retained earnings	77	78	80	81	83	84	86	88	90	91
Total Liabilities	**1422**	**1391**	**1368**	**1359**	**1358**	**1369**	**1386**	**1411**	**1447**	**1483**

	2016-1 2016-2	2016-2 2016-3	2016-3 2016-4	2016-4 2017-1	2017-1 2017-2	2017-2 2017-3	2017-3 2017-4	2017-4 2018-1	2018-1 2018-2	2018-2 2018-3
Assets										
Cash	112	112	113	114	116	118	117	117	118	119
Corporate bonds	157	157	158	160	162	165	163	164	165	166
Government bonds	207	207	208	210	214	218	215	216	217	219
Equity	63	64	64	65	66	67	66	66	67	67
Retail loans	963	981	995	998	1001	994	1004	1008	1011	1015
Total Assets	**1503**	**1522**	**1537**	**1547**	**1558**	**1562**	**1565**	**1570**	**1578**	**1587**
Liabilities	2016-1 2016-2	2016-2 2016-3	2016-3 2016-4	2016-4 2017-1	2017-1 2017-2	2017-2 2017-3	2017-3 2017-4	2017-4 2018-1	2018-1 2018-2	2018-2 2018-3
Deposits	1018	1019	1021	1019	1020	1018	1012	1009	1008	1009
Wholesale funding	311	327	340	350	360	366	374	383	392	400
Share capital	81	81	81	81	81	81	81	81	81	81
Retained earnings	93	95	96	97	97	97	97	97	97	96
Total Liabilities	**1503**	**1522**	**1537**	**1547**	**1558**	**1562**	**1565**	**1570**	**1578**	**1587**

Figure 40: *Screen shot of the balance sheet projections at the start of each period.*



Profit & Loss

	2013-3 2013-4	2013-4 2014-1	2014-1 2014-2	2014-2 2014-3	2014-3 2014-4	2014-4 2015-1	2015-1 2015-2	2015-2 2015-3	2015-3 2015-4	2015-4 2016-1
Income										
Corporate bonds	1,0	1,5	1,9	2,3	2,5	2,8	3,1	3,2	3,2	3,4
Government bonds	0,5	0,9	1,5	1,9	2,2	2,4	2,8	2,9	2,9	3,1
Equity	0,3	0,3	0,3	0,3	0,4	0,4	0,4	0,4	0,4	0,5
Retail loans	14,5	14,6	14,9	15,6	16,5	17,5	18,8	20,2	22,2	23,8
Total income	**16,3**	**17,3**	**18,6**	**20,2**	**21,5**	**23,1**	**25,0**	**26,7**	**28,7**	**30,8**
Expenses										
Deposits	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3
Wholesale funding	-0,7	-1,3	-2,5	-4,2	-5,8	-7,4	-9,2	-10,8	-12,7	-14,3
Total expenses	**-1,9**	**-2,6**	**-3,7**	**-5,5**	**-7,0**	**-8,6**	**-10,5**	**-12,1**	**-14,0**	**-15,6**
Defaulted value										
Corporate bonds	-0,3	-0,3	-0,3	-0,3	-0,3	-0,3	-0,3	-0,3	-0,3	-0,3
Retail loans	-13,1	-13,2	-13,3	-13,4	-13,6	-13,7	-13,8	-14,0	-14,9	-15,7
Total defaulted value	**-13,4**	**-13,5**	**-13,6**	**-13,8**	**-13,9**	**-14,0**	**-14,1**	**-14,3**	**-15,2**	**-15,9**
Recovered value										
Corporate bonds	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Retail loans	9,2	9,2	9,3	9,4	9,5	9,6	9,7	9,8	10,4	11,0
Total recovered value	**9,4**	**9,4**	**9,5**	**9,7**	**9,7**	**9,8**	**9,9**	**10,0**	**10,6**	**11,1**
Total lost value due to defaults	**-4,0**	**-4,0**	**-4,1**	**-4,1**	**-4,2**	**-4,2**	**-4,2**	**-4,3**	**-4,6**	**-4,8**
Gross income before operating costs	10,4	10,7	10,8	10,5	10,3	10,3	10,3	10,3	10,1	10,4
Operating costs	-4,3	-4,3	-4,3	-4,4	-4,4	-4,5	-4,5	-4,6	-4,7	-4,7
Gross income	**6,1**	**6,4**	**6,5**	**6,2**	**5,9**	**5,8**	**5,8**	**5,7**	**5,5**	**5,7**
Tax deduction (%)	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Tax payment	-1,8	-1,9	-1,9	-1,9	-1,8	-1,7	-1,7	-1,7	-1,6	-1,7
Net income	**4,3**	**4,5**	**4,5**	**4,3**	**4,2**	**4,1**	**4,0**	**4,0**	**3,8**	**4,0**
Dividends	3,0	3,1	3,2	3,0	2,9	2,8	2,8	2,8	2,7	2,8
Dividend payout target	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
Retained earnings (for one quarter)	**1,3**	**1,3**	**1,4**	**1,3**	**1,2**	**1,2**	**1,2**	**1,2**	**1,2**	**1,2**

	2016-1 2016-2	2016-2 2016-3	2016-3 2016-4	2016-4 2017-1	2017-1 2017-2	2017-2 2017-3	2017-3 2017-4	2017-4 2018-1	2018-1 2018-2	2018-2 2018-3
Income										
Corporate bonds	4,0	4,5	4,9	4,6	6,1	9,0	7,9	6,2	5,2	4,7
Government bonds	3,2	3,2	2,8	2,2	2,2	2,3	1,5	1,3	1,6	1,7
Equity	0,5	0,5	0,4	0,5	0,5	0,4	0,5	0,7	0,7	0,7
Retail loans	25,4	26,9	27,7	28,3	28,8	29,0	29,1	29,2	29,2	29,4
Total income	**33,1**	**35,0**	**35,8**	**35,6**	**37,6**	**40,7**	**39,0**	**37,3**	**36,7**	**36,5**
Expenses										
Deposits	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3	-1,3
Wholesale funding	-15,7	-15,9	-13,4	-13,7	-14,3	-21,3	-16,7	-11,9	-12,5	-12,9
Total expenses	**-17,0**	**-17,1**	**-14,7**	**-15,0**	**-15,6**	**-22,6**	**-17,9**	**-13,2**	**-13,7**	**-14,2**
Defaulted value										
Corporate bonds	-0,3	-0,3	-1,4	-1,3	-1,2	-1,6	-4,4	-4,5	-4,5	-4,6
Retail loans	-16,4	-17,2	-35,1	-37,1	-38,3	-39,4	-40,6	-41,4	-42,3	-43,2
Total defaulted value	**-16,7**	**-17,5**	**-36,5**	**-38,4**	**-39,5**	**-41,0**	**-45,1**	**-45,9**	**-46,8**	**-47,8**
Recovered value										
Corporate bonds	0,1	0,1	0,7	0,7	0,6	0,8	2,2	2,3	2,3	2,3
Retail loans	8,2	8,6	17,6	18,5	19,2	19,7	20,3	20,7	21,1	21,6
Total recovered value	**8,3**	**8,7**	**18,2**	**19,2**	**19,8**	**20,5**	**22,5**	**23,0**	**23,4**	**23,9**
Total lost value due to defaults	**-8,3**	**-8,7**	**-18,2**	**-19,2**	**-19,8**	**-20,5**	**-22,5**	**-23,0**	**-23,4**	**-23,9**
Gross income before operating costs	7,8	9,1	2,9	1,4	2,2	-2,4	-1,5	1,2	-0,4	-1,6
Operating costs	-4,8	-4,8	-4,9	-5,0	-5,0	-5,0	-5,1	-5,1	-5,2	-5,2
Gross income	**3,0**	**4,3**	**-2,0**	**-3,6**	**-2,8**	**-7,4**	**-6,6**	**-4,0**	**-5,6**	**-6,8**
Tax deduction (%)	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Tax payment	-0,9	-1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Net income	**2,1**	**3,0**	**-2,0**	**-3,6**	**-2,8**	**-7,4**	**-6,6**	**-4,0**	**-5,6**	**-6,8**
Dividends	1,5	1,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dividend payout target	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
Retained earnings (for one quarter)	**0,6**	**1,2**	**-2,0**	**-3,6**	**-2,8**	**-7,4**	**-6,6**	**-4,0**	**-5,6**	**-6,8**

Figure 41: *Screen shot of the P&L account.*

Risk appetite

	2013-3 2013-4	2013-4 2014-1	2014-1 2014-2	2014-2 2014-3	2014-3 2014-4	2014-4 2015-1	2015-1 2015-2	2015-2 2015-3	2015-3 2015-4	2015-4 2016-1	2016-1 2016-2	2016-2 2016-3	2016-3 2016-4	2016-4 2017-1	2017-1 2017-2	2017-2 2017-3	2017-3 2017-4	2017-4 2018-1	2018-1 2018-2	2018-2 2018-3
CET 1 Ratio	14,3%	14,4%	14,2%	14,4%	14,4%	15,0%	15,1%	15,1%	15,3%	14,7%	15,1%	15,3%	15,5%	15,7%	16,0%	16,2%	16,4%	16,6%	17,0%	16,5%
Lower limit	3,5%	3,5%	4,0%	4,0%	4,0%	4,0%	4,5%	4,5%	4,5%	4,5%	5,1%	5,1%	5,1%	5,1%	5,8%	5,8%	5,8%	5,8%	6,4%	6,4%
Upper limit	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%
Target	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%	10,5%
CET 1 capital	158	160	163	165	168	170	173	175	178	180	182	185	187	189	192	194	197	200	202	205
RWAs	1102	1118	1144	1146	1164	1140	1144	1161	1158	1227	1206	1204	1211	1205	1203	1199	1202	1206	1189	1241
Regulatory minimum (lower limit)	3,5%	3,5%	4,0%	4,0%	4,0%	4,0%	4,5%	4,5%	4,5%	4,5%	5,1%	5,1%	5,1%	5,1%	5,8%	5,8%	5,8%	5,8%	6,4%	6,4%

	2013-3 2013-4	2013-4 2014-1	2014-1 2014-2	2014-2 2014-3	2014-3 2014-4	2014-4 2015-1	2015-1 2015-2	2015-2 2015-3	2015-3 2015-4	2015-4 2016-1	2016-1 2016-2	2016-2 2016-3	2016-3 2016-4	2016-4 2017-1	2017-1 2017-2	2017-2 2017-3	2017-3 2017-4	2017-4 2018-1	2018-1 2018-2	2018-2 2018-3
ROE	20,8%	20,4%	20,6%	19,9%	19,8%	19,4%	18,5%	17,6%	17,2%	17,4%	17,4%	17,8%	17,1%	17,2%	17,8%	17,5%	17,6%	17,4%	17,3%	17,3%
Lower limit	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%
Upper limit	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%	29,0%
Target	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%	17,0%

	2013-3 2013-4	2013-4 2014-1	2014-1 2014-2	2014-2 2014-3	2014-3 2014-4	2014-4 2015-1	2015-1 2015-2	2015-2 2015-3	2015-3 2015-4	2015-4 2016-1	2016-1 2016-2	2016-2 2016-3	2016-3 2016-4	2016-4 2017-1	2017-1 2017-2	2017-2 2017-3	2017-3 2017-4	2017-4 2018-1	2018-1 2018-2	2018-2 2018-3
Leverate Ratio	11,2%	11,6%	12,0%	12,3%	12,6%	12,8%	12,9%	12,9%	12,9%	12,8%	12,9%	13,0%	13,1%	13,1%	13,2%	13,3%	13,3%	13,4%	13,4%	13,4%
Lower limit	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%
Higher limit	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%
Target	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%
Regulatory minimum (lower limit)	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%

	2013-3 2013-4	2013-4 2014-1	2014-1 2014-2	2014-2 2014-3	2014-3 2014-4	2014-4 2015-1	2015-1 2015-2	2015-2 2015-3	2015-3 2015-4	2015-4 2016-1	2016-1 2016-2	2016-2 2016-3	2016-3 2016-4	2016-4 2017-1	2017-1 2017-2	2017-2 2017-3	2017-3 2017-4	2017-4 2018-1	2018-1 2018-2	2018-2 2018-3
NSFR	120,9%	124,6%	126,4%	129,6%	130,7%	131,0%	130,6%	129,5%	128,2%	126,7%	126,3%	124,7%	124,6%	124,4%	122,9%	123,0%	122,1%	121,4%	120,9%	119,2%
Lower limit	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Upper limit	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%	135,0%
Target	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%	115,0%
Regulatory minimum (lower limit)	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

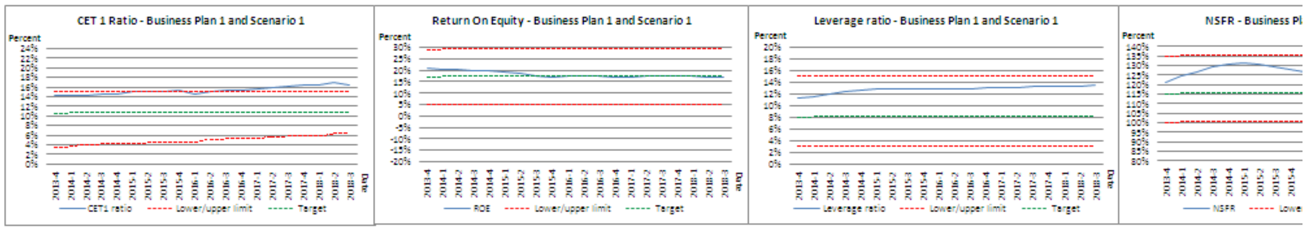


Figure 42: *Screen shot of the risk metric results.*

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