UNIVERSITY OF TWENTE

MASTER'S THESIS

The impact of interest rate risk-taking on a bank's profitability

A new dimension to balance sheet improvement

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Abstract

With term premia present in the yield curve, banks have incentives to create mismatches between term structures of cash flows and with this, expose themselves to interest rate risk. Especially in the current period of historically low interest rates and rising pressure of competition, the consequences of a return to pre-crisis interest rate levels could be disastrous if this mismatch is too big. Regulators also acknowledge this problem, for which they come to introduce new guidelines to manage and quantify interest rate risk in the banking book (IRRBB) in a more standardized manner.

We examine the impact of a bank's interest rate risk appetite on its return on equity, as well as give insight in the impact of a direct capital charge for IRRBB. We do this by creating a model that reallocates the exposures to balance sheet items. Our model is a stylized reflection of an average, small Dutch bank and optimizes the return on equity of a bank while being subject to interest rate risk, liquidity and capital constraints originating from the Basel accords. In order to provide a precise calculation of the interest rate measures, the balance sheet items are allocated to detailed subclasses based on fixed interest rate periods. We quantify IRRBB by the change in net interest income (NII) and the change in economic value of equity (EVE) resulting from a set of alternative interest rate scenarios. Subsequently, banking instruments are subject are subject to optionality, creating uncertainties in future cash flows. We analyze the impact of changes in two sources of optionality embedded in banking instruments on a bank's interest rate risk exposure.

Our findings show the added value of the introduced alternative interest rate scenarios and the importance of the complementary use of the two interest rate risk measures in controlling earnings and economic value volatility. Furthermore, we illustrate that the impact of a decrease in term transformation by lowering thresholds on interest rate risk measures on a bank's interest rate spread. We find a decrease in interest rate risk-taking when a direct capital charge for IRRBB would be implemented in the form of a capital indicator based on the EVE. Finally, our findings indicate that even small changes in the duration of core non-maturity deposits and the magnitude of the prepayment rate cause relatively big fluctuations in a bank's interest rate risk exposure. With this, we lay out that the interest rate risk exposure is highly sensitive to changes in client behavior, making interest rate risk management an even more dynamic process.

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List of Abbreviations

ALM	**A**ssets **L**iability **M**anagement
ASF	**A**vailable **S**table **F**unding
EAR	**E**arnings **At** **R**isk
BCBS	**B**asel **C**ommittee on **B**anking **S**upervision
BIS	**B**ank for **I**nterational **s**ettlements
CCR	**C**ounterparty **C**redit **R**isk
CPR	**C**onditional **P**repayment **R**ate
CVA	**C**redit **V**aluation **A**djustment
EAD	**E**xposure **At** **D**efault
EBA	**E**uropean **B**anking **A**uthority
EV	**E**conomic **V**alue
EVE	**E**conomic **V**alue **E**quity
HQLA	**H**igh **Q**uality **L**iquid **A**ssets
ICAAP	**I**nternal **C**apital **A**dequacy **A**ssessment **P**rocess
IE	**I**nterest **E**xpense
II	**I**nterest **I**ncome
IRRBB	**I**nterest **R**ate **R**isk in the **B**anking **B**ook
LCR	**L**iquidity **C**overage **R**atio
LTV	**L**oan-**T**o-**V**alue
LR	**L**everage **R**atio
NHG	**N**ationale **H**ypotheek **G**arantie (National Mortgage Guarantee)
NII	**N**et **I**nterest **I**ncome
NSFR	**N**et **s**table **F**unding **R**atio
NMD	**N**on-**M**aturtity **D**eposit
O/N	**O**ver **N**ight
RMBS	**R**esidential **M**ortgage-**B**acked **S**ecurity
ROE	**R**eturon **O**n **E**quity
RSF	**R**equired **S**table **F**unding
SE	**S**wap **E**xpense
SREP	**S**upervisory **R**eview and **E**valuation **P**rocess
TDDR	**T**erm **D**eposit **R**edemption **R**ate
TIA	**T**ime **I**mpact **A**nalysis
TSA	**T**ime **S**eries **A**pproach
TCR	**T**otal **C**apital **R**atio

Chapter 1

Introduction

I wrote this thesis during an internship at the Financial Services Risk department of EY, located in Amsterdam. This department is specialized in both qualitative and quantitative financial risk and compliance challenges. One of today's main topics playing a role in new regulation is interest rate risk in the banking book. EY supports, among others, banks in organizing the implantation of new interest rate risk regulations.

This chapter provides context to the thesis' subject, the thesis' objective and elaborates on the structure of the thesis.

1.1 Problem Context

In a period of an increasing internationalization of financial systems and a rising pressure of competition, every bank is obliged to seek an equilibrium between a prudent and balanced term structure of assets and liabilities while pursuing higher levels of profitability, resulting in differing magnitudes of exposure across banks (BCBS, 2010). A bank should have sufficient capital to withstand the impact of adverse scenarios until it can implement mitigation actions, such as reducing exposures or increasing capital. The possible impact of these risks a bank is exposed to is covered by both Basel's Pillar 1 and Pillar 2 legislation. Pillar 1 focuses on the minimum amount of capital a bank should hold and liquidity ratios that should be satisfied. In addition, Pillar 2, the supervisory review process, tends to complete this through a supervisory review of overall capital adequacy in relation to their risk profile (Hull, 2012). The measurement of interest rate risk in the banking book (IRRBB), the biggest market risk for most retail banks, presents a number of major practical difficulties including modeling the value of future cash flows and determining the appropriate value of banking book assets and liabilities for which a tailored approach is preferred. It is for this reason that IRRBB is part of Pillar 2.

The financial condition of a bank is sensitive to fluctuations in interest rates. Banks generally transform safe deposits that are due within short notice into long-term, illiquid and more risky loans (Hull, 2012). The mismatch in maturity is a substantial source of income for most banks, as long-term interest rates tend to be higher than short-term rates. However, this mismatch in maturities also exposes a bank to interest rate risk. This exposure can easily be hedged using interest rate swaps, making the exposure to a large extent a deliberate trade-off made by the bank managers

(Memmel, 2011). Decreasing earnings as a result of low interest rates create incentives for banks to search for yields by taking on more interest rate risk (Memmel, Seymen, and Teichert (2016), Rajan (2005)). Especially in an environment with high competition and low interest rates, the impact of rising interest rates could be disastrous when this mismatch is too big. Particularly regulators are concerned for this type of risk and have been investigating for numerous years how to capture the mismatch in loans, deposit and other banking book products in a standardized framework. Calculations of interest rate risk measures are often opaque due to the many assumptions that need to be made in the process, resulting in a difficult comparison across banks (BCBS, 2016). Furthermore, with the fundamental review of the trading book (FRTB) (BCBS, 2013b), the Basel Committee on Banking Supervision (BCBS) has remained focused on addressing the regulatory arbitrage across the banking book/trading book boundary. For these reasons, the BCBS introduced new guidelines on the management of interest rate risk, strengthening the old standards by offering a tighter outlier test, new guidelines on model assumptions and enhanced disclosure (BCBS, 2016). Despite the BCBS dropping their proposed standardized capital charge framework, the new guidelines make it possible to better include the change of prescribed shocks on a bank's capital (ΔEVE) and interest income (ΔNII) in balance sheet simulation. Furthermore, Basel's new standards strengthen the set of shocks to the yield curve by including non-parallel shifts. By using these more standardized measures and guidelines for interest rate risk in the banking book, the author of this thesis and his supervisors, hereinafter referred to as we, judge the trade-off between interest rate risk and return. Subsequently, the new guidelines make it possible to calculate an approximation of capital that should be held for interest rate risk in the banking book and evaluate the impact of tighter capital requirements and changes in customer behavior.

1.2 Research Objective

The objective of this paper is to investigate the interaction between the magnitude of a bank's interest rate risk and the associated returns, together with addressing a method for improving a bank's balance sheet and giving insight in the impact of stricter interest rate risk regulation. We shed light on this topic by developing a tool to improve a bank's interest rate spread. We then analyze the impact of different limits of interest rate risk measures and modeling assumptions on the dynamics and profitability of a stylized balance sheet while improving the interest rate spread.

1.3 Research design

To achieve the research objective, we have formulated research questions for structuring the research. Our main research question is:

What would be the impact of stricter regulation on interest rate risk in the banking book and how could a bank improve its balance sheet given its interest rate risk appetite?

In order to answer this main research question, we have formulated several sub-questions:

1. (a) What is interest rate risk in the banking book and how does it relate to profitability?
   (b) What are the regulatory developments regarding interest rate risk in the banking book and what other regulatory requirements are applicable to a bank's balance sheet?
   (c) How can the interest rate risk exposure of a balance sheet be quantified?
2. (a) How does a typical balance sheet of a small Dutch bank look like?
   (b) How can the impact of setting a bank's interest rate risk appetite be illustrated and how can this be used to create an improved balance sheet allocation?
3. (a) How severely does a bank's interest rate risk appetite affect its earnings?
   (b) What is the impact of stricter capital requirements on a bank's interest rate risk taking and what the impact of changes in key modeling assumptions on the interest rate risk exposure of a bank?

1.4 Thesis Outline

Our paper is organized as follows:

In Chapter 2, we review the definition of interest rate risk, the origins of its exposure and how it contributes to the profitability of a bank. We conclude this chapter by summarizing how interest rate risk in the banking book can be quantified.

Chapter 3 explains the developed model for improving a bank's interest rate spread given prudential measures. Furthermore, it describes the steps taken to construct a stylized balance sheet of a small Dutch bank to illustrate the direct impact of limits in interest rate measures and enhanced IRRBB regulation.

In Chapter 4, this stylized balance sheet is used as input for the model in order to analyze the impact of interest rate risk legislation, which is done by altering limits on IRRBB measures while improving the interest rate spread. Moreover, we illustrate the change in risk-taking by including a capital charge through the weighted exposure for interest rate risk in the total capital ratio. Subsequently, we make suggestions to improve the allocation of our balance sheet and analyze the impact of changes in assumptions regarding optionality on the disclosed EVE measure by altering the repricing assumptions of non-maturity deposits and prepayment rates of residential mortgages.

Our thesis concludes with Chapter 5, where we discuss the findings and limitations and do recommendations for further research.

We focus on standardized method proposed by the BCBS in their latest version of standards on IRRBB (BCBS, 2016) and, where needed, complement this by using the previous draft (BCBS, 2015) to somewhat simplify the interest rate risk calculations. Because data are limited, we use simple financial products and assume bullet payments for most balance sheet items, a single realistic value for the conditional prepayment rate and use a stylized balance sheet without the presence of a trading book. We use a number of annual reports and performance reports of Dutch RMBSs for computing this stylized balance sheet and for determining the fixed interest periods.

Chapter 2

Literature Review

In Section 2.1, we summarize on the concept and definition of interest rate risk, the components of interest rate risk and the building blocks of interest rates. Section 2.2 summarizes the findings of academic literature on the relationship between a bank's interest rate risk taking and its returns. Section 2.3 gives background on the developments in interest rate risk regulation. This chapter concludes with Section 2.4, which elaborates on the commonly used measures to quantify interest rate risk.

2.1 Definition and Origins

2.1.1 Banking Book Versus Trading Book

To clearly understand the risks posed by movements in interest rates for a banking book and the motivation of regulators to introduce a more standardized capital charge, one should know the difference between a banking book and trading book of a bank. Due to capital purposes, all activities of a bank should be divided over two books. As the name implies, the positions of a bank that are held for trading purposes are held in the trading book, where positions that are held to maturity belong in the banking book. Regulation judges the risks for products that are held for trading and held to maturity differently. With different risk measures for the two books, an asset in one book can have a different capital charge compared to the exact same asset in the other book (BCBS, 2013b). This is also the case for interest rate risk. Interest rate risk in the trading book is part of Pillar 1 , which inflicts a direct capital charge, where interest rate in the banking book is part of the Basel capital framework's Pillar 2. This results in different capital requirements for the same type of risk, which triggers potential capital arbitrage (Jones, 2000). To tackle this capital arbitrage, the Basel Committee on Banking Supervision (BCBS) tries to regulate the switching between banking and trading book and limits the derived capital benefits. Aligning capital charges for market risks to the different books is particularly important given the enhancements in the capital treatments for trading book positions, including the BCBS's Fundamental Review of the Trading Book (FRTB) (BCBS, 2013b).

2.1.2 Definition

The theory of financial intermediation attributes a number of activities, commonly referred to as qualitative asset transformation. THese activities are seen as the core activities of a retail bank, and include taking on credit risk, liquidity provision and maturity transformation. The latter evolves in most cases as a result of liquidity provisions when long term fixed-rate loans are funded using short-term deposits (Bhattacharya and Thakor, 1993). With term premia present in the yield curve, banks have incentives to create maturity gaps, i.e., a mismatch between term structures of cash flows. Hereby, banks expose expose themselves to interest rate risk (Memmel, 2011).

Before we include the banking book aspect, we first take a look at the definition of interest rate risk. One definition, often used in academic literature, is the following:

Definition 2.1. Interest rate risk encompasses all risks that are directly or indirectly induced by uncertainty about future interest rates (Hellwig, 1994).

Several variables, for instance probability of default, exposure at default, loss given default and repayment behavior, are correlated with movements in the yield curve. Drehmann, Sorensen, and Stringa (2006) introduced a theoretical framework in which they illustrate the difference between measuring the combined impact of interest rate risk and credit risk in stressed scenarios and measuring the impact separately. However, due to a split in credit risk and interest rate risk in the Basel regulatory measurement framework, we primarily focus on the direct impact on a bank's capital and earnings under adverse fluctuation in the yield curve, ignoring the correlation between credit and interest rate risk under the alternative interest rate scenarios. Another definition, given by Koch and MacDonald (2014), reflects the scope of this research better:

Definition 2.2. Interest rate risk is the potential loss from unfavorable changes in interest rates on a bank's profitability and market value of equity.

In this thesis we use the definition of interest rate risk in the banking book provided by the BCBS (2016). This definition resembles the previous definition, but stresses the direct effect of adverse fluctuations in the yield curve on earnings and capital.

Definition 2.3. Interest rate risk in the banking book refers to the current or prospective risk to a bank's capital and to its earnings, arising from the impact of adverse movements in interest rates on its banking book.

2.1.3 Components Of Interest Rate Risk

In this section, we elaborate on the three main types of interest rate risk defined by the BCBS (2016):

1. Gap risk, which arises from a mismatch in term structure of interest rate sensitive instruments in the banking book. A position with long-maturity assets which is funded by short-term liabilities is exposed to this type of interest rate risk. If the returns on long term investments are fixed and the interest rate turns out to be higher than expected, it is possible that refinancing costs exceed the returns on the long term investment resulting in a negative net interest income. Subsequently, following the theory of term structure of interest rates (Cox, Ingersoll, and Ross, 1985), if the repricing periods of the assets perfectly match those of the funding, the interest rate risk exposure is zero.

2. Basis risk. One complication of interest rate risk is that there are different reference rates. These interest rates tend to move together, but are not perfectly correlated (Memmel, Seymen, and Teichert, 2016). Basis risk describes the impact of relative changes in interest rates for interest rate bearing instruments with the same term structure but different interest rate indices. For instance, a basis risk exposure will arise if the spread between three-month Treasury and three-month LIBOR changes. This change will affect the net interest margin of a bank as a result of changes in the spreads received or paid on instruments that are repriced at that time. In the previous section, we stated that the exposure to interest rate risk equals zero if the maturity of assets perfectly matches the payments of the funding. We assumed here that the interest rate indices for the payments are the same. Whether this is not the case, there is still a basis risk component that can cause exposure.

3. Option risk arises from alternative levels and terms of cash flows as a result of optionality. Interest rate levels can trigger events embedded in banking products. Common examples of banking products with embedded optionality are redemption of deposits and prepayment of loans. Also automatic optionality, for example the change in value of certain interest rate derivatives, belongs to this type of risk.

2.1.4 Composition Of Interest Rates

The required return by investors consists out of two components: the risk-free rate and a risk premium. The risk premium can again be divided into several spreads to compensate for risks associated with investing in certain instruments and counterparties (Hull, 2012). In this section we will elaborate on which spreads compose the interest rate and specify which rates and spreads are contributing in determining the IRRBB according to the BCBS (2016). In Figure 2.1 the composition of interest rates is illustrated. For fair value priced instruments, e.g. bonds and interest-earning securities, interest rates contain the following building blocks:

1. The base of the interest rate is the *risk-free rate*, the return that can be obtained without assuming any risks (Hull, 2012).

2. Investment instruments with longer maturities and higher volatilities are more exposed to interest rate changes than instruments with short maturities and low volatilities. The *duration liquidity spread* compensates for this uncertainty.

3. Even risk-free instruments may have a premium representing the market appetite for investing. This premium is named the *market liquidity spread*.

4. The credit spread can be divided into two premiums, a *general market credit spread* and an *idiosyncratic credit spread*. The *general market credit spread* represents the spread associated with the risk premium required by market participants for a given credit quality and is typically the required yield of a debt instrument from a party with a specific credit rating over a risk-free alternative. The *idiosyncratic credit spread* is the premium for the credit quality of the specific individual borrower and the risks associated with the credit instrument. The *idiosyncratic credit spread* takes into account other information as well, such as risks from the sector, geographical location of the borrower and risks associated with the credit instrument (BCBS, 2016).

The required return for instruments valued at amortize cost, e.g. consumer or corporate loans, are based on two components BCBS (2016):

1. A funding rate, which is the cost of funding the loan and consists of a reference rate plus a funding margin. The reference rate is an externally set benchmark rate, such as the London interbank offer rate (LIBOR). To come to a bank's own funding rate, the funding margin is added.

2. A credit margin, also called commercial margin, which is an add-on to the funding rate. The other option is an administered rate, a rate set by the control of a bank.

As illustrated in Figure 2.1, IRRBB regulation comprises the possible negative effects of changes in the risk-free rate including the a spread for duration. Credit spread risk includes any kind of asset/liability spread risk of credit-risky instruments that is not explained by IRRBB and by expected credit or jump to default risks and does not comprises the scope of IRRBB (BCBS, 2015). Therefore, banks should exclude any commercial margins and other spread components while computing their IRRBB exposure, as these spreads are not covered in IRRBB-metrics, for which it is also not covered in the model proposed in Chapter 3. The alternative is including these spreads in the discount factor (BCBS, 2016), which will nullify this inclusion to a large extent.

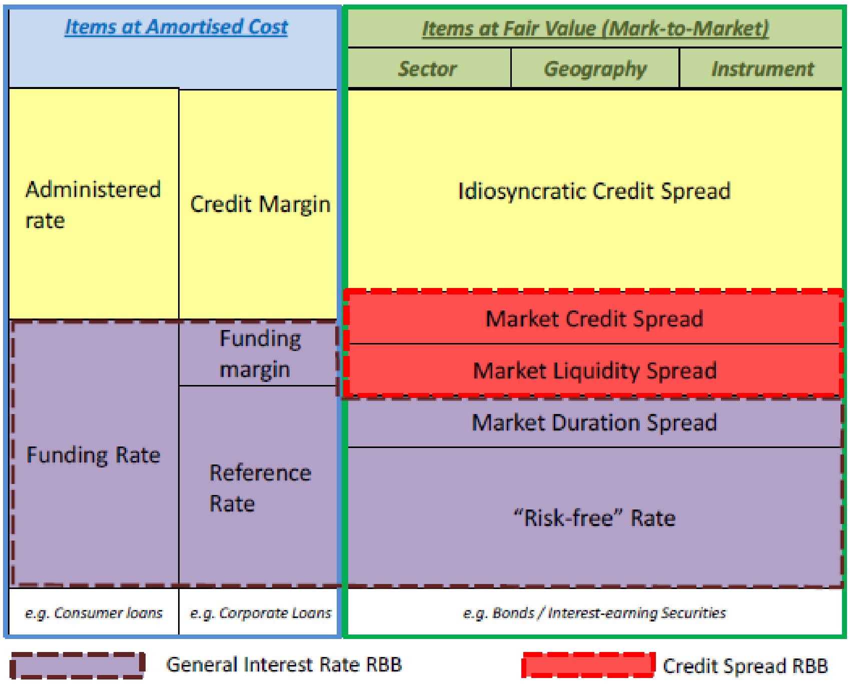


FIGURE 2.1: Components of interest rates (BCBS, 2016).

2.2 Interest Rate Risk and Bank Stability

Authors of empirical academic papers find it hard to determine the relationship between interest rate risk taking and a bank's stock returns or stability due to the complex environment and risk heterogeneity across banks. Fraser, Madura, and Wigand (2002) found a negative relation between interest rates and bank stock returns, which seems logical, since one of the sources of income of a bank is through term transformation. Because of this, a decrease in interest rates results in less interest expenses, while interest income decreases less due to a longer repricing period. Chen and Chan (1989) argue that these empirical studies often are the result of the sample period and can not be generalized. Furthermore, Flannery (1983) does not find proof to confirm the conventional wisdom that banks typically borrow short and lend long. Moreover, he argues that also small banks are well hedged against interest rate fluctuations. However, BIS study by English (2002) concludes that it seems unlikely that interest rate fluctuations are a major factor for a bank's stability, even though he acknowledges an impact of interest rate fluctuations on profit volatility. Maes (2005) found the impact of interest rates on the stability of the banking industry more severe than in English' research. However, the empirical evidence of both studies is weak (Dunn and McConnell, 1981). Memmel (2011) states the interest rate risk exposure moves in accordance with the possible earnings from term transformation. On the other hand, he found that the interest rate margin is not affected much by the exposure to interest rate risk, which makes it interesting to look at it from a model perspective.

2.3 IRRBB Regulation

We begin this section with a short introduction to the Bank for International Settlements (BIS) and the Basel Committee for Banking Supervision (BCBS) by providing a shortened version from the origins provided on their website (Bank for International Settlements, 2015). This section concludes with a summary of new developments in interest rate risk regulation.

2.3.1 Bank For International Settlements

The Bank for International Settlements (BIS) is an international financial institution which fosters international monetary and financial co-operations and serves basically as a bank for central banks. Originally, BIS was founded in 1930 to facilitate reparations imposed on Germany by the Treaty of Versailles after World War I and to act as a trustee to the German Government International Loan, also known as the Young Loan. After suspension of the reparation payments, the BIS started to focus more on its second task: fostering the cooperation between its member central banks. Due to collapses of internationally active banks, and in specific the bankruptcy of Bankhaus Herstatt in 1974, it became clear that there was a need for more banking supervision on an international level. As a reaction to this event, the central bank governors of the G10 countries established a committee we now know as the Basel Committee for Banking Supervision (BCBS). This committee provides a forum for regular cooperation on banking supervisory matters and has the objective to enhance financial stability by improving supervisory practices and the quality of banking supervision worldwide.

The BCBS aims to achieve its goals by setting minimum standards for the supervision of banks and by sharing supervisory issues, approaches and techniques to promote best practices and to improve cross-border cooperation. Furthermore, the BCBS exchanges information on developments in the banking sector and financial markets to identify emerging risks. Although the BCBS determines minimum standards and supervisory approaches, the BCBS decision does not have legal force. The BCBS formulates supervisory standards and appropriate practices to be implemented by individual national authorities.

2.3.2 The Basel Regulation

With a committee setting international standards for banks, the foundation of supervision on internationally active banks was laid. In the beginning, the primary focus of the BCBS was on capital adequacy to cover losses of credit risk. In July 1988, a first capital measurement system was issued by the BCBS. This measurement system, also known as the Basel Capital Accord, the 1988 Accord or simply Basel I, called for a minimum capital ratio of eight percent of a bank's risk-weighted assets, and had to be implemented by 1992. In 1995, the framework was refined to address also market risk in addition to credit risk, via an amendment to the Capital Accord. This amendment also made it possible for banks to make use of internal models to determine their adequate market risk capital requirements.

In June 2004, after a consultation period of almost six years, the Revised Capital Framework, better known as Basel II, was introduced. This framework consists of three pillars, a structure which is still being used in the Basel regulation. The minimum requirements are captured in the first pillar. The second pillar treats the supervisory review of the capital adequacy and internal processes of a bank. Standards of effective use of disclosure to strengthen market discipline belong to the third pillar (Hull, 2012). The objective of Basel II was to improve the reflection of underlying risk by regulatory capital and capture risks from innovation in the financial industry. Furthermore, the new framework sought to encourage and reward improvements in risk measurement and controls. After the introduction of Basel II, the BCBS started to focus more on the trading book in addition to the banking book. A new amendment was issued governing the treatment of risk measurements of banks' trading books in 2005, which was integrated in Basel II in 2006 (BCBS, 2006).

During the crisis, the need for increasing supervision and more severe capital requirements rose. Financial institutions were too leveraged and their capital buffers were inadequate. The absence of these standards in combination with poor internal risk management resulted in practices such as the mispricing of credit and liquidity risk and excess credit growth (Baldan and Zen, 2013). As a response to the need for more supervision, the BCBS introduced a first set of principles to manage liquidity risk in September 2008. In 2009, new documents were issued in order to further strengthen Basel II. These packages of documents mostly contained treatments for complex securitization positions, off-balance sheet vehicles and trading book exposures.

The financial crisis shed a light on the risks taken by banks. Often, banks were not able to impose losses on their capital buffers (Baldan and Zen, 2013). Inevitably, the BCBS announced higher capital standards for international active banks in 2010. This reform in the design of capital and liquidity was the basis of Basel III. In addition to a higher percentage common equity to cover potential losses, the leverage ratio, capital conservation buffer and counter cyclical capital buffer were introduced. Also liquidity risk is covered more comprehensively through the introduction of the liquidity coverage ratio (LCR) and net stable funding ratio (NSFR), see Appendix E. Moreover, global systematic important banks (G-SIBS) are exposed to extensive additional capital and supervision.

2.3.3 New Developments In IRRBB Regulation

Since the introduction of Basel II, IRRBB is captured using a Pillar 2-approach due to the heterogeneity across managing risks in banking books. The Pillar 2-approach allows banks to use outcomes from internal models to determine their exposure without a direct capital charge for it. Therefore, financial institutions need to establish their capital adequacy by means of an assessment process: the Internal Capital Adequacy Process (ICAAP) (De Nederlandsche Bank N.V., 2005). The supervisor's task is to evaluate the methodology and systems used by the financial institution to evaluate and determine capital adequacy through a Supervisory Review and Evaluation Process (SREP). The interest rate risk is judged by the adequacy of the risk management and the magnitude of the interest rate risk Hull (2012).

Interest rate risk in the banking book has been on the supervisory authorities' agenda since 1993, when the BCBS issued its first consultation paper on this type or risk. In this 38-paged document the BCBS (BCBS, 1993) consulted on measures for interest rate exposure in order to create a common standard measurement framework for international active banks. In the resulting guidelines, published in 1997, the BCBS set out general principles for managing interest rate risk (BCBS, 1997). These principles, which got revised in 2004 with the revision of the Capital Adequacy Framework, do not involve any specific capital requirement to cover potential losses of positions in the banking book due to interest rate fluctuations. Instead, they set out guidelines on policies, procedures and how to monitor IRRBB. Furthermore, they make some suggestion on measuring interest rate risk, leaving the definite choice for measurement systems to the bank or national regulator.

Also in the next consultation papers, no general agreement was given on how to calculate the appropriate amount of capital to cover potential losses. It was left to the national regulator to determine the magnitude of the capital requirement for this risk. To facilitate the national supervisors in the comparison of interest rate risk exposures across financial institutions, an economic value approach with standardized rate shocks was introduced (BCBS, 2004b). For this process, a bank had the choice between two options regarding the interest rate shock. This process, focusing on G10 currencies, gave banks freedom to choose between using parallel upward and downward 200 basis point shocks, or the 1st and 99^{th} percentile of observed interest rate changes of the last 240 working days holding period and a minimum of five years of observations could be used. One flaw in this version of the economic value measure is that only parallel interest rate shock scenarios are used, ignoring positions that might be exposed to risks arising from twists in the yield curve. To resolve this, banks were expected to come up and perform multiple scenarios evaluating their interest rate risks from different angles.

In 2012, the BCBS began to examine a capital charge for interest rate risk in the banking book (IRRBB) in a more standardized approach. The reasons are simple: firstly, to help ensure that banks have enough capital to cover potential losses resulting from interest rate risk exposure and secondly, to limit capital arbitrage between banking book portfolios and trading book portfolios, which are subject to different accounting standards. Although the motivation is logical, it is hard to create a standardized framework that captures the interest rate risk exposure, because of the heterogeneity in customers and risk appetite and optionality in banking products. This challenge was also reflected in the time it took to publish a first consultation paper. The BCBS spent no less than three years to publish its first consultation in which it made an attempt at standardizing IRRBB a little bit further by consulting on two options for regulatory treatments for IRRBB: a standardized Pillar 1-approach and an enhanced Pillar 2-approach (BCBS, 2015). Due to feedback from the banking industry, the BCBS acknowledged that including IRRBB in Pillar 1 would be less appropriate, because of the heterogeneous nature of IRRBB (BCBS, 2016).

In April 2016, the BCBS presented the enhanced Pillar 2-approach in which it continued to create a more standardized criterion to identify outliers by pleading for improved development of interest rate shocks, key behavioral and modeling assumptions and internal validation processes for internal measurement systems and models used for IRRBB. New in this enhanced Pillar 2-approach is the more standardized disclosure of the change in economic value of equity (EVE) based on standardized interest rate shock scenarios. More on the new interest rate risk disclosures can be found in Appendix F. In addition to previously prescribed shifts, a set of non-parallel shifts is added for the EVE measure. Finally, some more modeling restrictions are introduced for non-maturity deposits (BCBS, 2016). With the introduction of new IRRBB guidelines, the introduction of an explicit capital framework for interest rate risk in the banking book seems averted for the time being. The recurring debate of a standardized versus the Pillar 2-approach was died down until the next regulatory attempt will introduce itself. Until then, the task is left to the national regulators to determine whether banks hold an appropriate amount of capital for this type of risk.

2.4 Interest Rate Risk Measures

Hellwig (1994) argues that limiting interest rate risk for banks is not that obvious from an economic view due to the fact that fluctuations in interest rates affect the economy as a whole. This makes it a non-diversifiable risk. The interest-induced valuation risks of long term assets can be shifted from one agent to another or shared between agents, but cannot be diversified away. Following this zero-sum view, the vision that interest rate risk in banking needs to be controlled by regulation can not be based on the notion that these risks are otherwise insufficient diversified, as this would mean that either the economy as a whole needs to limit its exposure to interest rate risk or parties other than banks are better qualified to bear these risks. Here, the issue is what the optimal level of exposure to interest rate risk is and how these risk are shared efficiently? From a banking supervisory perspective, it is more clear: banks are the cornerstones of the economy, meaning the risks banks are exposed to must be within limits.

It is important for a bank to measure its interest rate risk exposure regularly. This can be done by undertaking sensitivity analyses of shifts in the yield curve. A variety of techniques and models are used by banks to analyze their interest rate risk exposure. In this section, we will elaborate on the most commonly used techniques listed by De Nederlandsche Bank N.V. (2005). This section concludes with the measurement techniques proposed by guidelines of the BCBS and our motivation to measure interest rate risk in the banking book.

2.4.1 Gap Analysis

One of the first and simplest techniques of determining the interest rate risk exposure is gap analysis, which is still common practice for financial institutions. Gap analysis measures a bank's interest rate risk exposure by allocating assets, liabilities and off-balance sheet items to time buckets according to their repricing characteristics (Hull, 2012). The net difference in a specific bucket indicates the net exposure to changes in interest rates. Because of this netting procedure, gap analysis may fail to recognize nonlinearities, resulting in an underestimation of the interest rate risk. By modeling the cash flows of the whole portfolio we can capture this compression in banks' net margins better. The advantage of this method is that it is easy to comprehend, which makes it easy to be communicated to management and used as a first step in analyzing the interest rate risk in the banking book (De Nederlandsche Bank N.V., 2005).

Because of the simplicity of this method, it has some weaknesses. Firstly, it is a very static method and ignores optionality embedded in bank products. Subsequently, gap analysis fails to capture yield curve and basis risk in an adequate manner, as it only illustrates the mismatches per bucket and does not give a clear indication in the form of a number. Yield curve risk, the risk of non-parallel changes in the yield curve, can be determined through gap analysis, but it needs further analysis in order to do so. Finally, using gap analysis one assumes all positions within a maturity segment expire or reprice at the same time (De Nederlandsche Bank N.V., 2005).

2.4.2 Duration of Equity

Duration is a widely used measure of a portfolio's exposure to movements of interest rates and it is used to estimate changes in a portfolio's value as a result of small changes in the yield curve. The duration itself is similar to the effective maturity, but includes both principal and coupon cash flows. The fraction of a change in bond price as a result of a one percent change in its yield can be estimated by multiplying the present values of the cash flows as a fraction of the total bond price by the time of cash flow. The formula can be seen in Equation 2.1. The change in value of the portfolio can then be estimated with Equation 2.2. A portfolio duration of zero does not per se indicate perfectly matched cash flows, but it indicates small changes in interest rate will cause no change in portfolio value (Hull, 2012).

$$D = -\frac{1}{B} \cdot \frac{dB}{dy} = \sum_{i=1}^{n} t_i \cdot (\frac{cf_i \cdot e^{-y \cdot t_i}}{B}) \tag{2.1}$$

$$\Delta B = -D \cdot B \cdot \Delta y \tag{2.2}$$

Where:

D = Duration
B = Bond price
y = Interest rate
t_i = Time of cash flow i
cf_i = Cash flow i

The duration ignores the curvature in the relative change curve of the value of the portfolio. This can partially be overcome by capturing the convexity, the slope of the change as result of interest rate changes as can be seen in Formula 2.3. The change in value can be calculated using Formula 2.4 (Hull, 2012).

$$\mathrm{C} = -\frac{1}{B} \cdot \frac{d^2B}{d^2y} = \frac{\sum_{i=1}^{n} cf_i \cdot t_i^2 \cdot e^{-yt_i}}{B} \tag{2.3}$$

$$\Delta B = -D \cdot B \cdot \Delta y + \frac{1}{2} \cdot B \cdot C \cdot (\Delta y)^2 \tag{2.4}$$

Generally, duration is used in two common used measures: the duration of equity and the price value of a Basis point (PV01). The duration method can be generalized to use in determining the price sensitivity of all interest rate dependent instruments on a balance sheet. Because the duration of both assets and liabilities can be calculated, the duration of the equity can be constructed, as the definition of economic value of equity is the economic value of the assets minus that of the liabilities. The duration of equity gives an indication about the value change as a result of relatively small changes in the yield curve. Using the duration of equity for a one basis point parallel change will result in the PV01.

The convexity expansion for the duration can be used to calculate the effect of relatively large shifts in the yield curve on the bond price. Still, duration only considers parallel shifts in the yield curve, because of the generalization of cash flows over time. In an environment of historically low interest rates non-parallel shifts in the yield curve should be considered. In addition to yield curve risk, basis risk cannot be measured using this approach. Furthermore, durational measures ignore change in cash flow as a result of optionality affected by interest rate changes (De Nederlandsche Bank N.V., 2005). Many banking products have embedded optionality triggered by interest rates, which causes alternative expected cash flows. This makes it important to include optionality in determining interest rate risk in the banking book. Finally, duration is a static measure, meaning it does not include new business or the possibility of applying mitigation strategies.

2.4.3 Economic Value Perspective

When interest rates deviate, the value of the underlying assets and liabilities of a bank changes due to changes in expected future cash flows and discount rates. Unless the repricing of the assets matches the repricing of liabilities perfectly, the economic value of a bank changes, since the economic value of equity equals the value of the assets minus liabilities. The economic value of equity measure (further referred to as EVE or ΔEVE) determines the change of a bank's economic value of equity as a result of interest rate scenarios. Firstly, the economic value under a base interest scenario is calculated. After that, the balance sheet is revalued under the alternative interest scenarios and the differences in a bank's economic value are determined, see Equation 2.5.

The EVE measure is a gone concern measure, meaning that positions on a bank's balance sheet run off and are not replaced by new business. In 2016, the BCBS introduced a standardized ΔEVE approach to compare interest rate risk in the banking book through a common, standardized measure. Because all cash flows are used for this calculation, this approach is often used to measure the potential long-term impact of interest rate shocks on banks and is seen as a proper indicator for the required amount of capital a bank should hold to cover IRRBB losses (Cohen (2012), BCBS (2016)).

One disadvantage of this method is that most of the assets and liability in the banking book are hard to price, since they are not traded on the market. Because of this, banks often use a 'mark-to-model'-approach in which theoretical models are used to come up with an appropriate price. Furthermore, since for this measure a run-off balance sheet is used, new business or mitigation strategies are not incorporated. It cannot make allowance for the market valuations of future growth in existing or new business activities (De Nederlandsche Bank N.V., 2005).

$$\Delta EVE = \max_{i \in \{1,2,\ldots,6\}} (\max(0; \sum_{c:\Delta EVE_{i,c}>0} \Delta EVE_{i,c})) \tag{2.5}$$

Where:

$\Delta EVE_{i,c}$ = Change in EVE under interest rate scenario i in currency c

2.4.4 Earnings Perspective

During severe shocks, a sufficient ΔEVE is not a guarantee that a bank will face no problems. Heavy losses over a short or medium period of time could pose a threat to a bank's capital position and could cause liquidity problems due to lack of cash or to a downgrade of credit score. Earnings-based measures focus on controlling the variability of a bank's interest margin and therefore implicitly also of its profitability on a short-term time horizon. The models that apply this approach are based on the finding of mismatching between the maturity periods or first repricing events for the lending and borrowing positions within a given period of analysis (Cohen, 2012). As with the EVE, the earnings at risk (EaR) measure determines the change of the expected net interest income as a result of interest rate shocks and is more suited for determining risks for a short to medium term, typically one to two years. With the EaR variant described by the BCBS (further referred to as NII) one is assuming a static balance sheet, meaning the size and shape of a bank's balance sheet remains the same by assuming like-for-like replacements of balance sheet items as they run off. Besides from a regulatory perspective, the NII is often used for internal management as it gives a complete picture of earnings risk resulting from interest rate movements by analyzing the interest risk profile of a banking book in a detailed and tailored way (BCBS, 2015). In contrast to the EVE, the NII as described by the BCBS only considers the two parallel shocks to the yield curve and evaluate the change in net interest income over a specific horizon, making the NII an important indicator, but less suitable as a standalone measure. Moreover, EaR measures can be complex and non-transparent as a result of underlying repricing assumptions (De Nederlandsche Bank N.V., 2005).

2.4.5 Regulatory Scope

We previously summarized the most commonly used interest rate measures and their advantages and disadvantages. From a regulatory perspective, it is of essence that all material sources of interest rate risks are covered. Table 2.1 summarizes the coverage of the measures discussed and illustrates that covering all risk components using a standalone measure is not possible. The BCBS argues that focusing primarily on minimizing one measure can result in high volatility of earnings or equity and can pose a threat to a bank's capital base or future earnings (BCBS, 2016). It is therefore that the standards in *Interest rate risk in the banking book*, issued by the BCBS in April 2016, states that a bank should determine its IRRBB risk appetite in both economic value and earnings-based measures, where banks often solely use the latter measure. The two measures show commonalities, but can be used in a complementary manner, as can be seen in Table 2.1. These measures are preferred over the other two measures, as gap analysis fails to capture optionality and basis risk and cannot be expressed as a single number. Durational measures are found less appropriate than earnings-based measures due to the limited capture of optionality and basis risk. Moreover, durational measures fail to estimate the impact of larger shocks to the yield curve. The BCBS emphasizes the economic value measures as capital indicator due to the inclusiveness of all banking book cash flows, while still limiting the earnings volatility under interest rate scenarios over a short-term period. We therefore include the combination of the ΔEVE and ΔNII as interest rate risk indicators in our model.

TABLE 2.1: Summary interest rate risk measures.

Component	Gap analysis	PV01/Duration	ΔEVE	EaR / ΔNII
Short-term exposure	Yes	No	No	Yes
Long-term exposure	Yes	Yes	Yes	No
Gap risk	Yes	Yes	Yes	Yes
Basis risk	No	No	Yes	Yes
Optionality	No	Limited	Yes	Limited

2.5 Conclusions

In this chapter, we answered our first sub-questions, by determining the definition of interest rate risk in the banking book and its components, together with the components of the required return for banking products. We furthermore treated the relationship between interest rate risk taking and bank earnings. Finally, we treated the developments in interest rate risk regulation and the measures to quantify interest rate.

- *What is interest rate risk in the banking book and how does it relate to profitability?*

We define IRRBB as the risk to the current or prospective risk to a bank's capital and to its earnings, arising from the impact of adverse movements in interest rates on its banking book (BCBS, 2016). Taking on interest rate risk contributes to the interest rate spread of a bank, due to term-premia present in the yield curve. By increasing its interest rate risk exposure, i.e., lend long and borrow short, a bank can increase its interest income.

- *What are the regulatory developments regarding interest rate risk in the banking book?*

Interest rate risk has increased focus on the regulator's agenda, due to the increased competition and the current low interest rate environment. The BCBS strives to more standardization, but IRRBB remains, due to heterogeneity and the tailored approach that is needed, part of Pillar 2. However, new guidelines on measuring and disclosing IRRBB are introduced recently. These guidelines have been used as much as possible in supporting the IRRBB calculations in our model.

- *Which other regulatory requirements are applicable to a bank's balance sheet?*

Besides limits on interest rate exposures, a bank is subject to other requirements on liquidity, i.e., the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR), and capital, i.e., the leverage ratio (LR), common equity tier 1 ratio (CET1 ratio) and the total capital ratio (TCR)

- *How can the interest rate risk exposure of a balance sheet be quantified?*

While measuring interest rate risk in the banking book, it is of essence that all interest rate risk components are covered. We laid out the commonly used measures in interest rate risk management. Moreover, we illustrated that based on coverage of interest rate risk components, the combination of the EVE and NII is found most suitable in measuring IRRBB by the BCBS . These risk measures are used in the next chapter to quantify the interest rate risk exposure on balance sheet level.

Chapter 3

The Model

In this chapter, the model we use to improve the balance sheet, and with this, illustrate the impact of changes in regulations and model assumptions is introduced. Section 3.1 elaborates on the items for our stylized balance sheet as well as introduces the objective function of the model. Section 3.2 explains the balance sheet definition and key constraints. Section 3.3 treats how we include the EVE and NII measures and elaborates on our choice for the interest rate floor. This chapter concludes with Section 3.4, in which we explain how we come to our starting exposures and decision space.

3.1 Model Objective

To assess the impact of a bank's interest rate risk appetite and new regulation on its profit, we compare the improvement of a balance sheet of a hypothetical bank in a base scenario with alternative interest rate scenarios. We introduce a model to capture the effects of a bank's interest rate risk exposure while improving its profitability by reallocating assets and liabilities given a realistic decision space. We compose a hypothetical balance sheet using several annual reports and performance reports of Dutch RMBSs. For this, we focus on smaller, traditional retail banks whose core activity is providing mortgages and is mainly funded by deposits and debt securities. The model makes use of the sequential quadratic programming (SQP) algorithm for non-linearly constrained gradient-based optimization, based on the Kraft's implementation, see Kraft (1994), and is included through the NLOPT package for R.

Our addition to earlier balance sheet simulations and improving methodologies is adding a detailed specification of cash flows which allows us to include interest rate risk parameters. By including this, we can lay out the impact of tighter IRRBB regulation and the interaction between a bank's IRRBB appetite and its interest spread. A bank can use this approach to get insights in a possible improved allocation over assets and repricing maturities and can get insight in the costs of tighter interest rate risk appetite on balance sheet level.

3.1.1 Asset and Liability Mix

The asset and liability mix of the hypothetical bank results from the comparison of balance sheets across Dutch banks that match the profile of our

TABLE 3.1: The stylized balance sheet.

The Stylized Balance Sheet	
Assets	Liabilities and Equity
- (i=1) Cash and balances with central banks	- (j=1) Due to banks
- (i=2) Loans and advances to banks	
	Retail:
Government bonds:	- (j=2) Demand deposits
- (i=3) Government bonds (AA- +)	- (j=3) Savings deposits
- (i=4) Government bonds (A- to A+)	- (j=4) Term deposits
Retail:	*Corporate and commercial:*
- (i=5) NHG	- (j=5) Secured wholesale funds
- (i=6) Loan-to-value <60%	- (j=4) Other liabilities
- (i=7) Loan-to-value 60%-80%	
- (i=8) Loan-to-value 80%-102%	- (j=5) Total equity
- (i=9) Other assets	
Off-balance sheet instruments:	
- (k=1) Interest rate swaps	

hypothetical bank and can be seen in Table 3.1.

As can be seen in the stylized balance sheet, our hypothetical bank is only involved in mortgage lending. Not all of these banks solely sell mortgages. In most cases, a bank as ours has a small amount of customer or corporate loans without collateral. For simplicity and because these amounts are relatively small, we exclude these items from the balance sheet. A trading book is also not included in the model, since these banks often do not have a trading book.

For capturing the cash flows of the asset and funding mix, we split each balance sheet item up into nineteen maturity classes based on the maturity buckets suggested by the BCBS (2016). For a bank which is funded for a substantial part through customer deposits, modeling assumptions on the repricing dates of deposits can have a big impact on its interest rate risk exposure. To determine the distribution of savings and demand deposits over the time buckets, we use the Time Series Approach (TSA) (BCBS, 2015), in which we first determine the number of core deposits. The core deposits for the savings deposits and the demand deposits are uniformly slotted over nine and ten years respectively. The non-core deposits are slotted in the overnight bucket. Although this methodology is standardized, the high level of standardization could result in not capturing the reality appropriately. Furthermore, relatively small differences in the implied cap for core deposits result in different repricing dates, which subsequently result in different EVE and NII factors. This methodology is elaborated in Appendix B.

For simplicity and to avoid making repayment assumptions, all assets and liabilities except for mortgages are assumed to be bullet payments. For all balance sheet items, the interest payment and payment of the principal are calculated monthly.

To avoid making assumptions about the redemption of mortgages, the repayment of the principal for the mortgages is modeled solely through a conditional prepayment rate of five percent of the principal amount at the time of the cash flow. This value in line with the CPRs of the RMBSs used to construct our stylized balance sheet (Dolphin Master Issuer B.V. (2016) and Goldfish Master Issuer B.V. (2016)).

Definition 3.1. A conditional prepayment rate (CPR) is a loan prepayment rate equal to the proportion of the principal of a pool of loans assumed to be paid off prematurely in each period.

For a more detailed description of the balance sheet items, see Appendix E.

3.1.2 Interest Rate Swaps

Nowadays, banks are managing their interest rate risk in different manners. A frequently used method used by banks is to exchange repricing maturities using interest rate swaps. Because interest rate swaps are vital instruments for banks to hedge interest rate risk (Bucksler and Chen, 1986), we include ten different fixed/floating interest rate swaps in our model, which only deviate in time to maturity. This way, we cover the possibility across all maturities to swap fixed for floating interest rates without creating too many decision variables.

Definition 3.2. An interest rate swap is an agreement between two parties to exchange a series of interest payments without exchanging the underlying debt (Bucksler and Chen, 1986).

In a typical fixed/floating rate swap, the first party promises to pay to the second at designated intervals a fixed amount of interest calculated at a fixed rate on the "notional principal". The second party promises to pay to the first at the same intervals a floating amount of interest on the notional principle calculated according to a floating-rate index. The first party in a fixed/floating rate swap, which is paying the fixed amount of interest, is known as the fixed rate payer, while the second party, which is paying the floating amount of interest, is known as the 'floating-rate payer'. By paying a fixed rate and receiving a floating one, a bank can swap a long repricing time for a short repricing time and the other way around.

In our model the fixed coupon are determined such that the net present value of the fixed leg equals that of the floating leg. By using this par coupon, the fair value of the interest rate swap at initiation equals zero. Despite a fair value of zero, an interest rate swap still exposes a bank to risks for which capital should be held. Interest rate swaps are traded over-the-counter, meaning that the swap is traded directly between two parties, which causes direct counterparty credit risk (CCR) (Bucksler and Chen, 1986). The second factor that can be distinguished is credit valuation adjustment (CVA), for which also capital should be held (BCBS, 1993). The calculation of the required capital for interest rate swaps is treated in Appendix C.

3.1.3 The Objective Function

Different approaches are used within balance sheet analysis and improvement. An often used approach is the Modern Portfolio Technique (MPT) by Markowitz (1952), based on the well-known Capital Asset Pricing Model (CAPM). In this method, the spread is optimized for a given risk, which is quantified by the volatility of the portfolio. Although the portfolio's volatility is a commonly used method to quantify the portfolio risk, we choose not to include the volatility constraint. The reason is that the focus of this paper is on the impact of a bank's interest rate risk appetite on its potential spread given other, mostly regulatory, risk parameters. Furthermore, on the asset side of the balance sheet, our hypothetical bank is rather conservative by solely focusing on mortgages and by not being involved in trading activities. However, we do make use of the spread component in our objective function.

It is safe to say that positions in the banking book are not created over a short period of time. A typical mortgage is repaid in fifteen to twenty-five years and also exposures on the liability side of a bank can have maturities exceeding ten years. Given the severe fluctuations in interest rates during the last years combined with the current continuous low interest rate (BCBS, 2016), new business is acquired against different rates than current exposures. Since we want to see the effect of a shift in balance sheet composition in the current situation, our objective function distinguishes new and old business, as they yield different rates. This way we can observe which shift given a set of risk constraints is advised and evaluate the corresponding effect on a bank's profit. Before we define our objective function, we define the net interest income (NII) as a function of the existing business, new to be acquired business and their interest income and expenses. Table 3.2 gives a numerical example of the how $\mathrm{x}_{\mathrm{old}}$ and $\mathrm{x}_{\mathrm{new}}$ are determined.

$$NII = \vec{x}_{old} \cdot \vec{II}_{old} + \vec{x}_{new} \cdot \vec{II}_{new} - \vec{y}_{old} \cdot \vec{IE}_{old} - \vec{y}_{new} \cdot \vec{IE}_{new} + \vec{o} \cdot \vec{SE} \tag{3.1}$$

Where:

$x_{\text{old}}(y_{\text{old}})$	= Asset (liability) exposure after repayment
$x_{\text{new}}(y_{\text{new}})$	= New acquired amount of the asset (liability)
o	= Notional interest rate swaps
II	= Interest income
IE	= Interest expense
SE	= Expected swap payment - fixed coupon

Table 3.3 summarizes the main revenues and costs of a bank's income statement. Due to a point in time optimization, our objective function does

TABLE 3.2: Numerical example NII calculation.

Current exposure	New exposure	Repayment	x_{old}	x_{new}
100	110	20	80 (=100 - 20)	30 (=110 - 80)
100	90	20	80 (=100 - 20)	10 (=90 - 80)

TABLE 3.3: Typical income statement of a bank (Bessis, 2011).

Interest margin (NII) and fees	
+	Capital gains and losses
-	Operating costs
=	Operating income (EBITDA)
-	Depreciation
-	Provisions for loan losses
-	Tax
=	Net income

not consider depreciations nor expected capital gains, making the depreciations and expected capital gains zero. Following from this, our objective function can be defined as:

$$\text{Return on equity} = \frac{\delta\,(NII - LL - C_{operating})}{Equity} \tag{3.2}$$

Where:

δ = Tax factor
LL = Loan loss provisions
$C_{\text{operating}}$ = Operating costs

Since we define our operating costs as a percentage of the balance sheet size, and keep the balance sheet size and the amount of equity constant in the simulation, the true objective we optimize under a set of risk constraints is the interest spread minus the provisions for the expected loss of loans. The provisions for the expected loss of loans are calculated through a percentage of the loan, which is the result of a balance sheet regression performed by EY internally.

3.2 Model Definition

3.2.1 The Balance Sheet Definition

A balance sheet is subject to different requirements. We start by defining the sum of the assets (x) and the sum of liabilities and equity (y), which is equal by definition, and equals one in our model. The notional amounts of our interest rate swaps are defined by o_i.

$$\text{Total assets} = \sum x_{i,t} = 1 \tag{3.3}$$

$$\text{Total liabilities and equity} = \sum y_{i,t} = 1 \tag{3.4}$$

$$\text{Interest rate swap notional} = o_t \tag{3.5}$$

The decision space of our hypothetical bank depends on several assumptions, such as liquidity, availability for sale and repayment of the balance sheet item. To set the decision space of our bank, we insert upper and lower bounds for our balance sheet items, which can be written as follows:

$$x_{i,t}^- \leq x_{i,t} \leq x_{i,t}^+ \tag{3.6}$$

$$y_{i,t}^- \leq y_{i,t} \leq y_{i,t}^+ \tag{3.7}$$

$$o_t^- \leq o_t \leq o_t^+ \tag{3.8}$$

Here, $x_{i,t}^-$ and $x_{i,t}^+$ respectively represent the lower and upper bound of asset i.

3.2.2 Model Constraints

While improving the spread, we restrict six risk measures, which we include through a set of twelve constraints. Background on the regulatory ratios can be found in Appendix D. Moreover, risk weights and other factors can be found in Appendix E.

- Total capital ratio (TCR)

$$TCR = \frac{y_6}{\sum \vec{x} \cdot \vec{RW} + GI \cdot 0.15 + CCR\,(\vec{o}) + CVA\,(\vec{o})} \tag{3.9}$$

- Liquidity coverage ratio (LCR)

$$LCR = \frac{\sum \vec{x} \cdot \vec{HQLA}}{\sum \vec{y} \cdot \vec{CO} - min\left(0.25 \cdot \sum \vec{y} \cdot \vec{CO}, \sum \vec{x} \cdot \vec{CI}\right)} \tag{3.10}$$

- Net stable funding ratio (NSFR)

$$NSFR = \frac{\sum \vec{y} \cdot \vec{ASF}}{\sum \vec{x} \cdot \vec{RSF}} \tag{3.11}$$

- Leverage ratio (LR)

$$LR = \frac{y_6}{\sum x_t + PFE(\vec{o})} \tag{3.12}$$

- Economic value of equity under scenario i (ΔEVE)

$$\Delta EVE_i = \frac{\sum \vec{x} \cdot \Delta \vec{E}V_{x,i} - \sum \vec{y} \cdot \Delta \vec{E}V_{y,i} + \sum \vec{o} \cdot \Delta \vec{E}V_{o,i}}{y_6} \tag{3.13}$$

- Net interest income under scenario i (ΔNII)

$$\Delta NII_i = \frac{\sum \vec{x} \cdot \Delta \vec{I}I_{x,i} - \sum \vec{y} \cdot \Delta \vec{I}E_{y,i} + \sum \vec{o} \cdot \Delta \vec{S}E_{o,i}}{y_6} \tag{3.14}$$

3.3 Measuring Interest Rate Risk

We quantify the interest rate risk in the banking book by evaluating the change in economic value of equity and the one year change in net interest income resulting from a set of interest rate scenarios as described in the latest guidelines on managing interest rate risk by the (BCBS, 2016). These interest rate scenarios include a complete set of both parallel and non-parallel shocks to the yield curve, also covering scenarios of a steepener and flatteren yield curve and fluctuations in the short rate. The composition of these interest rate scenarios are described in Appendix A. An example of a stressed interest rate scenario according to the standards set out by the BCBS can be seen in Figure 3.1.

Prepayment rates of loans and redemption rates of deposits are also affected by interest rate movements. In a scenario with increasing interest rates, the conditional prepayment rate (CPR) tends to be lower than in the base scenario and for term deposit redemption rates (TDRR) vice versa (Dunn and McConnell, 1981). In the model, the CPR will be stressed by a scalar appropriate to the corresponding scenario in the model. The TDRR is not included, since the penalty for redeeming term deposits earlier than the contractual maturity often compensates for the interest rate risk exposure created. By using these stressed scenarios, the value of a banks equity and their net interest income deviates compared to the baseline interest and prepayment rate. In this section, we first explain the choice for the interest rate floor. Afterwards, we will elaborate on the application of the ΔEVE- and ΔNII-measure in our model.

3.3.1 Interest Rate Floor

Negative interest rates have now been introduced in five currency areas, corresponding to around 20 percent of global economic output. However, guidelines by De Nederlandsche Bank N.V. (2005) on interest rate risk still prescribe a floor of zero for interest rate scenarios. Since interest rates are of crucial importance for the economy and in view of the fact that negative interest rates are now widely introduced, the question is whether negative scenarios should be included in the calculation of ΔEVE and ΔNII, and if so, which interest rate floor should be considered.

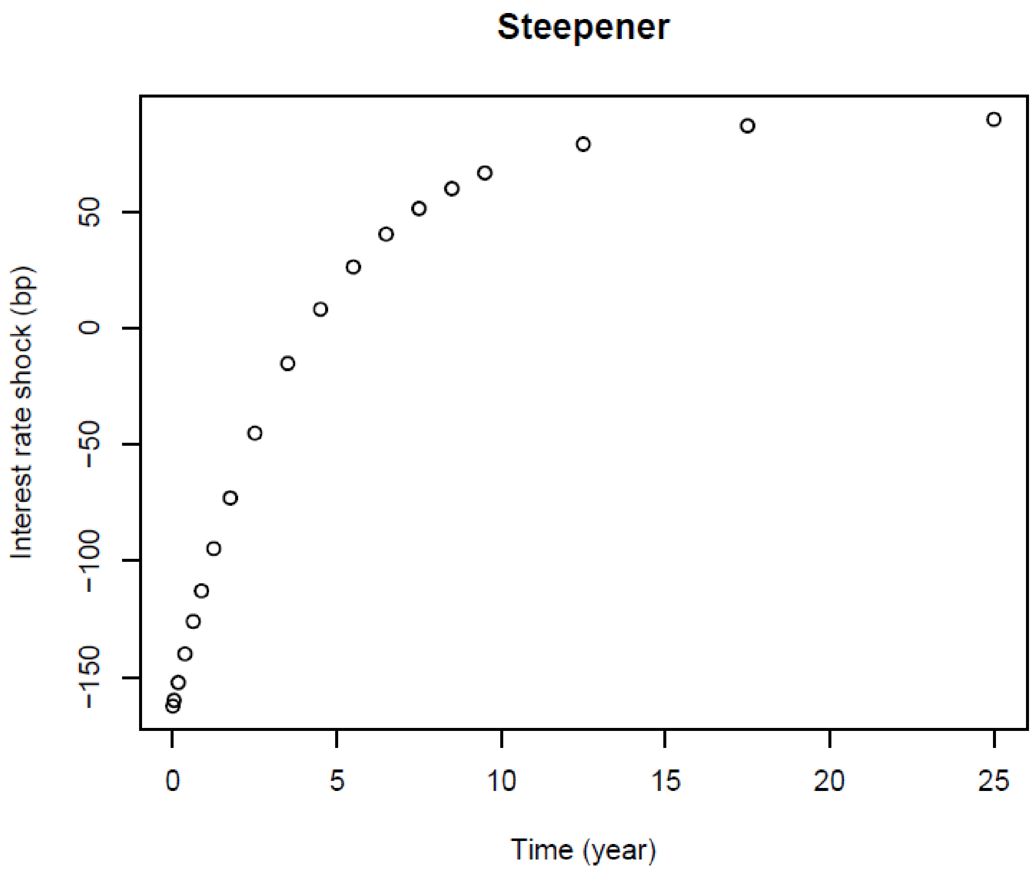


FIGURE 3.1: Interest rate shock for the Euro in a steepener interest rate curve scenario.

Researchers of the Japanese holding company Nomura state the ultimate lowest interest rate can occur when the deposit money is not reinvested. Following from this, the long term storage cost of money would be the ultimate lowest interest rate possible, since the invested money yields zero. Nomura makes the comparison with the average long term storage price of gold implied by historical future prices, which they use as a proxy for globally long term storage cost of money (Nomura, 2016). They argue, that based on this comparison, the ultimate lowest interest rate on the long term would be around minus 2.4 percent. A note should be made that the implied storage cost fluctuates heavily over time as Figure 3.2 illustrates.

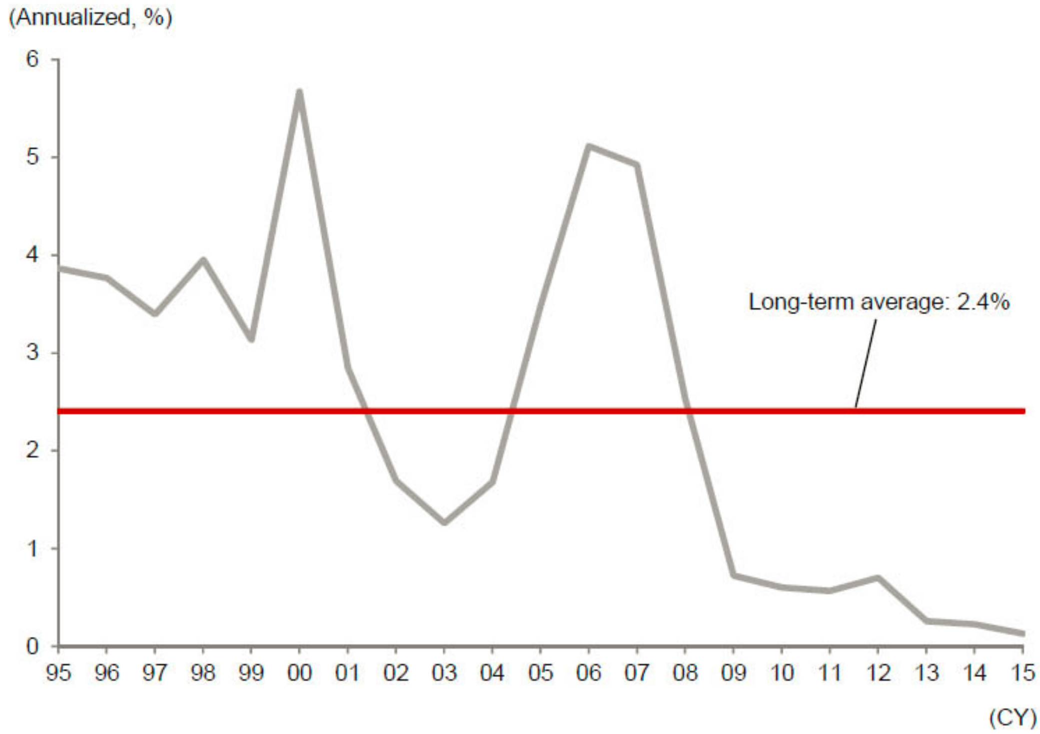


FIGURE 3.2: Estimated gold storage cost based on gold future prices (Nomura, 2016).

A survey among 42 European banks, conducted by EY (2016), shows that the vast majority of the responding Dutch banks already consider negative interest rate scenarios in IRRBB modeling, but still report to DNB using scenarios floored at zero percent. Given that negative interest rates are widely introduced and the absolute theoretical lowest interest rate is still a significantly lower than current yields, we include an interest rate floor level between the theoretical minimum and current regulatory floor, namely minus one percent for interest rates after shock.

3.3.2 ΔEconomic Value of Equity

Alternative interest rate scenarios have two factors that influence a change in a bank's economic value of equity:

1. The cash flows: loans are subject to prepayment risk. In our model only mortgages are subject to this risk and this is included in the model through a stress factor of the CPR.

2. The discount factor: the discount factor changes due to changes in the interest rate.

For the following calculations we see a liability as a negative asset. For simplicity and to match the cash flows as well as possible, we assume monthly interest and principal payments, meaning that there is a monthly interest payment of a twelfth of the annual interest income of that asset. We use the following four steps to determine the change in economic value of equity for the six alternative interest rate scenarios:

We start by constructing the cash flows. The k^{th} cash flow resulting from asset i with maturity T can be written as:

$$CF_{i,T,k} = (t_k - t_{k-1}) \cdot C_{i,T} \cdot N_{i,T} + N_{i,T} \cdot I_{k=K}, \text{ for } k \in 1..K \tag{3.15}$$

Where:

t_k = the timing of cash flow k
$C_{i,T}$ = the coupon of asset i with maturity T
$N_{i,T}$ = the principal of asset i with maturity T
$I_{k=K}$ = 1 if k equals K, otherwise 0

Mortgages are subject to prepayments. Therefore, the cash flows of mortgages include a constant prepayment rate and are determined as follows:

$$CF_{i,T,k} = (t_k - t_{k-1}) \cdot (C_{i,T} + CPR) \cdot N_{i,T,k-1} + N_{i,T,K} \cdot I_{k=K}, \text{ for } k \in 1..K \tag{3.16}$$

Where the remaining principal amount evolves through:

$$N_{i,T,k} = N_{i,T,k-1} \cdot (1 - (t_k - t_{k-1}) \cdot CPR)\,, \text{ for } k \in 1..K \tag{3.17}$$

The payments are then slotted over nineteen time buckets as described by the BCBS (2016). Ultimately, the commercial spreads should be subtracted from the cash flows. An alternative given by the BCBS (2016) is to discount using the original spreads. Since we use a hypothetical balance sheet, we are unable to determine the precise spreads of our positions. Instead, we use the current yield curve of the asset or liability as input for the discount factor. By doing so, we assume that the current commercial margins equal the commercial margins of the current portfolio.

The second step is to calculate the economic value of an asset under all interest rate scenarios. The economic value of asset i with maturity T under scenario s can be defined as the sum of the discounted cash flows:

$$EV_{s,i,T} = \sum_{k=1}^{K} DF_{s,i,k} \cdot CF_{s,i,T,k} \tag{3.18}$$

Where the discount factor equals:

$$DF_{s,i,k} = e^{-r_{s,i,t_k} \cdot t_k} \tag{3.19}$$

The third step is to determine the percentage of change per asset per maturity under all interest rate scenarios. This percentage change serves as a factor which can be scaled by the exposure in order to calculate the change in economic value of an asset subclass under an alternative interest rate scenario, due to the linear relationship between the change in economic value of the asset and the principal of the asset. Because of this linearization, the model has only to calculate the change in economic value of an asset once, which increases the speed of the simulation. The factor of asset i and maturity T for scenario s is calculated by:

$$\Delta EV_{i,T,s} = \frac{EV_{i,T,0} - EV_{i,T,s}}{EV_{i,T,0}} \tag{3.20}$$

Finally, the change in the economic value of equity under scenario s is calculated by taking the sum of the product of the ΔEV-factors and the corresponding exposures plus the decrease in fair value of the automatic interest rate options.

$$\Delta EVE_s = \sum_{i=1}^{I} \sum_{b=1}^{19} \Delta EV_{i,T,s} \cdot x_{i,T} - \sum_{j=1}^{J} \sum_{b=1}^{19} \Delta EV_{j,T,s} \cdot y_{j,T} + KAO \tag{3.21}$$

Where:

$x_{i,T}(y_{i,T})$ = Amount of asset (liability) i (j) with maturity T
KAO = The decrease in fair value of automatic interest rate options

Where the decrease in fair value of the interest rate swaps in scenario i is calculated by:

$$KAO_i = \sum_{o=1}^{n} \Delta FVAO_i^o - \sum_{q=1}^{m} \Delta FVAO_i^q \tag{3.22}$$

Where:

KAO_i = the add-on on the EVE-measure for scenario i
$FVAO_i$ = the fair value of the automatic option for scenario i
$n(m)$ = number of options sold (bought)

Figure 3.3 illustrates the EVE-factors for NHG mortgages under the six interest rate scenarios. In Figure 3.4 the effect of the parallel up-scenario on the economic value of two loans is illustrated. It can be seen that due to the earlier repayments of the mortgage, the change in economic value an asset is less, since the effective duration is less than that of a bullet bond. The impact of the alternative interest rate scenarios for the interest rate swaps is calculated likewise and is illustrated in Figure 3.5.

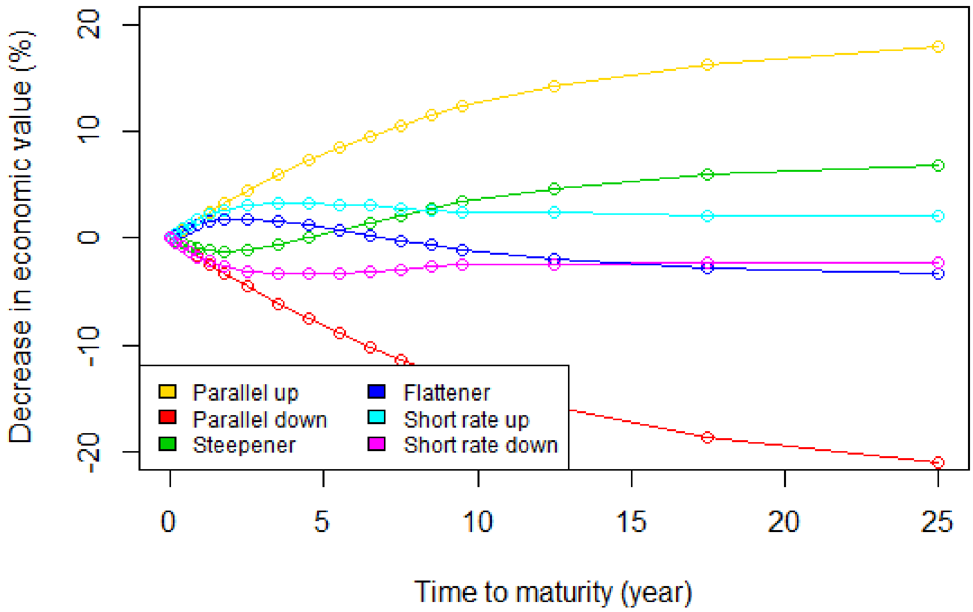


FIGURE 3.3: EVE factors for NHG mortgages buckets.

Another thing to notice is that, although the initial shocks are symmetric, the impacts of the shocks are not symmetric. One reason for this is that positive shocks, i.e., shocks that increase the yield curve, tend to have less impact than downward shocks. This can be seen in Table 3.4, where the change in present value of a payment of 100 in ten years is illustrated. This effect is also illustrated in Figure 3.3. Furthermore, the scenarios are also subject to different factors of optionality which triggers a change in cash flow. Finally, the interest rate floor is only triggered at short-term negative shocks, which causes a change in magnitude of the shock and can cause asymmetrical outcomes as well.

TABLE 3.4: Example of change in present value value of a 100 cash flow in ten years.

Scenario	Present value	Percentage change
Base	$100 \cdot e^{-0.02 \cdot 10} = 81.87$	-
+200bps	$100 \cdot e^{-0.04 \cdot 10} = 67.03$	-18.12%
-200bps	$100 \cdot e^{-0 \cdot 10} = 100.00$	22.14%

3.3.3 ΔNet Interest Income

As discussed in Chapter 2, a sufficient ΔEVE does not necessarily mean a low interest rate risk exposure. The difference in net interest income is also

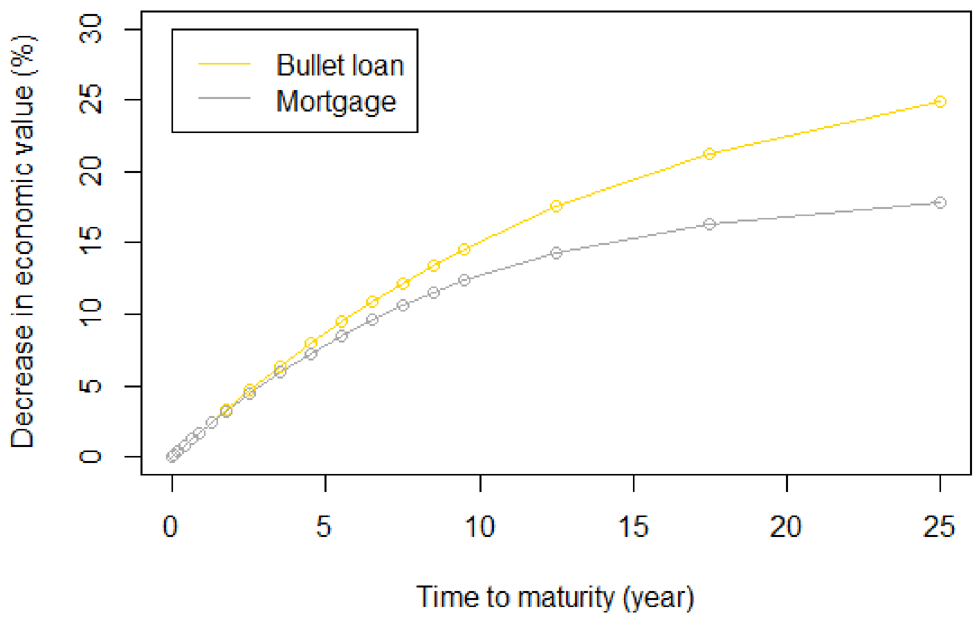


FIGURE 3.4: Change in value of bullet loan versus mortgage with prepayment rate of 5% in a parallel up scenario.

set out by the BCBS as a vital measure (BCBS, 2016). The ΔNII measures the change in interest income as a result of parallel interest rate shocks within a certain time period. Since the ΔNII is calculated by using the difference of the base rate and the shocked rate, it can be proved that the change is approximately independent of the underlying interest rate of the asset or liability and linear to the principal as pointed out by the BCBS (2015). As with the ΔEVE, we determine the percentage change in net interest income given fluctuations in the yield curve for every subclass and use the exposure to scale it.

Consider an asset with principal N that reprices at time t. Until time t, the asset will yield a rate r_t. After repricing the asset will generate a yield similar to the forward rate and will roll over over the time period from t to H. For simplicity, the difference in cash flows is received at H as was done in the calculations of the (BCBS, 2015). The total net interest income over horizon H can be written as the sum of the net interest income over the interest fixed period from 0 to t and sum of the net interest income over period t to H:

$$NII_{0,H} = NII_{0,t} + NII_{t,H} \tag{3.23}$$

In the following calculation we define the NII as the net interest income over the period as of t until the end of the horizon H. The total net interest income is then given by:

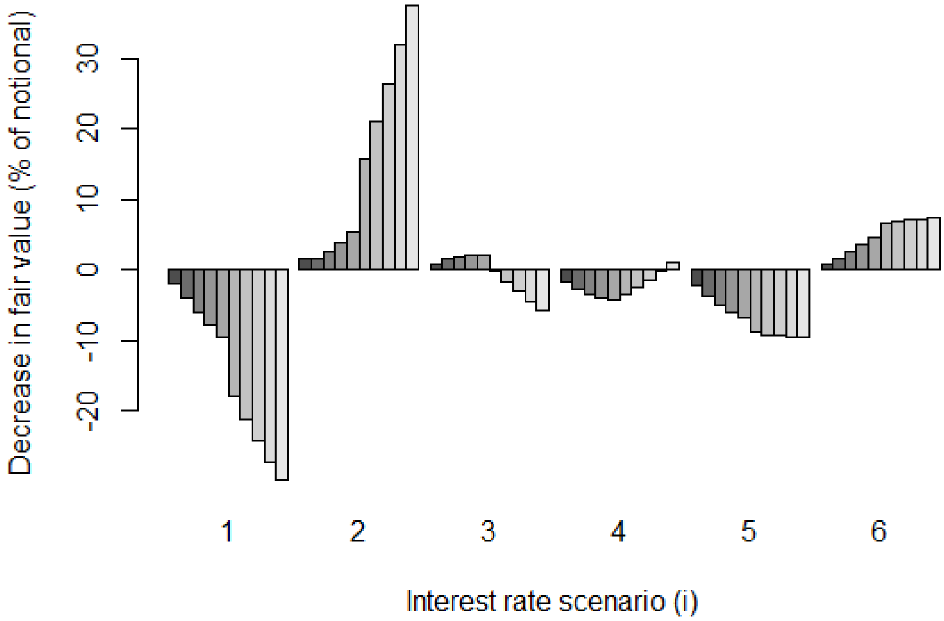


FIGURE 3.5: Impact of interest rate swaps on ΔEVE.

$$NII = N \cdot \left[e^{F_{tH} \cdot (H-t)} - 1\right] = N \cdot \left[e^{\frac{r_H \cdot H - r_t \cdot t}{H-t} \cdot (H-t)} - 1\right] = N \cdot \left[e^{r_H \cdot H - r_t \cdot t} - 1\right] \tag{3.24}$$

The present value of the net interest income between t and T can be written as:

$$PV\,(NII) = N \cdot \left[e^{r_H \cdot H - r_t \cdot t} - 1\right] \cdot e^{-r_H \cdot H} = N \cdot \left[e^{-r_t \cdot t} - e^{-r_H \cdot H}\right] \tag{3.25}$$

We do the same for the shocks NII:

$$\begin{aligned} PV\,(NII)_{shocked} &= N \cdot \left[e^{-(r_t + \Delta r) \cdot t} - e^{-(r_t + \Delta r) \cdot H}\right] \\ &= N \cdot \left[e^{-\Delta r \cdot t} \cdot e^{-r_t \cdot t} - e^{-\Delta r \cdot H} \cdot e^{-r_H \cdot H}\right] \end{aligned} \tag{3.26}$$

Substituting the first-order expansion of the shock terms as done by the BCBS (2015), $e^{-\Delta r \cdot t} \approx (1 - \Delta r \cdot t)$ and $e^{-\Delta r \cdot H} \approx (1 - \Delta r \cdot H)$, gives:

$$PV\,(NII)_{shocked} = N \cdot \left[(1 - \Delta r \cdot t) \cdot e^{-r_t \cdot t} - (1 - \Delta r \cdot H) \cdot e^{-r_H \cdot H}\right] \tag{3.27}$$

The difference in present value of the net interest incomes can now be calculated by combining Formula 3.25 and Formula 3.27.

$$\begin{aligned}\Delta PV\,(NII) &= PV\,(NII_{shocked}) - PV\,(NII_{base}) \\ &= N \cdot \Delta r \cdot \left(H \cdot e^{-r_H \cdot H} - t \cdot e^{-r_t \cdot t}\right) \\ &= N \cdot \Delta r \cdot (H \cdot DF_H - t \cdot DF_t)\end{aligned} \tag{3.28}$$

Finally, the ΔNII, which is equal to $-\Delta PV\,(NII)$ can be written as (BCBS, 2015):

$$\Delta NII = N \cdot \Delta r \cdot (t \cdot DF_t - H \cdot DF_H) \tag{3.29}$$

The factors for the decrease in interest income (II) and interest expense (IE) are determined by substituting $N = 1$ in Formula 3.29. As swap payments occur quarterly and the reset date is the first of the new calculation period, t is set to a fourth for all swaps. The NII-factor is then scaled by the exposure, making the total ΔNII under scenario s:

$$\Delta NII_s = \sum_{i=1}^{I} \sum_{b=1}^{19} \Delta II_{i,T,s} \cdot x_{i,T} - \sum_{j=1}^{J} \sum_{b=1}^{19} \Delta IE_{j,T,s} \cdot y_{j,T} + \sum_{k=1}^{K} \Delta SE_o \cdot o_k \tag{3.30}$$

Where:

$x_{i,T}(y_{\mathrm{i,T}})$ = Amount of asset (liability) i (j) with maturity T
o_k = Notional of interest rate swap k
ΔII = Factor for change in interest income
ΔIE = Factor for change in interest expense
ΔSE = Factor for change in swap payment

3.4 Simulation Input

One of the challenges is to construct a realistic banking book, since a bank's banking book is not publicly available. For many of our balance sheet exposures, we cannot use credit spreads of bond data as we look at banks' portfolios, which contain a wide range of non-traded assets and liabilities. Instead, the distribution of our hypothetical bank's portfolios and their returns are constructed using different sources available to us.

3.4.1 Starting Exposures

Using data extracted from annual reports of comparable banks (e.g. Achmea Bank (2015), Aegon Bank (2015), ASR Bank (2015) and Delta Lloyd Bank (2015)) an allocation over assets and liabilities can be made. However, the true challenge is to determine a plausible detailed distribution of balance sheet items over repricing dates, as this is only broadly revealed in annual reports. Furthermore, hedging activities, such as interest rate swap portfolios, are not published nor publicly available.

To still construct a realistic distribution of mortgages over the repricing buckets, we use two Dutch RMBS portfolios of ABN AMRO, namely Dolphyn (Dolphin Master Issuer B.V., 2016) and Goldfish (Goldfish Master

Issuer B.V., 2016). Based on the sum of size of the underlying mortgage, corresponding to roughly 15 percent of the total Dutch mortgages debt outstanding (CBS), combined with a geographical coverage of the Netherlands, we think the RMBSs' underlying mortgages are representative for a Dutch mortgage portfolio. The distribution of the mortgages over repricing dates are determined by using the remaining interest rate fixed period of the underlying mortgages. Because the performance report of the non-NHG RMBS does not specify the repricing per loan-to-value (LTV), we use a single distribution of mortgages over repricing dates for the non-NHG mortgages. The starting exposures, returns and regulatory risk factors are listed in Appendix E.

3.4.2 Decision Space

In determining the decision space of a bank given a time period, we consider multiple factors. The decision space is included in the model through setting the lower and upper bounds of balance sheet items. Because we use a point in time optimization of the balance sheet, one should first consider the time period to take into account when setting the lower and upper boundaries. We use boundaries based on a one year horizon as input variables. For determining the lower bound of a balance sheet item, the asset's availability for sale, liquidity and repayment of the principal given a time period of one year are judged. In determining the upper bound of an asset, we consider the liquidity and expected possible new business. Here, we assume that government bonds over a period of one year are liquid and can be bought and sold unlimitedly. We furthermore do not include transactions costs.

For mortgages, term deposits and covered bonds, we assume a five percent annual repayment of the principal as discussed earlier. For mortgages, we assume a possible acquisition of an additional five percent of the current exposure, as well as for demand and savings deposits. Secured funding is subject to a ceiling of 130 percent of the current exposure. Normally, covered bond programs come in big chunks. We relax this by assuming covered bonds can also be obtained in lower amounts.

Other balance sheet items, such as bank loans, cash and equivalents, other assets, other liabilities and equity, are seen as facilitating items and are held constant over the simulation.

3.5 Conclusions

In this chapter, we introduced the model objective, restrictions and implementation of risk measures as well as discussed the input sources used to construct our stylized balance sheet. With this, we answer the next set of sub-questions:

- *How does a typical balance sheet of a small Dutch bank look like?*

Our stylized balance sheet, a simplified reflection of a small Dutch bank, is constructed using average positions extracted from annual reports of banks resembling our bank's profile. For a more precise distribution of mortgages over maturity classes, we used the remaining fixed interest rate period of two Dutch RMBSs.

- *How can the impact of setting a bank's interest rate risk appetite be illustrated and how can this be used to create an improved balance sheet allocation?*

For illustrating the impact of setting the interest rate risk appetite, our model reallocates the assets and liabilities in an optimal manner in order to optimize the interest rate spread given a defined decision space. This decision space is based on a realistic shift given a horizon of one year. Here, not only the impact, but also the balance sheet allocation is monitored in order to illustrate possible shifts to improve the balance sheet allocation.

Chapter 4

Results

In the previous chapter, we described how we reallocate the balance sheet items in order to improve the interest rate spread, how we quantify risk exposures of our hypothetical bank and which building blocks we use for constructing a representative balance sheet. In this chapter, we will use this input to run the model in order to improve the spread given different constraints, functioning as a bank's risk appetite or regulatory constraints. This chapter is organized as follows:

Current exposure and impact of short term funding. In Section 4.1, we discuss the starting exposures of our balance sheet to different prudent measures and illustrate the impact of a reallocation of covered bonds by non-maturity deposits, i.e., demand and savings deposits.

Impact of interest rate measures. In Section 4.2 we illustrate the impact of including non-parallel interest rate scenarios in determining the EVE. Subsequently in Section 4.3, the risks of using only one interest rate measures while improving the interest rate spread is lay out to illustrate the need for both short-term and long-term measures. Furthermore, in Section 4.4 we illustrate the interest rate risk taking when a capital requirement for interest rate risk is introduced. Section 4.5 treats an example of a shift in balance sheet allocation to increase the interest rate spread while remaining within the limits.

Impact of differences in regulation and client behavior. Finally, we analyze the impact of increasing capital requirements in Section 4.6 and perform sensitivity analyses in Section 4.7 in order to illustrate the effect of changes in the stability of non-maturity deposits and the prepayment behavior of mortgagors on the EVE.

4.1 Short-Term Versus Long-Term Funding

We first discuss the starting exposures of our balance sheet to different prudential measures and analyze the impact of a reallocation of covered bonds to short-term funding, i.e., demand and savings deposits. As an example, we replace 15 percent of the total liabilities and equity placed in covered bonds and reallocate this over the demand and savings deposits while keeping a constant asset allocation. The interest rate swaps are excluded to illustrate the difference in exposures between the balance sheets. Table 4.1 lists the output measures of the balance sheets as well as the interest income and expense. Notable is that the starting LCR is extremely high compared to the regulatory minimum. A comparison with the balance sheets used for constructing our balance sheet illustrates that this is not unusual, as ASR Bank and Achmea Bank have liquidity coverage ratios of 824 and 1027 percent respectively, due to low cash outflows or high level of reserves. Furthermore, by replacing covered bonds by deposits the liquidity decreases significantly, since the 30-day stress-cash outflow increases. The increase in short-term funding decreases the interest expense by 0.39.

When we compare the impact on alternative interest rate scenarios listed in Table 4.2, we observe a difference in both EVE and NII. With the replacement of the bonds with deposits, we replace liabilities with typically longer repricing dates by liabilities with shorter repricing dates. As a result, the mismatch increases for the parallel shocks and for shocks in the short rate, as less net cash flows are now subject to differences in the short-term rate due to the overnight deposits. Subsequently, the NII increases substantially, due to the overnight repricing of the less stable deposits and short-term repricing of the stable deposits.

TABLE 4.1: Starting balance sheet exposures.

	No swaps	+ Deposits	Starting exposure
NSFR	148,3%	119,3 %	148,3%
LCR	201.3%	140.3%	201.3%
TCR	15.2%	15.2%	14.8%
Leverage ratio	4.51%	4.51%	4.53%
Interest income	3.35	3.35	3.35
Interest expense	2.02	1.66	2.02
Swap expense	-	-	0.14

TABLE 4.2: Starting interest rate risk exposures.

Measure	Scenario	No swaps	+ Deposits	Starting exposure
ΔEVE	Parallel up	61.74%	67.26%	2.89%
	Parallel down	-78.06%	-91.86%	-3.79%
	Steepener	29.74%	27.48%	18.07%
	Flattener	-16.57%	-13.42%	-14.66%
	Short rate up	0.92%	5.46%	-18.13%
	Short rate down	-1.99%	-7.64%	12.54%
ΔNII 1 year	Parallel up	3.21%	5.89%	0.41%
	Parallel down	-3.19%	-5.88%	-0.38%
ΔNII 2 year	Parallel up	4.66%	9.34%	1.58%
	Parallel down	-4.58%	-9.23%	-1.71%

For our starting position, we use a set of ten interest rate swaps to hedge the parallel interest rate risk exposure to more appropriate values. We use a solver to determine the allocation of interest rate swap to hedge the parallel shocks in terms of both EVE and NII. As a result, the total capital ratio in the new starting balance sheet is slightly lower due to the extra risk weights of the swaps. Furthermore, the interest rate spread is affected due to the payment of swap rates. We observe a lower interest rate risk exposure for parallel and steepener interest rate shocks by swapping long repricing cash flows, i.e., 25 years, to three months repricing cash flows. However, the equity volatility as a result of changes in the short-term rate rises, due to an increase in short-term fixed interest periods. The difference in net interest income arising from the non-maturity deposits is now covered by the floating interest income of the swaps, resulting in a significantly lower ΔNII.

4.2 Parallel Versus Non-Parallel Shocks

With the new guidelines on IRRBB of 2016, four non-parallel shocks have been added to the prescribed set of shocks. According to the BCBS, banks must set formal limits and disclose the impact on changes in the slope and shape of the yield curve (BCBS, 2016). Through this, the BCBS limits the exposure to the risk associated with a change in the relative interest rates of instruments at different tenors. However, the European Banking Authority (EBA) excludes non-parallel shocks in calculating the EVE (EBA, 2015). To illustrate the impact of setting formal limits on the four new shocks in addition to the two parallel shocks, we run the simulation with different shocks as input for the calculation of the EVE. In Figure 4.1 the improved spreads given variable limits on the EVE are visualized. Here, the EVE is built up using the following sets of shocks:

- Set 1 - Only parallel shocks
- Set 2 - All six prescribed shocks

The limits on the other ratio's correspond to the starting values of the balance sheet:

$$\text{Set} = [TCR, LR, LCR, NSFR] \tag{4.1}$$

$$\text{Set} = [14.86\%, 3.5\%, 201\%, 148\%] \tag{4.2}$$

It is interesting to see that limiting the EVE based on only parallel shifts of 200bps does not affect the return on equity as much as basing the EVE on the set of six shocks. This is due to excessive exposures in non-parallel scenarios. The model tends to hedge the limits on only the parallel shocks by simply hedging the parallel exposure with long-term swaps and bonds. This results in a small impact on potential parallel shocks, but still high exposures on non-parallel shocks as cash flows are not matched. With limiting only the parallel shocks, the exposures on the steepener and short rate down scenario remain high, namely 44 and 25 percent respectively. This indicates that the former limit of 20 percent of a bank's total capital on parallel shocks is not an appropriate standalone indicator of a bank's interest

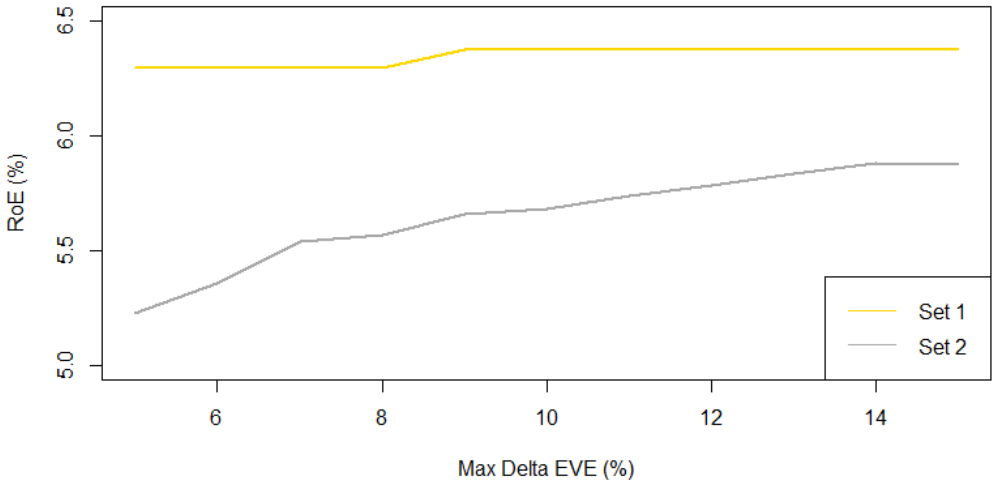


FIGURE 4.1: Impact of including non-parallel shocks.

rate risk appetite as non-parallel shifts could still have a great impact on the equity of a bank.

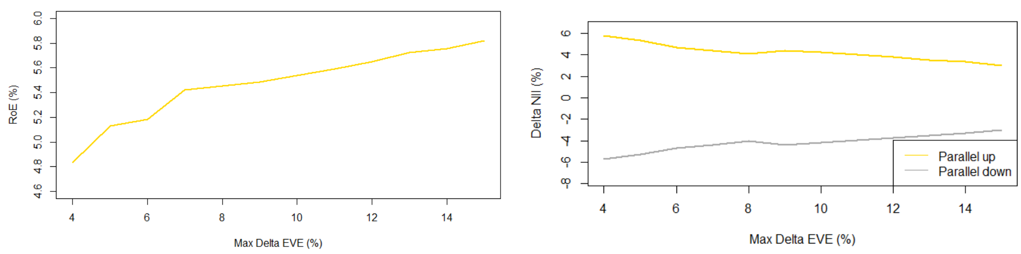
4.3 Short-Term Versus Long-Term Focus

A bank is obliged to set formal limits against the change in economic value and net interest income resulting from shocks to the yield curve. To show the direct impact of setting these limits, we improve the spread using different boundaries for EVE and NII.

By adjusting the limits on EVE, we restrict the term transformation by limiting the mismatch between repricing dates of assets and liabilities. Limiting the NII restricts the mismatch between repricing dates in the first year, which stabilizes the net interest income.

In Section 2.4 we laid out that the economic value tends to be a measure appropriate for the long-term interest rate risk, as all assets and liabilities are revalued. This way, all future cash flows are included in the calculation. Earnings-based measures focus on the short- to middle-long-term. We run two simulations, each focusing primarily on one of the two measures in order to illustrate the effects of managing IRRBB solely in terms of economic value or earnings. The regulatory maximum of 15 percent for the EVE is still applied for the earning-based measure, whereas the NII has no limit while focusing on the long-term impact.

The optimization of the spread with a long-term focus, i.e., a limited EVE, can be seen in Figure 4.2a. Increasing the maximum EVE from a conservative four percent to the regulatory maximum of 15 percent allows our bank to increase its return on equity with 1.12 percent to 5.83 percent. In Figure 4.2b the shadow values of the NII are illustrated. Focusing entirely



(A) RoE (B) ΔNII

FIGURE 4.2: Long-term focus.

on long-term measures, such as the EVE, can result in high earnings volatility of up to an NII of six percent of the bank's equity in our model. This means that in case of one of the two parallel alternative interest rate scenarios, the return on equity can deviate with six percent points a year.

Focusing entirely on earnings-based measures results in low earnings volatility over the evaluation horizon by definition. Using the one year NII-measure as control measure results in a relatively high return on equity of 5.79 percent. Our model looks for a reallocation of its assets and liabilities which maximizes the interest rate spread. From a credit risk perspective, our model allocates the assets to maximize its return given the allowed credit risk-weight exposure of the assets. The same is the case for the interest rate risk exposure. Our model allocates the balance sheet items such that the maximum impact given adverse interest rate scenarios remains within limits. Therefore, it makes sense that the model exposes our bank to the maximum EVE threshold of 15 percent in two shocks scenarios in order to pursue its maximum yield, as can be seen in Table 4.3. The impact of the NII on the return on equity is less than the impact of limiting the EVE, as it only takes into account the mispricing in the first year, which our bank hedges with one year swaps. Since these one year swaps affect the term transformation only for a small amount, the effect on the return on equity is not substantial. Furthermore, we evaluate our bank's two year NII in this scenario, which has a value of 3.80 percent of its equity, indicating that focusing on one year NII and the maximum EVE threshold of 15 percent can still result in a high middle-term earnings volatility. This also suggests that keeping the one year NII at the desired level could become costly due to the rollover of the hedging instruments against unfavorable rates.

In the previous examples we illustrated the impact of using only one of the two interest rate measures and laid out the need of combining both constraints in the model. In Figure 4.3 we improve the balance sheet using increasing limits on the EVE and NII. We use the balance sheet allocation of the best previous outcome as input for the next run. We plotted the outcome in a surface plot to illustrate the impact of the two measures on the return on equity of our bank. Although the interest rate swaps have no fair value, the annual fixed interest payments do have a negative impact on

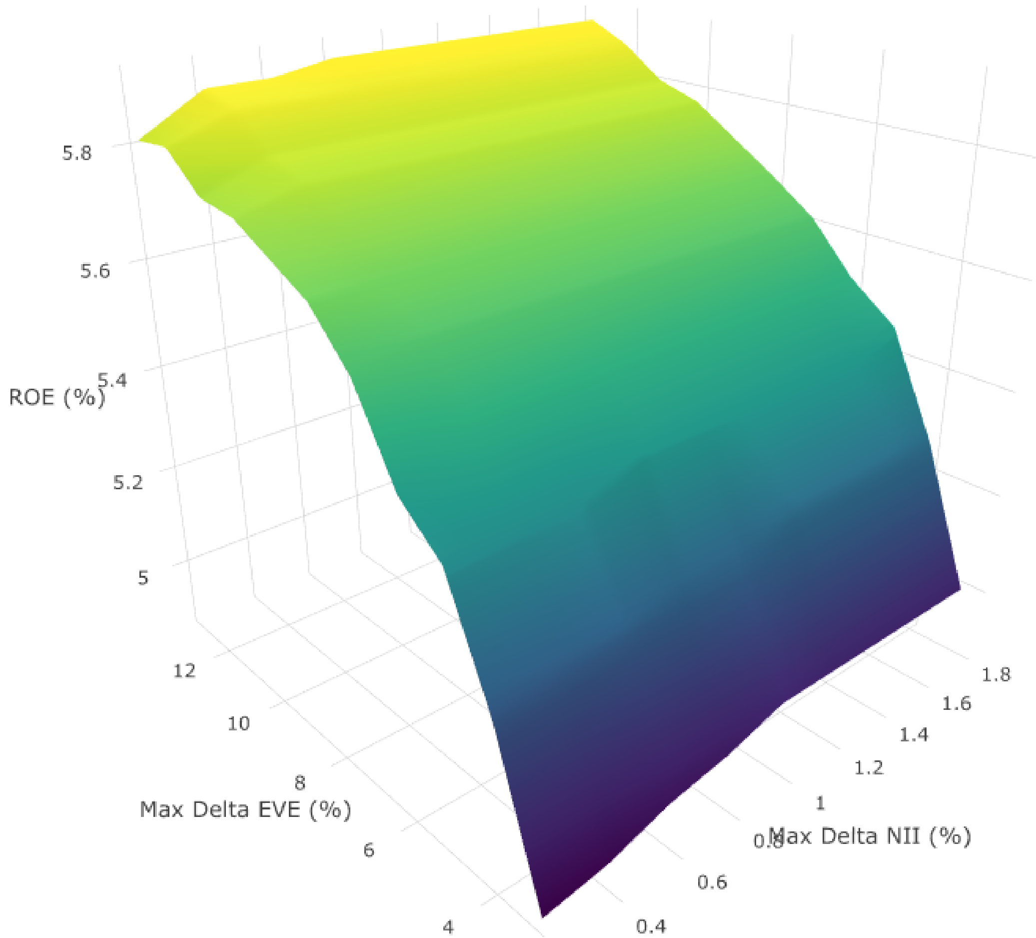


FIGURE 4.3: Impact of setting IRRBB risk appetite on return on equity.

TABLE 4.3: EVE values while focusing on NII.

Shock	Impact on EVE
Parallel up	15.00%
Parallel down	-17.36%
Steepener	15.00%
Flattener	-9.98%
Short rate up	-8.89%
Short rate down	7.25%

the return on equity. Given the maximization of short-term profits, i.e., the maximization of the return on equity, we can conclude a clear incentive for the bank to take on more interest rate risks in terms of both earnings and economic value perspective, despite the option to hedge its exposure freely in terms of value. We observe a slightly downward sloping curve for limiting the EVE, indicating that further decreasing the change in the economic value is relatively more expensive in terms of interest rate spread than applying a looser EVE. The earnings volatility can be hedged cheaply compared to the economic value volatility, since only the cash flows of the first year are taken into account. However, we observe higher potential rollover costs in case of a higher EVE, as the gaps of maturities exceeding one year are bigger.

4.4 Including Capital Requirements

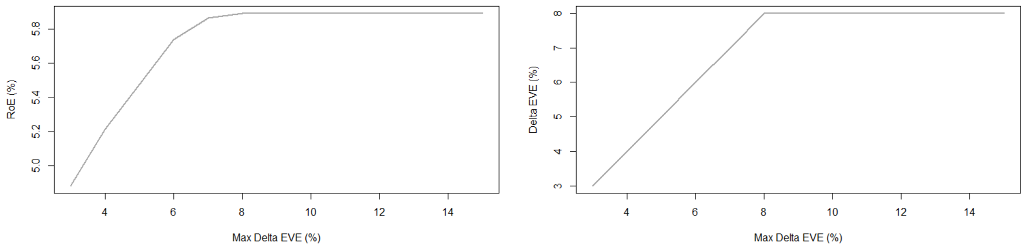
In the previous simulation, we used an abundant total capital ratio of 14.86 percent as minimum capital requirement. Here, the total capital ratio was based on the risk weighted exposure amount for credit risk completed with the weighted exposure for counterparty credit risk, the CVA capital charge and operational risk, as described in the Capital Requirement Directive IV (CRD IV) (European Parliament and the Council of the European Union, 2013). However, banks also need to hold capital for their interest rate risk exposure in the banking book. In the following simulation, we add the risk weighted exposure for interest rate risk to the total risk exposure amount. We define the risk weighted exposure for interest rate risk as 12.5 (the reciprocal of the minimum capital ratio of eight percent) times the ΔEVE. Following from this, the total capital ratio can be defined as:

$$TCR_{new} = \frac{y_6}{TREA_{new}} \tag{4.3}$$

Where the new total risk exposure amount equals:

$$TREA_{new} = TREA_{regulatory} + 12.5 \cdot max(\Delta EVE_i) \tag{4.4}$$

As a great part of the Pillar 2 capital is now covered in the total capital ratio, we decrease the limit of the total capital ratio with weighted interest rate risk exposure of 15% of its capital, making the the total capital ratio



(A) RoE (B) ΔEVE

FIGURE 4.4: Simulation including a capital charge for IRRBB.

12.09 percent. Now, our hypothetical bank must allocate its equity over the different TREA building blocks. The first thing to notice in Figure 4.4a is that by adding a capital charge for IRRBB, increasing the EVE limit has only effect to a certain point on the return on equity. This indicates that given a total capital ratio of 12.09 percent the maximum EVE threshold of 15 percent is not sought, since the capital is allocated over other risk exposures, mainly by increasing its credit risk exposure. Figure 4.4b shows the actual EVE values for the simulation, which confirms the observation that the maximum threshold is not sought.

4.5 Improving Our Balance Sheet

Now we have introduced all the risk measures and illustrated their contribution to a prudent balance sheet allocation, we run our model given the following set of constraints:

$$\text{Set} = [TCR_{new}, LR, LCR, NSFR, \Delta EVE, \Delta NII] \tag{4.5}$$

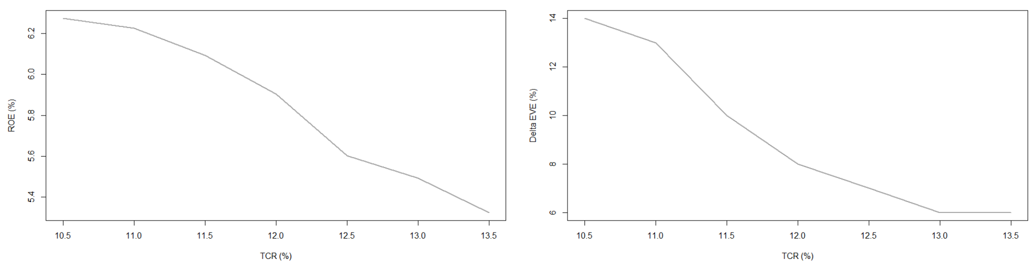
$$\text{Set} = [12.09\%, 3.5\%, 201\%, 148\%, 10\%, 1\%] \tag{4.6}$$

Given the starting balance sheet and decision space described in Chapter 3, we reallocate the assets and liabilities in order to improve the interest rate spread of our bank within limits of its risk appetite. The first thing to notice in Figure E.4 (Appendix E) is that no term deposits are reallocated, as it is outranked by covered bonds. Moreover, on the funding side we observe a reallocation in long-term covered bonds combined with both demand and savings deposits. We furthermore observe a change in dynamics of liquidity: due to a decrease in covered bonds, the stressed cash outflow increases, which obligates our bank to increase its amount of high quality liquid assets. Subsequently, the less profitable AA- government bonds combined with increased mortgages lending are favored by our model over the A- to A+ government bonds.

Subsequently, we observe an EVE of eight percent, which indicates that given the decision space and EVE as capital indicator a decrease in interest rate risk exposure the maximum is not sought, leaving more capital to be allocated to credit risk exposure. The new available exposure on our TREA is filled with credit risk exposure by increasing the lending of more risky mortgages. Finally, we see a decrease in mortgages with a loan-to-value of less than 60 percent, as the NHG mortgages yield similar returns against less credit risk exposure.

4.6 Change in Capital Requirements

Under Basel III banks face stricter capital requirements, increasing the total capital ratio to a minimum of eight percent with an additional 2.5 percent capital conservation buffer. The goal of this more stringent capital ratio is to increase banks' resilience to future financial downturns. This ratio can be improved by raising equity or reducing the risk exposure. In our model we assume a fixed amount of equity, reducing the alternatives to increase its total capital ratio to decreasing its total risk exposure amount. To reveal the impact of tighter capital requirements, we illustrate the development of our bank's return on equity, interest rate risk and building blocks of the total risk exposure amount in case of a change in capital requirements.



(A) RoE (B) ΔEVE

FIGURE 4.5: Change in capital requirements.

In Figure 4.5a the impact on the return on equity is illustrated. We observe a steep decrease in return in case of tighter capital regulations. The argument explaining the decrease in maximum interest rate spread is the limitation of maximum risk the bank can take. The bank needs to adapt its risk taking as a result of changes in capital requirements. In our model this is done through altering its total risk exposure amount. One way for a bank to decrease its risk exposure is by decreasing the riskiness of its assets by investing in less risky assets, for instance NHG mortgages or government bonds. Another way is to hedge its interest rate risk exposure by decreasing the difference in repricing between assets and liabilities. Although the weighted credit risk exposure is also affected by changes in capital requirements, we mainly observe the latter. Figure 4.5b and Figure 4.6 illustrate it is more profitable to decrease interest rate exposure in case of increased capital requirements when using the EVE as capital indicator.

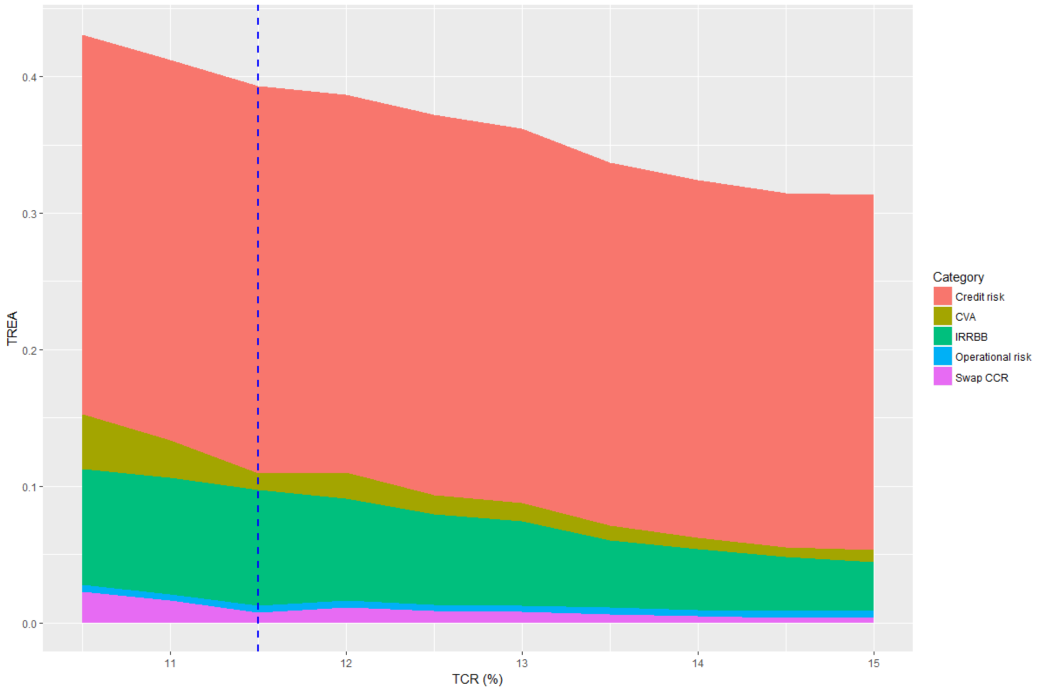


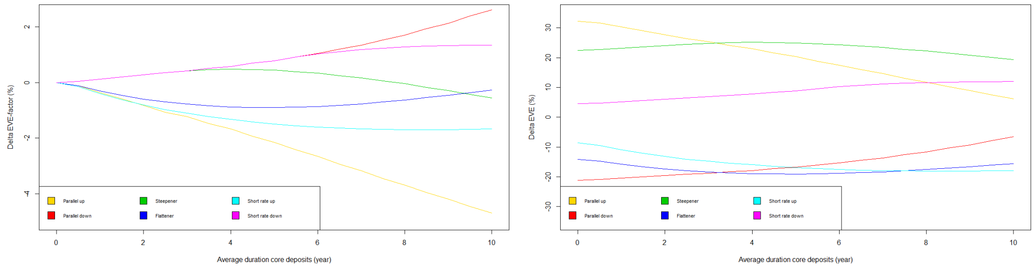
FIGURE 4.6: Development of TREA components while altering the total capital ratio.

4.7 Change in Optionality

Although the standardized EVE introduced by the BCBS limits the space for banks to use their own internal estimations, banks still have several modeling possibilities due to optionality. Especially, the inclusion of commercial margins and the repricing assumptions are seen as factors that make the comparison across banks not directly comparable. Banks are afraid investors know too little of this difficult topic to fully understand the impact of the EVE disclosures, as these measures are partly affected by modeling assumptions (Contiguglia, 2016). The calculation of our hypothetical bank's EVE is also subject to modeling assumptions. In this section we illustrate the impact of changes in the stability of deposits by altering the maximum average duration of the non-maturity deposits, and changes in prepayment behavior by altering the conditional prepayment rate of mortgagors.

4.7.1 Stability of Deposits

We perform a sensitivity analysis to show the direct impact of the average duration of our NMD's on the EVE of our starting balance sheet while keeping the pass-through rate and stability cap the same. This is illustrated in two steps. Firstly, we illustrate the changed EVE-factors of non-maturity deposits, i.e., the percentage decrease in economic value, as described in section 3.3.2, which can be seen in Figure 4.7a. Here can be seen that the



(A) ΔEVE factors (B) ΔEVE

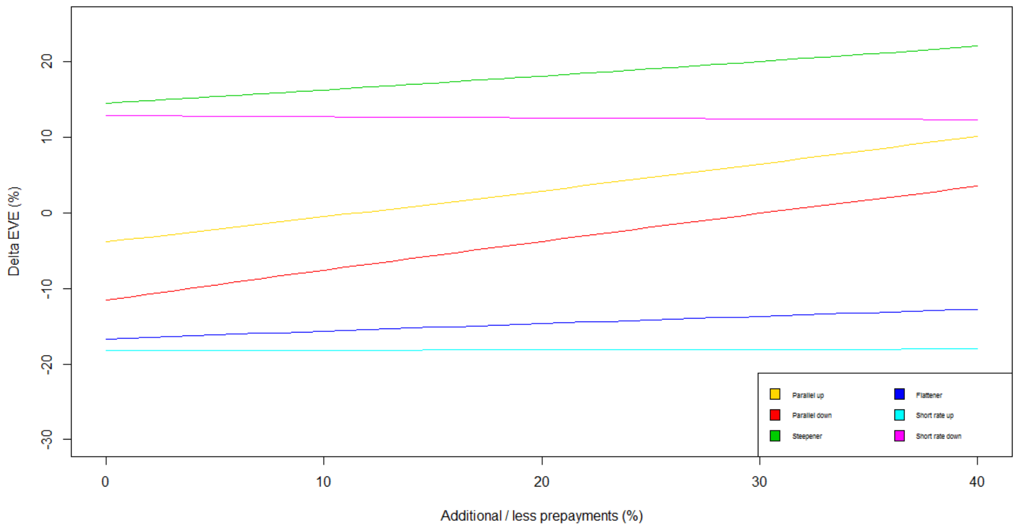
FIGURE 4.7: Impact of a change in the average duration of core NMDs on the EVE.

change in economic value is bigger when the average duration of core deposits is longer. Subsequently, we use these factors as new input in order to visualize the impact on balance sheet level for all six shocks to determine the impact on the disclosed EVE.

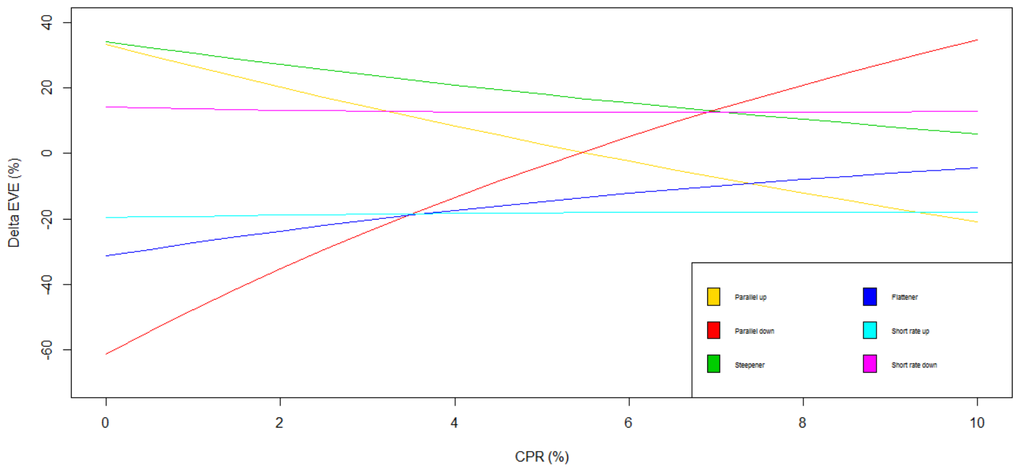
Figure 4.7b illustrates the EVE values for a constant balance sheet under different NMD repricing assumptions. Our hypothetical bank is funded by 28.20 percent non maturity deposits, which is low compared to the 49.50 percent overnight deposits to total EU household savings (Euro Area Statistics). Despite this, the EVE is affected heavily by a change in duration, in particular for the parallel shocks. A low duration of core deposits, i.e., less stable deposits, increases the magnitude of the alternative interest scenarios on balance sheet level, as deposits reprice earlier, which increases the gap between the repricing maturities of assets and liabilities. We furthermore observe that for an average duration of core deposits of two years and less, deposits are found not efficient compared to other short-term funding sources, as our model decreased its position instead of allocating new business. At this point, the benefits of the deposits, i.e., the low interest expenses, do not weight the disadvantages, i.e., the instability in the form of a high stressed cash-outflow factor and relatively low duration. Moreover, more stable funding with a higher duration against the same interest expense is possible in the form of covered bonds.

4.7.2 Prepayment Behavior of Mortgagors

The second source of optionality we analyze is the conditional prepayment rate. Given an optimal value-minimizing call policy, a mortgage should never be paid off early when the refinancing cost exceeds the coupon value. Similarly, a mortgage should be paid off early if the current coupon exceeds its refinancing costs. However, in both cases we see mortgagors not always act rationally, as in the former scenario prepayments still occur and in the latter scenario the maximum amount of prepayments are not made (Dunn and McConnell, 1981). In the current standardized EVE measure, the prepayment rates are stressed by 20 percent to reflect the change in prepayment behavior. We illustrate the sensitivity of change in prepayment rates



(A) CPR stress factor



(B) CPR

FIGURE 4.8: Impact of a change in the prepayment behavior on the EVE.

in two manners. Firstly, we stress the magnitude of the change in prepayment rates by increasing the stress factors of the CPR, which will result in higher differences in duration of mortgages across alternative interest rate scenarios. Lastly, we illustrate what a change in expected base CPR will cause in terms of EVE.

Figure 4.8a illustrates that by increasing the stress factor for interest rate scenarios, the magnitude of the EVE increases. The parallel shocks are affected the most followed by the steepener and flattener scenarios. An increase in rationality regarding the optimal value-minimizing call policy described above would result in an increasing difference in cash flow under the interest rate scenarios compared to the base case. This will, as Figure 4.8a shows, result in higher economic capital losses or less economic capital gains under alternative interest rate scenarios.

Besides, a change in expected prepayment behavior in the base case can also result in different values for the EVE. Although prepayment rates are based on multiple years of payment data, a change in the conditional prepayment rate can cause an offset in the EVE values on the longer term. Figure 4.8b indicates that given a constant balance sheet, an increase in prepayment rates of one percent causes an increase in EVE of 8.88 percent for the parallel down scenario due to premature cash flows. Likewise, a decrease in prepayment rates of one percent causes an increase of 5.48 percent for the parallel up scenario due to a longer duration. The third and fourth scenario are less affected. Finally, the shocks in the short rates are hardly affected, due to the fact that these scenarios do not shock the yield curve for longer maturities.

4.8 Conclusions

This chapter answers the remaining sub-questions:

- *How severely does a bank's interest rate risk appetite affect its earnings?*

We previously defined the interest rate risk appetite by a combination of both the EVE and NII. We illustrated the effect of setting our stylized bank's interest rate appetite using different limits on the EVE and NII. We observed that the EVE limits term transformation over all assets and liabilities, and with this, has the biggest impact on the interest rate spread. Increasing the EVE from a conservative 4% to the maximum threshold of 15% increased the return on equity with 1.12%. The NII could be hedged relatively cheaply by our model using one year swap contracts and has little impact on the interest rate spread. However, the observed two year NII was, even though the one year NII and EVE were within boundaries, still substantial, which could result in high rollover costs of hedging instruments.

- *What is the impact of stricter capital requirements on the potential interest rate spread and the impact of changes in key modeling assumptions on the interest rate risk exposure of a bank?*

We included the weighted interest rate risk exposure in the total risk exposure amount. Here, the total capital ratio is used as a scalar for capital requirements. We observed that the interest rate risk taking is more affected by an increase in capital requirement than other TREA components. This indicates that, given the capital indicator of 12.5 times the EVE used, the return per allocated capital is higher for credit risk exposure.

Furthermore, the sensitivity analysis concluded that our bank's interest rate risk exposure is highly affected by changes in the model parameters reflecting the optionality embedded in banking products. This indicates option risk is something banks should monitor properly, as a bank's interest rate risk exposure over time could be affected by changes in the stability of non-maturity deposits and client prepayment behavior. An opportunistic estimation of these parameters could therefore result in a severe underestimation of a bank's interest rate risk exposure.

Chapter 5

Conclusion, Discussion and Further Research

The current low interest environment combined with increasing competition results in more risk taking by banks in order to still make decent earnings (Memmel, 2011). The BCBS introduced new guidelines on how to manage interest rate risk to promote a resilient and balanced interest rate risk appetite. We used these guidelines complemented by other regulatory requirements to see the impact of interest rate risk measures on a bank's risk taking, behavior and return on equity and with this, addressed a method for improving a bank's balance sheet.

Firstly, we discuss our findings and address the answer to our main question: *What would be the impact of stricter regulation on interest rate risk in the banking book and how could a bank improve its balance sheet given its interest rate risk appetite?*. Furthermore, we discuss the limitations and possibilities for further research.

5.1 Conclusions

We illustrated the effect of including non-parallel shifts in the yield curve in the EVE calculation. Although the required capital for interest rate risk is not affected solely by parallel shocks yield curves, banks are obliged to disclose parallel shocks of 200bps to the public to promote greater transparency and comparability. We observed that disclosing values of parallel shocks does not reflect the interest risk taking of a bank properly, as our bank could expose itself heavily to non-parallel shocks. As a result, the objective in form of the return on equity was not affected much by further restricting exposures to parallel shocks only. However, including non-parallel shocks in the simulation resulted in a decrease in exposure to non-parallel scenarios for our hypothetical bank by matching the repricing maturities more properly. As a result, the return on equity also decreased by roughly 1.1 percent for conservative IRRBB limits (EVE of four percent) and 0.5 percent for a more risky IRRBB appetite (EVE of 15 percent) compared to restricting only parallel shocks.

Going forward, we showed that a balance sheet allocation considering only long-term measures while optimizing the short-term returns could result in a high earnings volatility on the short-term of as much as six percent. On the other hand, by focusing solely on a one year change in net interest income, our hypothetical bank will expose itself to the maximum EVE threshold in its search for yield as would be expected. Following from this, the two year difference in net interest income following from interest rate shocks can also be significant, which can result in high rollover cost of hedging instruments in order to keep the one year NII at the desired level.

Banks are obliged to hold capital for interest rate risk according to the internal capital adequacy assessment process (ICAAP). To complete our model, we used the proposed standardized method of the BCBS to compute the risk weighted exposure amount for interest rate risk as an approximation for the required capital for interest rate risk. We implemented this charge by including this weighted exposure as a building block of a bank's total risk exposure amount. By doing so, we included capital for interest rate risk in the banking book in the total capital ratio. What we observed during the simulation, is that the amount of required capital for interest rate risk has a negative correlation with interest rate risk taking of our bank as would be expected. We also observed that the regulatory thresholds on the EVE are not sought while improving the spread in case IRRBB risk taking is included in the capital allocation in the form of 12.5 times the EVE. Instead, our hypothetical bank searches for an optimum between the allocation of capital over credit risk and interest rate risk to maximize the interest rate spread. This optimum is found at an EVE of eight percent for a total capital ratio of 12 percent. Subsequently, the weighted interest rate risk exposure amount decreased more during tighter capital standards compared to the weighted credit risk exposure amount. Our findings indicate that, by using the EVE measure as capital indicator, interest rate risk taking is more sensitive to tighter capital requirements than credit risk taking. The reasons for that are a lower return in relation to the required capital and the possibility to decrease its exposure through interest rate swaps.

In Basel's latest guidelines on interest rate risk in the banking book we already observed more flexible caps on the amount of core deposits, the maximum average duration of non-maturity deposits and the magnitude of the prepayment rate shocks compared to the draft version of 2015. This leaves more space for banks to fill in these parameters according to their internal measurements, which supports limiting the gap between standardized measures and outcomes resulting from internal models. Our findings underline this decision space for banks to fill in these parameters according to their best estimation, as our findings show that a bank's EVE is highly dependent on model assumptions regarding both the sources of optionality included in our model. We also conclude that a change in optionality is a risk banks should consider with great care, as we showed that changes in optionality embedded in banking products and deposits can cause significant changes in future EVE values. An opportunistic estimation of these parameters could therefore result in a severe underestimation of a bank's interest rate risk exposure.

In summary, our main three conclusions towards answering our research question are:

1. As implied by the BCBS, a combination of limits on both NII and EVE is necessary in order to install a prudent interest rate risk management. While maximizing the return on equity, a bank will expose itself to the maximum EVE-threshold, likely under multiple alternative interest rate scenarios, in order to maximize the yield from term transformation. The NII measure has little impact on the interest rate spread, but is of essence in order to limit earnings volatility. However, the one year NII combined with relatively loose limits on the EVE might not be sufficient, as we laid out that the resulting two year NII could result in high rollover costs of hedging instruments.

2. Including a direct capital requirement for a bank's interest rate exposure in the form of 12.5 times the standardized EVE measure has a degrading effect on interest rate risk taking, as the return on required capital is higher for credit risk compared to interest rate risk this way.

3. A bank's interest rate risk exposure is highly sensitive to assumptions in optionality. Even small changes in clients' rationality regarding prepayment, i.e., a change in the prepayment multiplier under alternative scenarios, and in repricing characteristics of non-maturity deposits could result in a significant change in a bank's interest rate risk exposure.

Using the proposed model, a bank can get insights in a more profitable balance sheet allocation giving restrictions on prudential measures, visualize the impact of interest rate risk limits on its potential expected return, as well as determine the impact of possible changes in client behavior as result of behavioral optionality embedded in banking products.

5.2 Discussion and Further Research

With our thesis we proposed a method to incorporate interest rate risk measures in balance sheet improvement using a point in time optimization given a set of assets and decision space. By using this model, we illustrated the impact of more severe interest rate regulations in terms of NII and EVE exposure and capital requirements while improving a bank's return on equity. However, creating a complete representation of the reality is nearly impossible. For the balance sheet input, we were bounded by the available balance sheet data, hence we were forced to make assumptions on distributions of assets' and liabilities' cash flows and fixed interest rate periods. We covered this by using available performance reports of Dutch RMBSs, annual reports and assumed the uniform distribution for allocating assets of repricing maturities where needed. Furthermore, due to a lack of data about realistic interest rate swap portfolios, we used the current swap rates to hedge our starting exposure, using a set of ten swaps.

As interest rates are currently lower than ten years ago, the swap expenses tend to be less compared to real swap expenses of a bank. Subsequently, interest rate swaps are traded over the counter and can be customized to a bank's need. By assuming a set of only ten interest rate swaps, only the notional amounts between swap maturities can be determined. In order to make it more representative, interest rate swap exposures could be included in more detail. Moreover, we assumed our bank can influence its new acquired mortgages with a high level of precision. In real life, banks are less able to determine this acquisition. However, a bank is able to hedge its interest rate exposure more precisely to match repricing dates using customized notional amounts. This partly compensates for the discussed inefficiency, as swap rates resemble the change in interest fixed period for mortgages.

Our model indicates an optimal distribution of capital given a maximum level of risk exposure. Yet, it does not advise on the level of capital, nor we included other forms of capital than Tier 1 capital. Moreover, we do not include transaction costs, which a bank does pay in switching positions.

We included the main sources of embedded optionality in our model. Other forms of optionality, for instance embedded options to extend the duration or change interest rate characteristics, are not covered, but can cause a change in cash flows and interest rate fixed periods under interest rate scenarios.

Appendix A

Interest Rate Scenarios

In our model, we quantify the interest exposure of our hypothetical bank by determining the impact of interest rate shocks on its economic value and earnings. We use six prescribed shocks who cover all possible yield curve movements. More on the calculation of these shocks can be found in BCBS (2016).

The first scenario we use is a parallel shift upwards. For all maturities, so for every time bucket, the yield curve increases with the same amount. The conditional prepayment rate of fixed loans decreases with 20 percent, while the term deposit redemption rate increases with this same number for this stress scenario. The same is the case for the second scenario, where interest rates for every time bucket decreases with a prescribed number. The decrease of interest rates results in a higher conditional prepayment rate of fixed loans (+20 percent) and a lower term deposit redemption rate (-20 percent).

Expectations of investors about future interest rates can alter the steepness of the yield curve. Under the third scenario, interest rates are altered to create a *steepener* yield curve: interest rates for shorter maturities will be decreased and longer maturity rates will be increased. Subsequently, this scenario comes includes a decrease in the amount of prepayments on fixed loans and with a lower term deposit redemption rate. For the fourth scenario, a *flattener* yield curve, the effect the other way around.

The fifth and sixth scenario cover the changes in the short rate. The same effect on prepayments and deposit redemption rates as the parallel shocks are applicable for these scenarios. A summary of the scenarios and multipliers can be seen in Table A.1. The final shocks to the maturity buckets can be seen in Figure A.1. The base and alternative interest rate curves are illustrated in Figure A.2.

TABLE A.1: Interest rate shock-scenarios and multipliers.

Number (i)	Scenario	CPR multiplier	TDRR multiplier
1	Parallel up	0.8	1.2
2	Parallel down	1.2	0.8
3	Steepener	0.8	1.2
4	Flattener	1.2	0.8
5	Short rate up	0.8	1.2
6	Short rate down	1.2	0.8

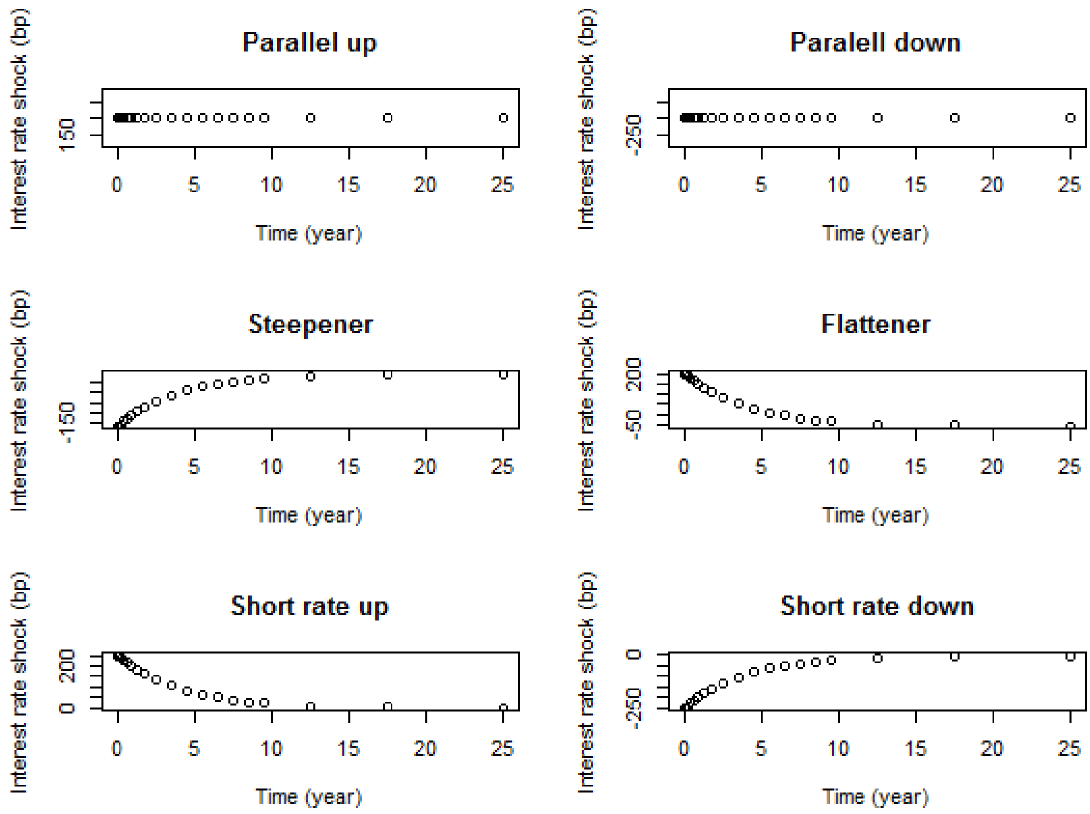


FIGURE A.1: Euro interest rate shock scenarios set out by the Basel Committee on Banking Supervision.

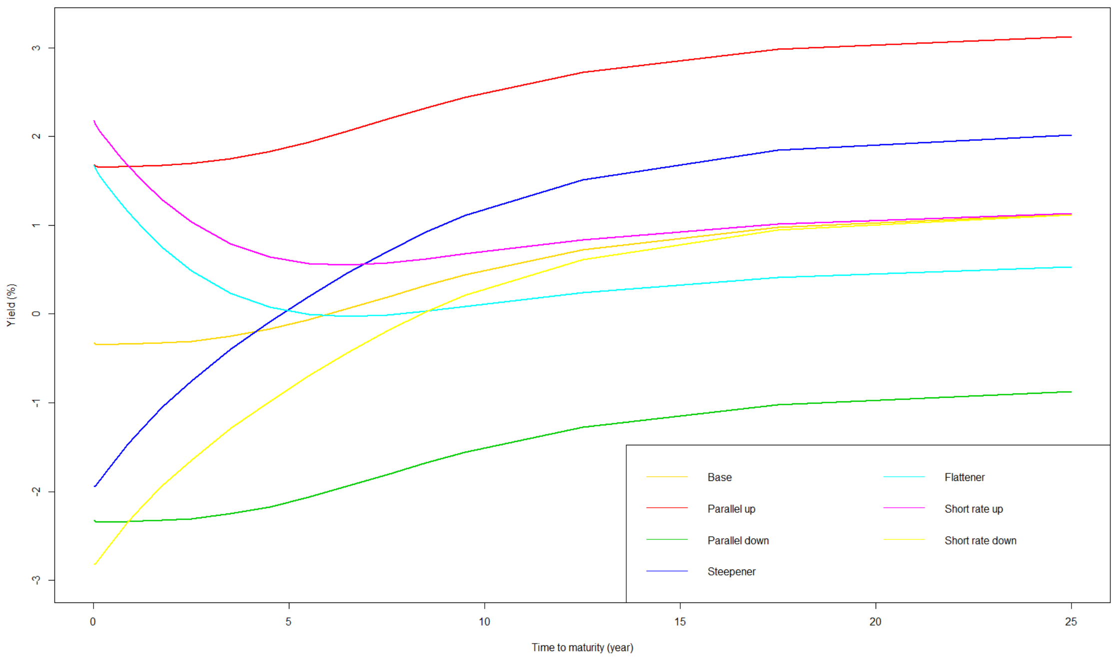


FIGURE A.2: Base and alternative interest rate scenarios.

Appendix B

Distribution of non-maturity deposits

Definition B.1. Non-maturity deposits are liability instruments for which there are two embedded options: one held by the bank (the right to change the interest rate) and a second held by the depositor (the right to withdraw its funds).

Due to the behavioral factor, NMDs can cause uncertainty and with this, potential future interest rate exposure. Furthermore, behavioral risk is heterogeneous, as factors rely on several parameters, such as the age of customers and geographic location. An example of heterogeneous optionality is the conditional prepayment rate (CPR), which we included in our model. In the Netherlands, clients are allowed to pay an additional 10% of their mortgage annually without receiving a penalty for it. In other countries, often other contractual terms are set regarding prepayment.

Banks use behavioral models to forecast the extend of withdrawals of depositors, but outcomes across banks can be very different, which makes comparing interest rate risk exposure across banks hard. Regulators acknowledge the heterogeneity, but restrict the average duration, as it can cause an underestimation of interest rate risk. In the consultation paper on IRRBB (BCBS, 2015), the BCBS proposed a more strict treatment of NMDs, with a maximum repricing date of 5 years versus an average of 4.5 and 5 years in the final guidelines (BCBS, 2016). For our model we use two types of non-maturity deposits: demand deposits and savings deposits. For these NMDs, we combine the treatment for NMDs proposed in the consultation paper with the restrictions of the final guidelines by using the Time Series Approach (TSA). For this, we distribute the NMDs over transactional and non-transactional deposits. The Stability cap and Pass-through floor can be seen in Figure B.1. We determine the stable amount of these deposits and determine the amount of core deposits, given by the stability cap:

$$\text{Amount of core deposits} = N \cdot S \cdot (1 - P) \tag{B.1}$$

Where:

N = the total amount of deposits
S = the stability cap
P = the pass-through floor

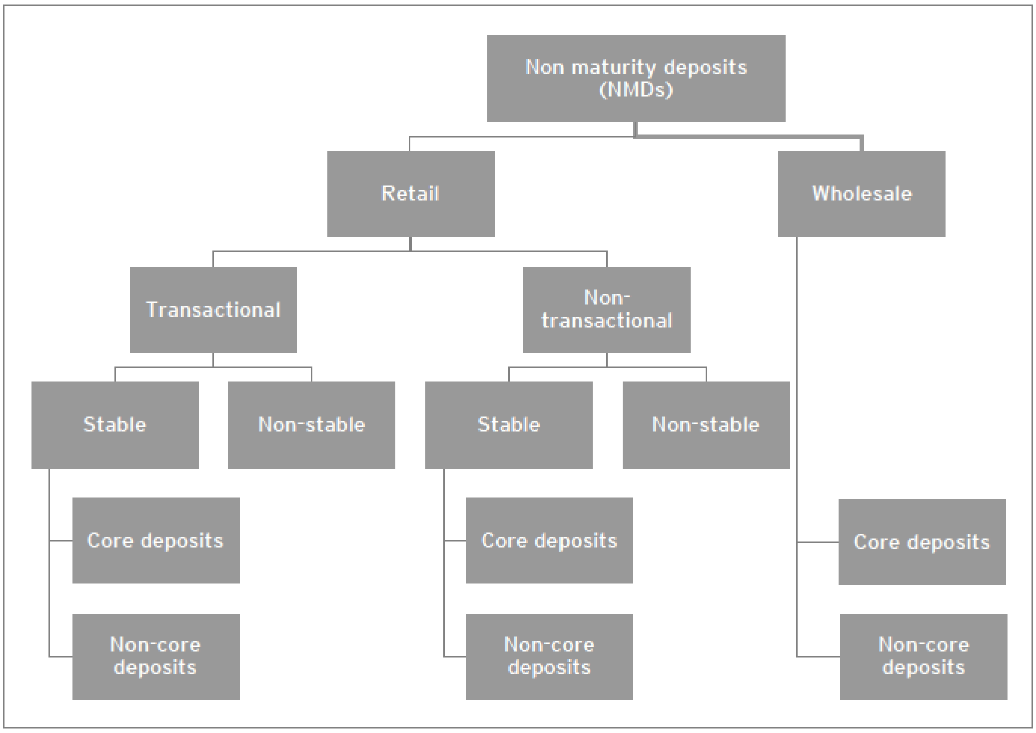


FIGURE B.1: Subclasses of non-maturity deposits.

TABLE B.1: Stability caps and pass-through floors for NMDs.

	Stability cap (%)	Pass-through floor (%)	Implied cap (%)
Demand deposits	80	25	60 (=0.8 ·(1-0.25))
Savings deposits	70	30	49

All core deposits are uniformly distributed such that the average repricing time equals the maximum average repricing time described in the final guidelines. Non-core deposits are seen as not stable, and are therefore slotted in the overnight bucket. The final distribution is illustrated in Figure B.2.

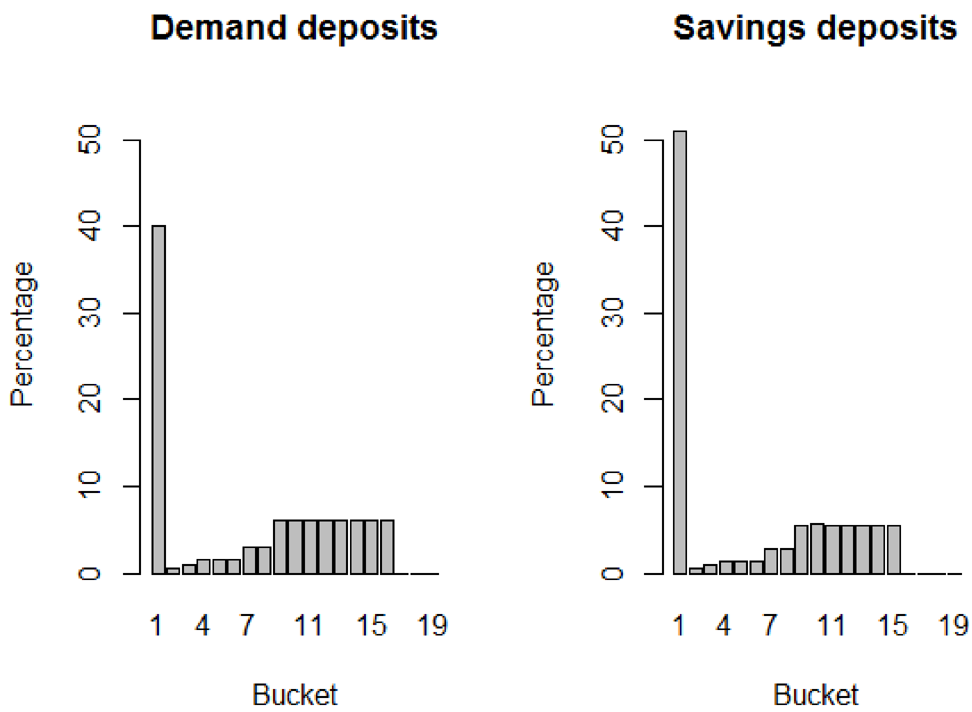


FIGURE B.2: Distributions of demand deposits and savings deposits over buckets.

Appendix C

Interest rate swaps

Despite that the fair value of the interest rate swaps at starting point in the simulation equals zero, interest rate swaps do have an impact on risk measures. In this section, we will elaborate on the impact of interest rate swaps on the ΔEVE, ΔNII and the additional capital requirements as a result of counterparty credit risk and credit value adjustment.

C.1 Impact On Economic Value And Net Interest Income

For our model we use four interest rate swaps with different maturities. To include the swaps without placing them on the balance sheet, we determine the par coupon, such that the fair value of the swaps equal zero.

TABLE C.1: Par rates interest rate swap (source: *Bloomberg*).

Time to maturity	Par coupon
1 year	-0.28508%
2 year	-0.23082%
3 year	-0.15883%
4 year	-0.07302%
5 year	0.03263%
10 year	0.65343%
12.5 year	0.88955%
15 year	1.06439%
17.5 year	1.16122%
20 year	1.24902%

C.2 Counterparty Credit Risk

The counterparty credit risk is calculated using the standardized counterparty credit risk approach (BCBS, 2014b). This calculation consist of two components: a risk weight and the exposure amount, where the exposure amount is the sum of the replacement cost (RC) and the potential future earnings (PFE) multiplied by a factor alpha, which equals 1.4, written mathematically:

$$\text{Exposure at default under SA} = EAD = alpha \cdot (RC + PFE) \tag{C.1}$$

Since we use fixed par rates, resulting in a fair value of the interest rate of zero, the replacement cost are zero. The potential future exposure can be calculated using the formula:

$$PFE = SF^{IR} \cdot |\delta_i \cdot d_i^{IR} \cdot MF_i^{type}| \tag{C.2}$$

Where:

SF = supervisory factor, for interest rate swaps equal to 0.5%.
δ_i = supervisory delta.
d_i^{IR} = adjusted notional.
MF_i^{type} = maturity factor, which is 1 for maturities higher than one year.

$$d_i^{IR} = TradeNotional \cdot \frac{exp(-0.05 \cdot S_i) - exp(-0.05 \cdot E_i)}{0.05} \tag{C.3}$$

Where:

S_i = begin date of swap i
E_i = end date of swap i

The potential future exposure is multiplied by the risk weight of the counterparty, in our case a bank, to determine the counterparty credit risk exposure.

C.3 Credit Valuation Adjustment

The CVA capital charge is calculated using the standard approach described in article 384 of the CRR (BCBS, 2014b). Based on this method, the capital charge is calculated as the sum of all CVA capital charges calculated on counterparty level. For simplicity we assume that all interest rate swaps are with one counterparty. The CVA capital charge can be calculated using the following formula:

$$K = 2.33 \cdot \sqrt{h} \cdot \sqrt{(\sum_i 0.5 \cdot w_i \cdot (M_i \cdot EAD_i^{total} - M_i^{hedge} \cdot B_i - \sum_{ind} w_{ind} \cdot M_{ind} \cdot B_{ind})^2 + \sum_i 0.75 \cdot w_i^2 \cdot (M_i \cdot EAD_i^{total}) - M_i^{hedge} \cdot B_i)^2} \tag{C.4}$$

As we do not include CVA hedges, the calculation can be simplified to:

$$K = 2.33 \cdot \sqrt{h} \cdot \sqrt{\left(\sum_i 0.5 \cdot w_i \cdot M_i \cdot EAD_i^{total}\right)^2 + \sum_i 0.75 \cdot w_i^2 \cdot \left(M_i \cdot EAD_i^{total}\right)^2} \tag{C.5}$$

Where:

h	= the one-year risk horizon in units of a year "1"
w_i	= the counterparty weight of i
EAD_i^{total}	= the exposure at default of counterparty i
M_i	= the effective maturity of the transactions with counterparty i

Appendix D

Risk Measures

D.1 Capital Requirements

D.1.1 Total Capital Ratio

The minimum amount of capital is determined through the calculation of the Total Risk Exposure Amount (TREA). According to the minimum capital requirement, the capital divided by the sum of risk exposure of a bank (i.e. interest rate risk exposure excluded) should be higher than 10.5% (European Parliament and the Council of the European Union, 2013).

$$TCR = \frac{y_6}{TREA} \geq 10.5\% \tag{D.1}$$

We define the following building blocks of the TREA of our bank:

- Credit risk exposure. We calculate this exposure using the standardized approach in which assets get a defined risk weight. For the weighting scheme of assets we refer to Table E.2.
- Operational Risk Exposure, which is calculated by taking 15 percent of the annual gross income.
- Exposure as a result of derivative exposure, for which we refer to Appendix C.

In a later scenario, we include an approximation for interest rate risk by adding the interest rate exposure to our bank's TREA in order to determine the minimum capital requirement on interest rate risk in the banking book:

- Interest rate risk exposure, 12.5 (i.e. the inverse of the minimum 8% risk-based capital requirement) times the EVE-measure.

The TCR of the proxy banks used for constructing our stylized balance sheet variates between 15.5 and 19.3 percent. A note should be made that these values only include exposures captured in pillar 1 and so do not reflect all risks, hence the relatively big difference compared to the regulatory minimum.

D.1.2 Leverage Ratio

One of the causes cause of the global financial crisis was the build-up of excessive on- and off-balance sheet leverage in the banking system. In many cases, banks built up excessive leverage while apparently maintaining strong risk-based capital ratios. Therefor, the BCBS finds the leverage ratio (Formula D.2) a necessary supplementary measure to the risk-based capital measures. More on the leverage ratio can be found in *Basel III leverage ratio framework and disclosure requirements* (BCBS, 2004a).

$$\text{Leverage ratio} = \frac{\text{Capital measure}}{\text{Exposure measure}} \geq 3\% \tag{D.2}$$

D.2 Liquidity

The first known literature on liquidity risk dates from 1876, when Knies (1976) stressed the need for cash buffers to compensate for possible gaps between cash in and out flows of banks in case the precise maturity could not be controlled.

Liquidity risk encompasses the risk a bank may be unable to meet short term financial demands and results from size and maturity mismatches of assets and liabilities (Bessis, 2011). A bank with long-term commitments and short-term funding generates cash-flow deficits. The liquidity risk results from insufficient resources to fund the long term assets, as a result of a decrease in available funds. Liquid assets, such as cash and government bonds, protect banks from market tension, as they can be used as alternative source of funding for short term obligations. The cost of liquidity for banks often refers to the cost of maintaining liquidity ratios at a an adequate level, i.e. generate more stable long-term funding or holding sufficient HQLA.

Since the global financial crisis of 2008, the focus of the BCBS on liquidity risk has increased. Despite their adequate capital levels, many banks experienced difficulties during the early "liquidity phase" of the financial crisis in 2007 as a result of not managing liquidity risk in the right manner. Before the crisis, the asset markets were resilient and funding could be acquired against low costs. A rapid reversal in market conditions showed the volatility of liquidity, resulting in severe stress scenarios under banks. According to Ferrari and Ruozi (2009), the insufficient liquidity of banks' is rather the result of the financial crisis than the cause of it. Instead, these authors state the crisis comes forth from the lack of proper principles of a healthy and prudent management together with pursuing too much short-term profits.

To promote both the short- and long-term resilience of banks' liquidity risk profiles and in order to manage and monitor liquidity risk, the BCBS introduced two liquidity measures (BCBS (2013a), BCBS (2014a)): the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR). The

LCR is developed to ensure that banks have an adequate stock of unencumbered high-quality liquid assets (HQLA). Here, the adequate amount of HQLA is quantified as the difference in cash-flows for a 30 day liquidity stress scenario. The NSFR requires banks to maintain a stable funding profile in relation to their balance sheet activities. By maintaining a stable funding profile, the likelihood that disruptions to a bank's regular sources of funding will erode its liquidity position in a way that could increase the risk of its failure will be reduced.

D.2.1 Liquidity Coverage Ratio

The liquidity Coverage Ratio (LCR) promotes short-term resilience by prescribing the sufficient level of high-quality liquid assets (HQLA). The amount of HQLA is quantified by a 30-day liquidity stress period. HQLA are characterized by their low risk, ease and certainty of valuation, absence of wrong-way risk and are traded on developed and recognized exchanges, and so can easily be liquidated (BCBS, 2013a). The BCBS assigned HQLA-factors to the asset classes based on this marketability.

$$LCR = \frac{\text{Stock of HQLA}}{\text{Total net cash outflows over the next 30 calender days}} \geq 100\% \tag{D.3}$$

D.2.2 Net Stable Funding Ratio

The net stable funding ratio (NSFR) requires banks to maintain a stable funding profile proportional to its balance sheet activities in order to reduce the likelihood that disruptions to a bank's regular sources of funding will erode its liquidity position in a way that could increase the risk of its failure and potentially lead to broader systemic stress.

$$NSFR = \frac{\text{Available amount of stable funding}}{\text{Required amount of stable funding}} \geq 100\% \tag{D.4}$$

Appendix E

Balance Sheet Definition

E.1 Asset Definitions

Cash and Balances with Central Banks
Cash and balances with Central banks are assumed to reprice overnight and are mainly held as a liquidity buffer.

Loans and Advances to banks
Loans and advances to banks with subclass maturity and are distributed focused on short term repricing.

Government Bonds
Bonds issues by sovereigns. Subclass: Credit rating and Maturity.

Retail Mortgages
This asset class includes loans secured by residential property and can be divided in subclasses based on loan-to-value and maturity.

Other Assets
This asset class encompasses other non-interest bearing assets and is therefor excluded from interest rate risk calculations.

Interest Rate Swaps
Financial agreement between two parties to exchange a series of interest payments without exchanging the underlying debt. Subclass: maturity.

E.2 Liability and Equity Definitions

Due to Banks
Deposits from banks. Subclass: maturity.

Demand Deposits
Funds held in an account from which deposited funds can be withdrawn at any time without any advance notice to the depository institution. Subclass: maturity.

Savings Deposits
Interest-bearing deposits that provides a modest interest rate. Sub-class: maturity.

Term Deposits
Deposits that has a fixed term. Subclass: maturity.

Secured Funding
Secured funds, on the shorter term (<1Y) commercial paper, on the longer term bonds.

Other Liabilities
This asset class encompasses other non-interest bearing liabilities and is therefor excluded from interest rate risk calculations.

Equity
Banks' shareholders' equity. This class is held stable over the simulation and is excluded from interest rate calculations by regulation.

E.3 Balance sheet input

TABLE E.1: Balance sheet distribution and data sources.

	Distribution	Current return	New return	Source
Assets				
Cash and equivalents	O/N	ECB deposit rate	ECB deposit rate	Bloomberg
Mortgages	According to mortgage portfolio	According to mortgage portfolio	Current market rates	Dolphyn (2016), Goldfish (2016), hypotheekrente.nl
Government bond (AA-)	Uniform <10Y	5Y average	Current yields	Bloomberg
Government bond (A- to A+)	Uniform <10Y	4Y average	Current yields	Bloomberg
Loans and advances to banks	Uniform <1Y	1Y average	Swap rate + CDS spread	Bloomberg
Liabilites				
Due to banks	Uniform <1Y	1Y average	Swap rate + CDS spread	Bloomberg
Demand deposits	TIA	0%	0%	-
Savings deposits	TIA	Average market rates	Average market rates	Spaarrente.nl
Term deposits	Uniform, in line with Annual Reports	Average market rates	Average market rates	Spaarrente.nl
Secured funding	Uniform <7Y	5Y average CB yield	ING covered bond yield	Bloomberg

TABLE E.2: Asset starting exposure and risk factors.

Asset	Start	RW <1Y	RW >1Y	HQLA	CI-Factor	RSF <6M	RSF 6M-1Y	RSF $\geq$1Y
Cash and equivalents	1.0%	0%	0%	100%	0	0%		
NHG	25,8%	5%	5%	0%	0,7%	50%	50%	65%
Loan-to-value <60%	22,8%	30%	30%	0%	0,7%	50%	50%	65%
Loan-to-value <80%	18,0%	35%	35%	0%	0,7%	50%	50%	65%
Loan-to-value <102%	17,3%	55%	55%	0%	0,7%	50%	50%	65%
Government bonds (AA-)	1,0%	0%	0%	100%	0%	5%	5%	5%
Government bonds (A- to A+)	1,4%	20%	20%	85%	0%	15%	15%	15%
Loans and advances to banks	7,7%	20%	50%	0%	According to maturity	0	50%	50%
Other assets	4,9%	60%	60%	35%	0%	100%		

TABLE E.3: Liability starting exposure and risk factors.

	Starting Weights	Cash Outflow Factor	ASF Factor <6M	ASF Factor 6M-1Y	ASF Factor $\geq$1Y
Due to banks	0,7%	100%	0	50%	50%
Demand deposits	12.0%	5%, 10%	90%	90%	100%
Savings deposits	16,2%	5%, 10%	95%	95%	100%
Term deposits	15,9%	100%	95%	95%	100%
Secured funding	45,6%	100%	0	50%	100%
Other liabilities	5,2%	0%	50%		
Equity	4,5%	0%	100%	100%	100%

Maturity buckets		0,0056	0,0833	0,25	0,5	0,75	1	1,5	2	3	4	5	6	7	8	9	10	15	20	25
Midpoint buckets	Total weight	0,0028	0,0417	0,1667	0,375	0,625	0,875	1,25	1,75	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	12,5	17,5	25
Assets																				
Cash and Central Bank deposits																				
Cash and equivalents	1,0 %	100,0 %																		
Mortgages																				
NHG	25,8 %	0,0 %	0,5 %	1,2 %	1,7 %	1,7 %	1,7 %	2,6 %	2,6 %	8,3 %	6,9 %	8,0 %	16,7 %	4,0 %	1,9 %	6,1 %	12,1 %	17,1 %	4,8 %	1,7 %
Loan to value < 60%	22,8 %	0,1 %	1,1 %	2,3 %	3,4 %	3,4 %	3,4 %	4,4 %	4,4 %	7,9 %	5,1 %	5,6 %	2,7 %	3,0 %	2,7 %	7,2 %	17,1 %	20,4 %	4,9 %	0,9 %
Loan to value < 80%	18,0 %	0,1 %	1,1 %	2,3 %	3,4 %	3,4 %	3,4 %	4,4 %	4,4 %	7,9 %	5,1 %	5,6 %	2,7 %	3,0 %	2,7 %	7,2 %	17,1 %	20,4 %	4,9 %	0,9 %
Loan to value < 102%	17,3 %	0,1 %	1,1 %	2,3 %	3,4 %	3,4 %	3,4 %	4,4 %	4,4 %	7,9 %	5,1 %	5,6 %	2,7 %	3,0 %	2,7 %	7,2 %	17,1 %	20,4 %	4,9 %	0,9 %
Government bonds																				
Government bonds, rated AA- or better	1,0 %	0,1 %	0,8 %	1,7 %	2,5 %	2,5 %	2,5 %	5,0 %	5,0 %	10,0 %	10,0 %	10,0 %	10,0 %	10,0 %	10,0 %	10,0 %	10,0 %	0,0 %	0,0 %	0,0 %
Government bonds, rated A- to A+	1,4 %	0,1 %	0,8 %	1,7 %	2,5 %	2,5 %	2,5 %	5,0 %	5,0 %	10,0 %	10,0 %	10,0 %	10,0 %	10,0 %	10,0 %	10,0 %	10,0 %	0,0 %	0,0 %	0,0 %
Bankloans																				
Loans and advances to banks	7,7 %	30,0 %	9,0 %	9,0 %	9,0 %	9,0 %	9,0 %	9,0 %	3,0 %	3,0 %	3,0 %	3,0 %	1,0 %	1,0 %	1,0 %	1,0 %	0,0 %	0,0 %	0,0 %	0,0 %
Other Securities																				
Other assets	4,9 %	100,0 %																		
Derivatives																				
Interest rate swaps		(0,0%)	(0,0%)	0,0 %	(0,0%)	(0,0%)	(0,0%)	0,0 %	0,0 %	0,0 %	9,0 %									
Liabilities																				
Due to banks	0,7 %	30,0 %	9,0 %	9,0 %	9,0 %	9,0 %	9,0 %	9,0 %	3,0 %	3,0 %	3,0 %	3,0 %	1,0 %	1,0 %	1,0 %	1,0 %	0,0 %	0,0 %	0,0 %	0,0 %
Due to customers																				
Demand deposits	12,0 %																			
Savings deposits	16,2 %																			
Term deposits	15,9 %	0,1 %	1,2 %	2,7 %	4,0 %	4,0 %	4,0 %	8,0 %	8,0 %	16,0 %	16,0 %	16,0 %	4,0 %	4,0 %	4,0 %	4,0 %	4,0 %	0,0 %	0,0 %	0,0 %
Wholesale funding																				
Secured wholesale funds, Covered bonds	45,6 %	0,1 %	1,1 %	2,4 %	3,6 %	3,6 %	3,6 %	7,1 %	7,1 %	14,3 %	14,3 %	14,3 %	14,3 %	14,3 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %
Other liabilities	5,2 %	0,0 %																		
Shareholder's equity																				
Equity	4,5 %																			

FIGURE E.1: Starting distribution of stylized balance sheet

Maturity buckets		0,0056	0,083	0,25	0,5	0,75	1	1,5	2	3	4	5	6	7	8	9	10	15	20	25
Midpoint buckets		0,0028	0,0417	0,1667	0,375	0,625	0,875	1,25	1,75	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	12,5	17,5	25
Assets																				
Cash and Central Bank deposits																				
Cash and equivalents		(0,4%)																		
Mortgages																				
NHG		1,8 %	1,9 %	2,1 %	2,5 %	2,9 %	3,3 %	3,6 %	3,9 %	4,2 %	4,2 %	3,9 %	3,9 %	4,0 %	3,9 %	3,5 %	3,2 %	4,8 %	4,5 %	5,2 %
Loan to value < 60%		1,8 %	1,9 %	2,1 %	2,5 %	2,9 %	3,3 %	3,6 %	3,9 %	4,2 %	4,2 %	3,9 %	3,9 %	4,0 %	3,9 %	3,5 %	3,2 %	4,8 %	4,5 %	5,2 %
Loan to value < 80%		2,0 %	2,1 %	2,3 %	2,6 %	3,0 %	3,4 %	3,8 %	4,1 %	4,3 %	4,3 %	4,1 %	4,1 %	4,1 %	4,0 %	3,7 %	3,4 %	4,9 %	4,6 %	5,3 %
Loan to value < 102%		2,2 %	2,3 %	2,5 %	2,9 %	3,3 %	3,7 %	4,0 %	4,3 %	4,6 %	4,6 %	4,3 %	4,3 %	4,4 %	4,3 %	3,9 %	3,6 %	5,2 %	4,9 %	5,6 %
Government bonds																				
Government bonds, rated AA- or better		(0,6%)	(0,6%)	(0,6%)	(0,6%)	(0,6%)	(0,6%)	(0,6%)	(0,6%)	(0,5%)	(0,4%)	(0,4%)	(0,3%)	(0,1%)	(0,0%)	0,1 %	0,3 %	0,5 %	0,7 %	0,8 %
Government bonds, rated A- to A+		(0,5%)	(0,4%)	(0,1%)	0,1 %	0,1 %	0,2 %	0,2 %	0,2 %	0,2 %	0,2 %	0,4 %	0,5 %	0,7 %	0,8 %	1,0 %	1,1 %	1,5 %	1,9 %	2,2 %
Bankloans																				
Loans and advances to banks		(0,0%)	(0,0%)	(0,1%)	(0,1%)	(0,0%)	(0,0%)	0,1 %	0,1 %	0,3 %	0,5 %	0,6 %	0,8 %	0,9 %	1,2 %	1,5 %	1,8 %	2,3 %	2,6 %	2,7 %
Other Securities																				
Other assets	2,0 %																			
Derivatives																				
Interest rate swaps		0,0 %	0,1 %	0,2 %	0,3 %	0,36 %	0,98 %	1,2 %	1,39 %	1,49 %	1,58 %									
Liabilities																				
Due to banks		(0,0%)	(0,0%)	(0,1%)	(0,1%)	(0,0%)	(0,0%)	0,1 %	0,1 %	0,3 %	0,5 %	0,6 %	0,8 %	0,9 %	1,2 %	1,5 %	1,8 %	2,3 %	2,6 %	2,7 %
Due to customers																				
Demand deposits		0,0 %																		
Savings deposits		0,4 %																		
Term deposits		2,4 %	2,4 %	2,5 %	2,7 %	2,7 %	2,7 %	2,8 %	3,0 %	3,1 %	3,2 %	3,2 %	3,2 %	3,3 %	3,3 %	3,4 %	3,4 %	3,6 %	3,9 %	4,3 %
Wholesale funding																				
Secured wholesale funds, Covered bonds		2,3 %	2,3 %	2,3 %	2,3 %	2,3 %	2,4 %	2,4 %	2,5 %	2,5 %	2,7 %	2,8 %	2,9 %	3,1 %	3,2 %	3,3 %	3,4 %	3,5 %	3,8 %	4,2 %
Other liabilities	3,0 %																			
Shareholder's equity																				
Equity																				

FIGURE E.2: Interest income and expense of current portfolio

Maturity buckets	Excluded	0,0056	0,0833	0,25	0,5	0,75	1	1,5	2	3	4	5	6	7	8	9	10	15	20	25
Midpoint buckets		0,0028	0,0417	0,1667	0,375	0,625	0,875	1,25	1,75	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	12,5	17,5	25
Assets																				
Cash and Central Bank deposits																				
Cash and equivalents		(0,4%)																		
Mortgages																				
NHG		1,8 %	1,8 %	1,8 %	1,8 %	1,7 %	1,7 %	1,7 %	1,7 %	1,8 %	1,8 %	1,8 %	1,9 %	1,9 %	2,0 %	2,0 %	2,0 %	2,3 %	2,7 %	3,3 %
Loan to value < 60%		1,8 %	1,7 %	1,7 %	1,7 %	1,7 %	1,7 %	1,7 %	1,8 %	1,8 %	1,8 %	1,8 %	1,9 %	2,0 %	2,0 %	2,0 %	2,0 %	2,3 %	2,7 %	3,3 %
Loan to value < 80%		2,0 %	1,9 %	1,9 %	1,9 %	1,9 %	1,9 %	1,9 %	1,9 %	2,0 %	2,0 %	2,0 %	2,0 %	2,1 %	2,2 %	2,2 %	2,2 %	2,5 %	2,9 %	3,6 %
Loan to value < 102%		2,5 %	2,4 %	2,4 %	2,4 %	2,4 %	2,4 %	2,4 %	2,4 %	2,4 %	2,4 %	2,5 %	2,5 %	2,6 %	2,6 %	2,7 %	2,7 %	3,0 %	3,4 %	4,2 %
Government bonds																				
Government bonds, rated AA- or better		(0,6%)	(0,6%)	(0,5%)	(0,5%)	(0,5%)	(0,5%)	(0,5%)	(0,5%)	(0,5%)	(0,4%)	(0,4%)	(0,3%)	(0,2%)	0,0 %	0,2 %	0,3 %	0,5 %	0,7 %	0,8 %
Government bonds, rated A- to A+		(0,5%)	(0,5%)	(0,4%)	(0,4%)	(0,3%)	(0,3%)	(0,3%)	(0,2%)	(0,1%)	0,0 %	0,1 %	0,3 %	0,5 %	0,8 %	1,0 %	1,1 %	1,4 %	1,7 %	2,0 %
Bankloans																				
Loans and advances to banks		(0,0%)	(0,1%)	(0,1%)	(0,1%)	(0,0%)	0,0 %	0,1 %	0,2 %	0,4 %	0,6 %	0,7 %	0,9 %	1,1 %	1,4 %	1,7 %	2,1 %	2,5 %	2,8 %	3,0 %
Other Securities																				
Other assets	2,0 %																			
Derivatives																				
Interest rate sv		0,0 %	0,1 %	0,2 %	0,3 %	0,36 %	0,98 %	1,2 %	1,39 %	1,49 %	1,58 %									
Liabilities																				
Due to banks		(0,0%)	(0,1%)	(0,1%)	(0,1%)	(0,0%)	0,0 %	0,1 %	0,2 %	0,4 %	0,6 %	0,7 %	0,9 %	1,1 %	1,4 %	1,7 %	2,1 %	2,5 %	2,8 %	3,0 %
Due to customers																				
Demand deposits		0,0 %																		
Savings deposits		0,4 %																		
Term deposits		0,4 %	0,4 %	0,5 %	0,7 %	0,7 %	0,7 %	0,8 %	1,0 %	1,1 %	1,2 %	1,2 %	1,2 %	1,3 %	1,3 %	1,4 %	1,4 %	1,6 %	1,9 %	2,3 %
Wholesale funding																				
Secured wholesale funds, Covered bonds		0,26 %	0,26 %	0,26 %	0,30 %	0,3 %	0,4 %	0,4 %	0,5 %	0,5 %	0,7 %	0,8 %	0,9 %	1,1 %	1,2 %	1,3 %	1,4 %	1,5 %	1,8 %	2,2 %
Other liabilities	3,0 %																			
Shareholder's equity																				
Equity	0,0 %																			

FIGURE E.3: Interest income and expense of new business

Maturity buckets ceiling		0,0056	0,0833	0,25	0,5	0,75	1	1,5	2	3	4	5	6	7	8	9	10	15	20	25	
Midpoint buckets		0,0028	0,0417	0,1667	0,375	0,625	0,875	1,25	1,75	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	12,5	17,5	25	Change
Assets																					
Cash and Central Bank deposits																					
Cash and equivalents		0,0 %																			0,0 %
Mortgages																					
NHG		0,4 %	0,4 %	0,3 %	0,2 %	(0,0%)	(0,0%)	(0,0%)	0,1 %	0,0 %	(0,1%)	(0,1%)	(0,2%)	0,1 %	(0,0%)	(0,1%)	(0,2%)	(0,2%)	(0,1%)	0,3 %	0,8 %
Loan to value < 60%		(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	0,0 %	(0,0%)	(0,1%)	(0,1%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,1%)	(0,2%)	(0,2%)	(0,1%)	(0,0%)	(1,0%)
Loan to value < 80%		(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	0,0 %	(0,0%)	(0,0%)	(0,1%)	(0,0%)	0,0 %	0,0 %	(0,0%)	(0,0%)	(0,1%)	(0,2%)	(0,2%)	(0,0%)	0,2 %	(0,5%)
Loan to value < 102%		0,2 %	(0,0%)	(0,0%)	(0,0%)	0,0 %	0,1 %	(0,0%)	0,2 %	0,2 %	(0,0%)	(0,0%)	0,1 %	0,0 %	(0,0%)	(0,1%)	(0,1%)	(0,2%)	(0,0%)	0,7 %	0,9 %
Government bonds																					
Government bonds, rated AA- or better		(0,0%)	0,8 %	0,5 %	0,1 %	(0,0%)	(0,0%)	(0,0%)	(0,0%)	0,1 %	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	0,0 %	0,0 %	0,0 %	0,7 %
Government bonds, rated A- to A+		(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	0,0 %	(0,0%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	0,0 %	0,0 %	0,4 %	(0,9%)
Bankloans																					
Loans and advances to banks		0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %
Other Securities																					
Other assets	0,0 %																				0,0 %
Derivatives																					
Interest rate swaps		1,9 %	0,1 %	(1,2%)	(2,0%)	(2,4%)	(3,6%)	(2,9%)	(0,2%)	2,3 %	1,0 %										
Liabilities																					
Due to banks		0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %
Due to customers																					
Demand deposits		0,1 %																			0,1 %
Savings deposits		0,8 %																			0,8 %
Term deposits		(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	(0,0%)	0,0 %	0,0 %	0,1 %	(0,7%)
Wholesale funding																					
Secured wholesale funds, Covered bonds		(0,0%)	(0,0%)	(0,1%)	(0,1%)	(0,1%)	(0,1%)	(0,2%)	(0,2%)	(0,3%)	(0,3%)	(0,3%)	(0,3%)	(0,3%)	0,0 %	0,0 %	0,0 %	0,0 %	0,8 %	1,3 %	(0,2%)
Other liabilities	0,0 %																				0,0 %
Shareholder's equity																					
Equity	0,0 %																				0,0 %

FIGURE E.4: Proposed changes in balance sheet allocation

Appendix F

Interest Rate Disclosures

The (BCBS, 2016) introduced a more standardized method to systematically quantify the interest rate exposure of banks in order to promote transparency and comparison across banks. The price that has to be paid for standardization is the possibility of misrepresenting the reality. Because of this, banks still have certain freedoms, such as determining the repricing distribution of NMDs. In order to compare the outcomes of the disclosed values across banks, banks need to disclose high-level assumptions on model choices.
The new guidelines on interest rate risk in the banking book of the BCBS include new public disclosure requirements. Banks are required to disclose the EVE impact under six prescribed interest rate scenarios. Furthermore, information on the maximum and average duration of deposits and assumptions that have been made regarding repricing of NMDs should also be disclosed to both the regulator and the public. In general, banks are afraid investors have too little knowledge of this difficult topic to fully understand the disclosures. Furthermore, banks fear that the disclosures will contain sensitive information (Contiguglia (2016), BBA (2015)). As a result, banks expect that too much attention will be focused on the disclosed EVE outcomes, ignoring the bank's interest rate risk management.
Besides, disclosure of quantitative parameters, such as current NMD repricing assumptions, can be used by competitors to calibrate their models (BBA, 2015). Banks usually base the interest on savings accounts by benchmarking their rates with the expected rates of their competitors. If information about repricing assumptions is publicly available, it gives competitors a better idea of the prices a bank will offer and anticipate on this.
The disclosing requirements could also give competitors insight into individual banks' pricing and hedging strategy. Banks claim that disclosing all fixed prescribed scenarios would effectively be the same as disclosing the duration of any bank's portfolio. This could lead to market participants frontrunning a bank's hedging needs based on its portfolio characteristics (Wilkes, 2016). Another argument against disclosing the interest rate shocks is that investors will misinterpret the disclosed EVE values, and will see the disclosed EVE values as a going concern measure. Therefore, banks will appear to be at greater risk due to the absence of mitigation strategies, which will cause unnecessary panic in the market (BBA, 2015). Finally, the EVE is only standardized to some extent, which can cause more confusion under investors. For instance, a bank has the choice to include

or exclude commercial margins. In case the bank chooses to include them, commercial margins should be included in the discount rate, which can result into different outcomes. Also the treatment of NMDs is not entirely standardized. There are caps on the amount of core deposits and average duration, but distributions and durations can still differ across banks.

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