

# **BANK BALANCE SHEET OPTIMIZATION**

UNDER BASEL III

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# Preface

The Master program Business Analytics (previously called Business Mathematics & Informatics) at the VU University Amsterdam is concluded by an internship. My internship took place at the Financial Services Risk Management department of Ernst & Young. A thorough description of the analysis carried out during my internship period and the results are presented in this report.

I would first like to thank my supervisor, Sandjai Bhulai, for his support throughout this internship. His good and useful ideas helped me overcome hurdles and gave me a lot of guidance in successfully completing the internship. Also I would like to thank Diederik Fokkema, who supervised me from within Ernst & Young. His help was also crucial in order to tackle the problems encountered during the internship period and eventually to the creation of a very useful decision support tool. Then, a word of thank goes to Rob van der Mei, who took on the task of second reader. His comments on the report have helped a lot in improving it.

Finally, I would also like to thank my colleagues at Ernst & Young for their help and support. There was plenty of opportunity to share my thoughts and progress with them, which led to a lot of useful feedback that definitely helped to improve the quality of the research and final report.

John Puts  
- Amsterdam, March 2012



# Abstract

Effectively performing strategic balance sheet management is a difficult challenge for many banks, given the fact that new stronger regulatory constraints, under the name of Basel III, are soon to be introduced. Besides the regulatory constraints, bank's need to keep their strategic goals, risk profile, managerial constraints and exogenous influences into account as well. Trial and error approaches are sub-optimal, therefore banks need reliable quantitative risk management models and tools that can serve as decision support systems.

Taking the current balance sheet, the banks risk profile, strategy and other preferences and properties as a starting point, this report gradually presents a modeling framework for bank balance sheet optimization under Basel III. A thorough explanation of all the components of the model and a scientific reasoning for the choices and assumptions made is included. The report explains why the approach that is presented is a very effective way of strategic balance sheet management, especially in the current uncertain economic times.

The results of the report show that the applied methodology can result in a solution for banks on how to optimally compose their balance sheet, given their strategy, risk profile and other preferences. They show how a bank can achieve a higher profitability and become and remain Basel III compliant throughout the whole phase-in period by solely modifying its balance sheet slightly. Besides that, some other smart ways of how banks can prepare themselves for Basel III are presented.



# Contents

<b>List of Tables</b>	<b>9</b>
<b>List of Figures</b>	<b>11</b>
<b>1 Introduction</b>	<b>13</b>
1.1 Business Analytics . . . . .	13
1.2 Ernst & Young . . . . .	14
1.3 The problem . . . . .	15
1.4 Literature overview . . . . .	16
1.5 Report outline . . . . .	18
<b>2 Basel Framework</b>	<b>20</b>
2.1 About the BIS . . . . .	20
2.2 Regulatory history . . . . .	22
2.2.1 Basel I . . . . .	23
2.2.2 Basel II . . . . .	25
2.3 Basel III . . . . .	30
2.3.1 Capital base . . . . .	33
2.3.2 Leverage . . . . .	37
2.3.3 Liquidity . . . . .	38
<b>3 Modeling the BS</b>	<b>43</b>
3.1 Components of the model . . . . .	44
3.1.1 The balance sheet . . . . .	45
3.1.2 Assets & Liabilities composition . . . . .	48
3.1.3 The input . . . . .	49
3.1.4 Capital . . . . .	54
3.1.5 P&L account . . . . .	55
3.1.6 Risk weighted assets . . . . .	56
3.1.7 Balance sheet transition . . . . .	57
3.2 BIII constraints formalization . . . . .	58
3.3 Risk profile . . . . .	60

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3.4	Stochasticity . . . . .	65
3.5	Strategic BS management . . . . .	67
<b>4</b>	<b>Optimization technique</b>	<b>69</b>
4.1	Optimization problem . . . . .	69
4.1.1	Penalty function . . . . .	74
4.2	Solver vs OptQuest . . . . .	76
4.3	Choice of constraints . . . . .	78
<b>5</b>	<b>Results</b>	<b>81</b>
5.1	Base versus optimal balance sheet . . . . .	81
5.2	How to find the optimal BS . . . . .	83
5.3	Sensitivity analysis . . . . .	84
5.4	Impact of risk profile modification . . . . .	86
5.5	Scenarios . . . . .	86
<b>6</b>	<b>Conclusion</b>	<b>90</b>
6.1	The optimal balance sheet . . . . .	90
6.2	Further research . . . . .	92
	<b>Bibliography</b>	<b>95</b>
	<b>Appendix</b>	<b>96</b>
A.1	. . . . .	96
A.2	. . . . .	98
A.3	. . . . .	99
A.4	. . . . .	100

# List of Tables

2.1	Risk weights per asset class . . . . .	24
2.2	Capital ratios in BII and BIII . . . . .	35
2.3	Individual bank min capital conservation standards . . .	35
2.4	Capital buffers in BII and BIII . . . . .	35
3.1	Basel III constraints in a time-line . . . . .	58
4.1	Thought experiment on constraints choice . . . . .	79
5.1	Performance of starting and optimal BS . . . . .	83
5.2	Basel III ratios comparison . . . . .	83
5.3	Impact of risk profile modification . . . . .	86
5.4	Influence of a bank run scenario . . . . .	87
5.5	Influence of a credit rating downgrade scenario . . . . .	88
5.6	Influence of an unexpected large loss scenario . . . . .	88
5.7	Impact on ROE when incorporating stress in optimization	88



# List of Figures

2.1	Finding a balance between demands of shareholders and supervisory authorities . . . . .	22
2.2	Phase-in process of the Basel III capital ratios . . . . .	36
2.3	Countercyclicality . . . . .	37
3.1	The stylized balance sheet . . . . .	46
3.2	The main input parameters of the model . . . . .	50
3.3	The three incorporated risk profiles in the model . . . . .	64
3.4	Stochasticity in the model . . . . .	66
3.5	Context of strategic balance sheet management . . . . .	67
4.1	The optimization environment with ROE as the target function . . . . .	73
4.2	The two used optimization techniques in the model . . . . .	77
4.3	ROE development with yearly BIII constraints . . . . .	80
5.1	Optimal versus starring balance sheet . . . . .	82
5.2	Sensitivity analysis on return on equity . . . . .	85



# Chapter 1

## Introduction

### 1.1 Business Analytics

Business Analytics (BA)<sup>1</sup> is a multidisciplinary programme that consists of mathematics, computer science and business knowledge. The programme provides the student with expertise from these three fields, in order to be able to analytically approach problems and finding appropriate solutions for them. The diversity of the programme ensures that the BA student is equipped with skills from many areas that can be combined in a smart way to find a way how to optimally perform processes within companies. Many different optimization methods are treated throughout the five year research master. Because of the fact that the programme is set up very pragmatic, the student works on a lot of projects and cases. This gives the student the opportunity to apply the theoretical knowledge learned on real-life practical problems that firms deal with. The six month internship at the end of the programme is the final part of the BA Master. This is a project to be carried out within a business, industry or research facility other than the department of Mathematics and Computer Science. The Business Analytics internship fits in one of the specializations: Optimization of Business Processes, Computational Intelligence or Financial Risk Management. This report describes the work carried out during the internship, and presents the results.

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<sup>1</sup>In the school year 2011-2012 the name of the programme was changed from "Business Mathematics and Informatics (BMI)" into "Business Analytics (BA)".

## 1.2 Ernst & Young

Ernst & Young is a global leader in assurance, tax, transaction, advisory services and strategic growth markets. Ernst & Young aims to have a positive impact on businesses and markets, as well as on society as a whole. Ernst & Young is a globally recognized leader in knowledge management. They invest in developing processes and systems for their people to create, share and reuse our intellectual capital on a global scale, enabling them to efficiently deliver the most relevant insights for companies and financial institutions.

The department where the research was undertaken is called the Financial Services Risk<sup>2</sup> department. FS Risk offers strategic and operational services that help clients assess, improve and monitor their systems of internal controls. FS risk has deep experience in credit, market and operational risk; process risk and controls; quantitative analysis; regulatory compliance and corporate treasury – and the breadth of core skills to help clients assess their options, improve their operations and manage their risk as an enterprise-wide discipline.

The main subject of the report can best be placed under the work that is performed by the Quantitative Advisory Services (QAS) team, which is part of the FS Risk department. The FS Risk Quantitative Advisory Services (QAS) Team provides financial and risk modeling services to a diverse client portfolio primarily operating in the Financial Services Industry - essentially modeling for banks, insurers and asset managers. The main services are:

- Valuations: asset pools, financial instruments, derivatives and structured products.
- Credit risk: portfolio and loss forecasting, stress-testing, impairment, capital and Basel II IRB modeling (build and validation).
- Market risk: VaR, stress-testing, portfolio management and risk analytics.
- Operational risk: data and scenario driven operational risk modeling powered by our internal modeling framework.
- ALM: banking, asset management and insurance.

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<sup>2</sup>From now on: FS Risk.

### 1.3 The problem

Banks are financial institutions that are dealing with a lot of risk. Therefore risk management is a vital activity that helps banks maintaining adequate amounts of capital and liquidity, together with liabilities that stay within limits. To make sure banks remain reliable factors for customers, governments and other involved parties, global regulatory standards have been developed. The most current one is called Basel III, that was developed in a response to the deficiencies in financial regulation revealed by the global financial crisis. It is the successor of Basel II. In this accord, many restrictions are included that strengthen bank capital requirements. Since banks are very important financial institutions in our society, it is of big importance to come up with good ideas to how to deal with the gradually strengthening regulations. Also the development of models and decision support tools is very relevant. Especially in these economically uncertain times, banks need to base their decisions on reliable research and tools, because small mistakes or wrong risk estimations can lead to severe financial problems. On a more specific level; banks are in great uncertainty on how to make sure that they will be able to live up to all the new strict regulations of Basel III that will be implemented from 2013 to 2019, while still maximizing their profits.

As described in the previous section, banks are strongly seeking advice on how to deal with the strict upcoming Basel III regulations. This is the reason why it is of great importance to understand the new standards that Basel III introduces in the best possible way, to be able to come up with ideas that describe how a bank should perform. There is a need for models and tools that help to support decisions that have to be taken by banks. Therefore research on bank balance optimization under Basel III is a very necessary business. So the subject of the internship is a very topical matter that needs to be addressed right now. This statement is strengthened by the fact that there is not too much material on this topic available yet. This is mainly due to that it is still very new and the starting date of implementation of the regulations is more than a year ahead from now. But if banks want to be able to meet the restrictions of Basel III in 2013, they will need to start taking measures now. So the outcome of the research will be very useful, since it will provide better understanding on how a bank needs to compose its balance sheet to meet the Basel III restrictions, while maintaining profitable.

The main research question is:

**Problem.** “How can a bank optimally compose its balance sheet in order to maximize its profit, while meeting all restrictions that the Basel III accord brings along?”.

The answer of this question is not a single line of text, it is a much more complex problem that exists of many sub questions and needs to be analyzed thoroughly. A few important sub problems could be formulated as follows:

- Are we satisfied with our current risk profile or do we need to apply a level of conservatism?
- What factors are of (big) influence on our performance?
- Which balance sheet (BS) positions do we have to expand, and which do we have to reduce?
- How much capital should we hold to be prepared for unforeseen events?

During the research, a model was developed, which is a representation of a bank’s functioning, a close approximation of reality. As regards the scope of the research problem; the focus will be on a non-investment retail bank. This report describes what consequences the Basel III accord will have, how these consequences translate into factual information that touches a bank’s operating, and how this formalization process looks like. The report also shows in what way a bank should react to the upcoming stricter rules, to be able to meet all legal demands in the future while maximizing their profit. Another part of the problem is: “How should a specific bank optimally compose its BS positions to maximize profits under Basel III?” The user-friendly decision support tool that was developed allows users to input the data and properties of a bank, choose a risk profile, a tax & dividend policy, a starting optimization date and more, in order to optimize the balance sheet of that specific bank.

## 1.4 Literature overview

In this part, an overview is given of related work on the subject of this report. As it is not convenient to collect all literature references in one

section, most references in this report are included in the section that touches the referring work as closely as possible. In this part, we will focus on some relevant work in order to place this report in the right context and to show how it fits in the total field of study performed on this topic. The work referred to in this section is also a good starting point for the rest of the thesis, to gain better understanding of the matter and thereby being able to read through this report more smoothly.

As mentioned earlier in the report, not too many studies have been performed on balance sheet optimization under Basel III/CRD IV<sup>3</sup>. The main reason for this is that it is a very topical matter that has not yet been totally addressed by most banks. Therefore there is a lot of uncertainty on this subject which causes the need for more information on this subject. Some papers/reports have been written on this or related subjects though.

A very interesting topical work that concerns a subject that is very related to the one discussed in this report was written by Pokutta and Schmaltz [15]. In this paper, a modeling framework for banks' business planning under Basel III is provided. In this paper, the effect of Basel III on the banks' product mix for a simplified, deterministic two-product case is analyzed. In what follows, they generalize the model by incorporating parameter uncertainty, adjustment cost, multiple time steps and products. This paper is interesting if one is interested to gain more understanding of the graduate process of bank modeling. Step by step more complexities and assumptions are added to the model, which gives good understanding of the influence of the individual factors.

A more general paper on the modeling of 'the banking firm' that also assesses the understanding of the banking firm's optimal behavior was written by Santomero [17]. This paper is somewhat outdated, but nevertheless a very important paper in the banking sector, that has been proven very valuable for further research. It also discusses two hundred contributions on the subject of bank behavior, and therefore gives a good overview of what has been written on this subject over the past decade.

For a better understanding of why strategic balance sheet management is crucial for banks, we refer the reader to a paper by Kretzschmar [12]. The paper discusses how a fully integrated risk analysis based on

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<sup>3</sup>CRD IV is the EU implementation of Basel III and applies to banks and investment firms.

the balance sheet of a representative Eurobank using an economic scenario generation model calibrated to conditions at the end of 2007 was implemented. The results suggest that the more modular, correlation-based approaches to economic capital that currently dominate practice will lead to an under-capitalization of banks. To this paper, we refer the reader that seeks more understanding of the graduate growth of stronger legislation needs in the banking sector, which relates to the introduction of Basel III.

A last reference that would be useful to consult before continuing with this report is a journal that discusses why banks hold capital in excess of regulatory requirements in relation to market discipline [7]. The literary works mentioned so far give a good starting point for the rest of this paper, but are definitely not the only publications on this and related subjects. More references to literature studies can be found throughout the different chapters of this report, in order to place them closer to the discussed matter of relevance.

## 1.5 Report outline

In this section, the structure of the report is described. Chapter two discusses the Basel framework. The chapter starts with a short introduction on the BIS<sup>4</sup>, followed by a description of Basel I, Basel II and Basel III. Also, the most important differences between Basel III and Basel II are highlighted, which are most relevant for this report. Chapter three treats the modeling process of the balance sheet, including an explanation on how the risk profile is modeled. This chapter also explains how the model accounts for uncertain volatile parameters affecting a bank's performance and shows how the formalization of the most important Basel constraints looks like. Another thing that is treated in chapter three is the description of the customizability of the model. Then, chapter four is dedicated to a thorough description of the optimization techniques that are used to come to an optimal balance sheet. Questions like why the used techniques are the most appropriate ones for the problem are answered here by the use of textual and visual explanations. Chapter five summarizes the most important results of the research, and explains how these results should be interpreted to make them useful for banks capital performance teams. This

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<sup>4</sup>Bank for International Settlements, serves (central) banks in their pursuit of monetary and financial stability, fosters international cooperation in those areas and acts as a bank for central banks.

chapter also includes a few scenarios that are built in to the tool. This will provide better understanding of the impact of certain scenarios on the optimal balance sheet (i.e. which ratio's are affected by what kind of unexpected event). The conclusion (chapter six) summarizes the most important findings of the research, and talk about what kind of further work might be interesting to undertake, and in what way the tool could be tweaked to become even more powerful.

## Chapter 2

# Basel Framework

### 2.1 About the BIS

The Bank for International Settlements is an organization based in Basel, established in 1930, and is not accountable to any government.

**Definition.** The Bank for International Settlements (BIS) is an inter-governmental organization of central banks which fosters international monetary and financial cooperation and serves as a bank for central banks.

Despite existing regulations issued by the BIS, many banks were in trouble during the crisis in the seventies. Therefore in 1974 the BIS, through the hands of central banks of 10 countries, established a committee with the aim of producing new guidelines to improve the capital positions of banks.

Because the meetings take place in Basel, where the secretariat is established, this committee is known as the Basel Committee. The official name reads: Basel Committee on Banking Supervision (BCBS).

**Definition.** The Basel Committee on Banking Supervision (BCBS) is a committee of banking supervisory authorities that was established by the central bank governors of the Group of Ten countries.

The BCBS provides a forum for regular cooperation on banking supervisory matters. Its objective is to enhance understanding of key supervisory issues and improve the quality of banking supervision worldwide. The Committee also frames guidelines and standards in different areas. The work is not carried out in Basel only. Subcommittees carry out the tasks of the BIS. It does not provide any services to retail clients, only for central banks or other international organizations. The BIS provides the Basel Committee on Banking Supervision (BCBS) with its seventeen-member secretariat. The committee meets every 3 to 4 months. BCBS provides recommendations to both the managers and the supervisors of the banks.

The recommendations are not binding. They are just standards or best practices formulated that can be adopted and implemented by individual authorities. Also the exact interpretation may be adjusted by the local authorities to suit the specific national situation. But facts learn us that these recommendations are often taken very seriously by local authorities, which is supported by the fact that binding regulations are imposed on banks. In (most of) Europe, these binding capital rules come in the form of the earlier mentioned CRD IV, which is the EU implementation of Basel III and applies to banks and investment firms.

The BIS is therefore a very important organization for banks, since it regulates capital adequacy and encourages reserves transparency with as goal to create and maintain a financial safety net. Banks cannot escape from the fact that they will have to fulfill certain requirements and maintain compliance. This reduces the amount of freedom banks have to operate how they want. They have as much freedom as running their operations how they want, as long as they live up to the standards and guidelines of the authorities.

These standards and guidelines are created in order to reduce the probability of insolvency for banks. One of the consequences for banks is that they have to reserve more capital than they might want to. After all, reserving capital costs money, since stakeholders demand a return on equity, and reserving more capital means less money to earn these profits with. The demands of the stakeholders on the one hand, and the demands of supervisory authorities on the other hands, force banks to look for a good balance between solvability, liquidity and profitability. See figure 2.1.

In a healthy economic period, banks are probably not overly concerned about surviving, but more with trying to be as profitable as possible.



Figure 2.1: Finding a balance between demands of shareholders and supervisory authorities

This would mean that the strategy of the bank would be somewhere high up in the profitability circle in figure 2.1. In economically hard times, banks are more conservative about their strategy, and will probably be more focused on maintaining high liquidity and solvency ratios. But at all times, banks will have to be compliant to all regulatory constraints, imposed by authorities. These regulatory demands become tangible in the form of guidelines and standards, described in accords. These accords are called Basel capital accords. We will talk about them now.

## 2.2 Regulatory history

Capital accords are very important in the financial world. They restrain banks, but maintain the stability of the financial system. The most important capital accords are the Basel capital accords. This section contains a brief history of how the Basel capital accords developed through time, and eventually mouths into the most topical Basel accord, Basel III, which is an indispensable part of the research problem of this thesis. But first we will give a short historical perspective of capital accords in the financial world, starting with Basel I.

### 2.2.1 Basel I

In 1988, the BCBS introduced the 'Basel Capital Accord'. This agreement is nowadays called the Basel I agreement. The aim of the agreement was to:

- Improve the strength and stability of the banking system as a whole.
- Create an equal basis for all internationally active banks.

This was done by imposing requirements on the amount of capital banks must have at the initiation of a loan. The Basel I agreement had a main rule: the 8 percent rule.

**Definition.** The 8 percent rule implied that for every € 100 lent money, at least 8 euros of equity should be held as reserve.

Exceptions were made when the loan was collateralized. In this case, there was a reduction of the risk premium<sup>1</sup>. After all, the bank has the right to sell the collateral at default. The amount of risk premium that has to be paid depends on the risk level of the asset. The scale that was introduced to measure the risk level of a loan was the risk-weighted assets scale.

A sovereign loan from a state with very good credit for example has a 0% risk weight, since the probability of default is well-nigh zero. Thus, for every type of exposure a bank has, a risk-weighting is attached that determines the risk premium. A bank that would have all their exposure in sovereign debt would not have to hold any capital, but since banks have their money invested in different type of assets, with different risk-weights, the bank will have to hold capital to be able to absorb losses. The Basel I agreement distinguishes four risk weight categories, that are set out in table 2.1

**Tier Capital.** As mentioned above, the minimum amount of capital the bank has to hold is 8% of the risk weighted assets. But what type of capital does the bank have to hold? Basel I says that both Tier 1 and Tier 2 capital are eligible.

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<sup>1</sup>A risk premium is the minimum amount of money by which the expected return on a risky asset must exceed the known return on a risk-free asset, or the expected return on a less risky asset, in order to induce an individual to hold the risky asset rather than the risk-free asset.

Risk weight	Asset Class
0%	Cash Sovereign bonds
20%	Claims on OECD banks Claims on municipalities
50%	Residential mortgages
100%	Assets involving businesses Personal consumer loans assets involving non-OECD governments

Table 2.1: Risk weights per asset class

Tier 1 capital consists of equity and retained earnings after tax. These are the two elements of capital which all banks have in common and that are the best indication of the extent to which banks are able to absorb losses. Tier 2 capital includes other elements of capital. In this case, the national supervisory bodies decide what type of capital may be placed under Tier 2 capital. National differences are therefore possible. Examples of Tier 2 capital can include hidden reserves, revaluation reserves, general provisions and subordinated loans.

Basel I also says that the amount of Tier 2 capital may not exceed the amount of Tier 1 capital. This means at least 4% of the risk weighted assets should be Tier 1 capital.

**Advantages and disadvantages of Basel I.** The advantage of Basel I is that it is relatively easy to calculate and monitor. One only needs to know the composition and value of the credit and trading portfolio in order to calculate the capital adequacy.

The disadvantage however is that it is a rigid system. It starts from a classical vision of banking in which one assumes that the bank is only concerned with borrowing and lending money. But in reality, a bank's operations stretch far beyond this simple vision. In reality, banks are much more dynamic. They are involved in many more occupations. For example, risks associated with securities are not included in this system. Also, Basel I offers no control over so-called 'Off-Balance Sheet' Instruments (OBSI) such as options and other derivatives.

A second disadvantage is that only the absolute amount of a loan is taken into consideration, ignoring other relevant properties of a loan.

Finally, Basel I does not look at the borrower itself. An unsecured loan to an AAA client is treated in the same way as an unsecured loan to a customer on the edge of bankruptcy. Obviously, this ignores a lot of risks, and therefore the amount of required risk premium estimated with this narrow vision will probably be underestimated.

For a more detailed description of Basel I, we refer the reader to the BIS Basel I accord, and the corresponding amendments [3], [6], [4].

### 2.2.2 Basel II

In June 1999, the Basel Committee proposed to replace the Capital Accord of 1988 by a more risk-sensitive framework. This led to the introduction of Basel II in 2004. While the original accord laid its focus mostly on market risk and credit risk, Basel II expands the treatment of these risks by including a specific operational risk component. Besides that, all risk components that a bank faces are described more thoroughly.

The purpose of the new capital accord Basel II is to provide guidance to financial institutions in order to determine how much capital they must at least hold to be able to absorb unexpected losses arising from their financial and operational risks.

Just like with Basel I, the guidelines are implemented in the European Union through the CRD directive (Capital Requirements Directive). Almost all EU Member States have this directive integrated into their national legislation. In the Netherlands for example, this directive is implemented in the "Wet financieel toezicht" (a law of supervision) and subordinate legislation. A number of non-EU countries such as Switzerland, Canada and Australia, also have implemented Basel II in their national law.

Basel II rests on three pillars, which financial institutions must implement in their entirety: minimum capital requirements, supervision and market discipline.

**Pillar 1.** Pillar 1 provides guidelines for calculating the minimum amount of capital that a financial institution must hold for credit, market and operational risks. Basel II gives financial institutions the opportunity to choose from a number of methods by which the minimum

capital requirements are calculated. These methods range from relatively simple to more sophisticated. For the latter, the use of internal models is most common. The supervisor must approve the use of these internal models for calculating the minimum capital requirements.

**Pillar 2.** Pillar 2 provides guidelines by which the solvency of a financial institution is assessed. It starts with the calculation of the minimum amount of capital that the financial institution needs to cover all its risks, according to the expectation of the institution itself. This does not just mean the risks under Pillar 1. This is usually called the 'economic capital'. This is then compared with the available capital of the institution. By means of this path, a financial institution remains adequately capitalized at all times. Pillar 2 also provides principles for supervisors on how the capital within a financial institution should be assessed.

An interesting article on the role and implementation of Pillar 2 under the Basel II framework can be found in the following works [16], [18].

**Pillar 3.** Pillar 3 provides guidelines for reporting to the outside world about the risks that a financial institution faces and the capital that the financial institution has available to cover unexpected losses resulting from these risks. Better disclosure increases the market discipline, and therefore to greater financial stability.

**Approaches to credit risk.** To calculate the Basel II Accord's requirements for risk-weights there are two methods: the standardized and the internal ratings-based approach. This part generally describes these two methods, and gives the reader a reference to a more in-to-depth description of the methods.

*Standardized approach (SA)*

The standardized approach overcomes a shortage of Basel I. There the original accord lacked the differentiation of risk, Basel II takes this important property in to account. Under the standardized approach, an exposure is multiplied by a risk weight to derive a risk-weighted asset (RWA). This methods takes in to account the difference of reliability between loans. An AAA loan for example will therefore get a lower risk weight than an BB loan. The standardized approach uses a

'lookup table' to find the right risk weight to its corresponding credit rating for each type of loan.

*Internal rating based approach (IRB)*

Instead of using a 'lookup table', the IRB approach includes three risk elements (risk components, risk-weight function, and minimum requirements). In the function that is used to calculate the capital requirement (K) for credit risk, the risk-weighted assets are a function of four components. This function looks as follows:

$$KC_{Credit,IRB} = LGD * f(PD) * g(M, PD) \quad (2.1)$$

The amount of risk-weighted assets then is:

$$RWA_{Credit,IRB} = 12.5 * EAD * K \quad (2.2)$$

with

<i>PD</i>	probability of default
<i>EAD</i>	exposure at default
<i>LGD</i>	loss given default
<i>M</i>	maturity

Besides the IRB method, there is also an advanced IRB method.

**Approaches to market risk.** The original Basel I Accord from 1988 charged banks for credit risk only. The 1996 Amendment added market risk. Basel II distinguishes between the bank's trading book (marked-to-market and held for shorter terms) and the banking book (valued at cost and held for longer terms). The banking book holds our traditional view of a bank loan asset; the trading book holds the rapidly-growing list of complex instruments that can include credit derivatives, securitizations and leveraged loans. The most important risks that fall under market risk are:

- Interest rate risk and trading book equity
- Foreign exchange risk and commodities (trading and banking books)

Market risk has two similar approaches to calculate the market risk charge: The first method is also called the standardized approach, the second method is called slightly different than in the credit risk approach, namely the internal models approach (IMA).

*Standardized approach (SA).*

Under the standardized approach, the market risk charge (MRC) is simply the sum of the charges of each position. This gives the following formula:

$$MRC_t^{Market, SA} = \sum_{IR, EQ, FX, CO, OP} MRC_t \quad (2.3)$$

The terms in the sum are interest rate (IR), equity (EQ), foreign exchange (FX), commodities (CO) and operations (OP).

*Internal models based approach (IMB).*

The IMA approach is a more accurate approach. It comes along with some quantitative and qualitative requirements. Not every bank is allowed to use the internal approach. Supervisory approval is necessary first. This property of the IMA approach therefore connects Pillar I with Pillar II. Banks using IMA, base the market risk charge on the daily value at risk (VaR). The market risk charge must use VaR but Basel does not insist on a particular VaR model. Minimum standards include:

- Daily 99th percentile confidence VaR.
- Ten-day time horizon.
- Quarterly updated data sets.
- The use of a variance-covariance model or a simulation model (Monte Carlo or historical).
- A historical observation period of at least one year.

The market risk charge (MRC) is the higher of:

the previous day's VaR or the average VaR over the last sixty business days multiplied by a multiplicative factor, which is at least three.

**Approaches to operational risk.** Basel II contains three methods for addressing the operational risk component, and therewith the risk charge for this component. These three methods will shortly be discussed in this part.

*Basic indicator approach (BA)*

This is the most simple method in use. Due to its simplicity, it is also

the most criticized method. The simplicity is underlined by the fact that the risk charge (K) according to this method is simple a fixed percentage ( $\alpha$ ) of the bank's three-year average gross income (GI). This percentage is currently set at 15%. Negative years are excluded from the average. We could write this down as follows:

$$K_{Operational, BIA} = \frac{\sum_{i=t-3}^t (GI_i * \alpha)}{3} \quad (2.4)$$

#### *Standardized approach (SA)*

The standardized approach does not differ too much from the BA approach. It is somewhat more realistic though, mainly due to the fact that it is a weighted average of the gross income. The weighted average depends on the business lines of the bank. Instead of a fixed percentage, as we saw in the BA approach, the SA approach makes use of a beta factor ( $\beta$ ), which is a multiplier that lies within a 12% to 15% range:

$$K_{Operational, BIA} = \frac{\left\{ \sum_{i=t-3}^t \max [\sum (GI_{i,lines\ 1-8} * \beta_{lines\ 1-8}), 0] \right\}}{3} \quad (2.5)$$

#### *Advanced measurement approach (AMA)*

The third approach to calculate the operational risk charge is the AMA approach. It is the most aberrant one, because it is not an incremental approach. The exposure to operational risk is estimated from a bottom-up perspective, while the other two approaches are top-down approaches. AMA is a very flexible approach, though a certain number of requirements have to be satisfied:

- Internal data needs to be available.
- External data needs to be available.
- Scenario analysis should be performed.
- The elements should have controls and tools.

The required amount of capital (K) using the AMA approach can be calculated as follows:

$$\begin{aligned}
K_{Operational, AMA} &= \sum_i \sum_j \left[ \gamma_{(i,j)} * EI_{(i,j)} * PE_{(i,j)} * LGE_{(i,j)} \right] \quad (2.6) \\
&= \gamma_{(i,j)} * EL_{(i,j)}
\end{aligned}$$

with

$EI_{(i,j)}$	exposure indicator (event type i, business line j)
$PE_{(i,j)}$	probability of a loss event (event type i, business line j)
$LGE_{(i,j)}$	loss given the events (event type i, business line j)
$EL_{(i,j)}$	expected loss (event type i, business line j)
$\gamma_{(i,j)}$	gamma multiplier (event type i, business line j)

An interesting publication on the topic of operational risk towards Basel III was written by Gregoriou. We refer the reader that is interested in some more information on modeling, management and regulation of operational risk to this work [9].

**Basel II and the financial crisis.** It is a widely discussed topic whether the global financial crisis showed the weaknesses and shortcomings of Basel II, or that Basel II even strengthened the effect of the crisis. Anyhow, it clearly showed that something had to happen with the way the regulations for financial institutions were organized. Therefore in response to the crisis, the BCBS started working on revised global standards, that eventually became known under Basel III. The BCBS claimed that Basel III will lead to a more stable financial system by enforcing a better quality of capital, stronger liquidity standards and an increased risk coverage.

For a more detailed and thorough description of Basel II, and all of its risk charge calculation methods, we refer the reader to the BIS documentation on Basel II [5].

## 2.3 Basel III

The financial crisis painfully brought to light that the current capital requirements under Basel II proved to be insufficient. More and more

banks found out they were exposed to risks that were not identified by Basel II. Therefore, in July 2009, the first supplement to Basel II was presented to provide a stronger framework.

In December 2009, the Basel Committee proposed to further improve the capital framework. Important topics of this proposal were:

- Increase the quality of capital.
- Improve the risk coverage of capital requirements.
- Introduction of a leverage ratio.
- Reducing procyclicality.
- Addressing systemic risk.

**Increase the quality of capital.** The crisis showed that only capital that is directly and fully available can be used to absorb unexpected losses. Unfortunately it turned out that not many banks had this strong and essential type of capital available. The Basel Committee therefore proposed that the majority of the banking capital should be of the highest quality. For listed companies this consists of share capital and retained earnings. For cooperatives like Rabobank, it consists of the earnings, the membership certificates or cooperative shares.

**Improving the risk coverage of capital requirements.** When a bank trades with options, futures, swaps and other derivatives, it also is exposed to the risk that the counterparties get downgraded. This risk appeared to be frighteningly real to parties such as Lehman Brothers, AIG and Bear Stearns. Part of the Basel proposals was therefore a new capital requirement for the risks that banks face when the creditworthiness of a counterparty deteriorates. Also, in the new proposals banks are stimulated to trade derivatives through central counterparties as much as possible. These parties provide netting of contracts in a standard way which reduces the systemic risk.

**Introduction of a leverage ratio.** The leverage ratio is the ratio between the balance sheet size and the amount of equity of a bank. The Basel Committee will set a maximum to this leverage ratio to prevent that a bank builds up excessive debt positions. After all this was one of the underlying causes of the crisis.

**Reducing procyclicality.** Capital requirements ensure that the bank has sufficient capital. However, these requirements also have a disadvantage, namely that when it goes bad with the economy, the risk of banks increases which forces banks to hold more equity. But thereby, banks will be able to grant less credits which leads to a strengthening of the economic slump. In good economic times, the risk lurks that too much credit is granted. The Basel Committee therefore proposed that the buildup of counter-cyclical buffers would be a good idea. This would connote that in good economic times, banks build up additional capital that can then be addressed in bad times.

**Addressing systemic risk.** Because of the fact that some banks are very large and interconnected to other banks and thus enormously important for a stable financial system, they are considered as 'too big too fail'. This can lead to a blind trust on the government, and take away all fear of taking more risk. The Basel Committee researched whether it is possible to make systemic banks hold additional capital.

**Impact of the new Basel proposals.** Because the new requirements provide a more stable banking sector, the new rules proposed were embraced by the authorities and politics.

The CRD directive mentioned earlier in the report is the tangible representation of these actions. All the recommendations and propositions that were made through time eventually led to the release of the Basel III document. The implementation of Basel III will start on January 1st, 2013.

But there are also comments. Because the capital requirement will increase significantly, all banks will start working on this capital buildup at the same time, which works price-raising. The costs of this will be passed on to customers. This can slow the growth of the global economy down thoroughly. A phased-in introduction of the requirements could diminish the effect of this.

Another question is whether banks will be able to pick up additional capital. Banks will have to make more profit to be an attractive option for potential investors. This is partly counteracted by the politically intervention, which tries to make the risk profile of banks more conservative and thus the profitability of banks will decrease. The question

is whether investors will still be willing to invest when bank returns will go down.

Finally, it is important to avoid that the new capital requirements will be seen as a synonym for a secure and stable financial system. Equity can naturally serve as a buffer against unexpected losses, but does nothing about the problems that lead to this unexpected losses.

The proposals made by the Basel Committee will lead to a more stable banking sector, as banks will be able to absorb losses better. However, there will be a lot of work for banks to find out how these rules should be implemented, to avoid undesirable side effects on the world economy.

The previous part made clear that Basel III was introduced because of the shortcomings of Basel II. Therefore it brings along stronger demands for banks in order to secure a stable, solvable and highly liquid bank. In order to achieve this, not only sharper capital demands are treated in the third Basel Accord, also new regulations are part of Basel III. The next sections will discuss the most important changes that Basel III introduces, together with the new liquidity rules it brings along.

### 2.3.1 Capital base

**Tightened Definition of Capital.** Before we will be able to tell something about the stronger capital ratios that Basel III introduces, it is necessary to gain more understanding of the tighter definition of capital. Where Basel II distinguished three types of Tier capital, Basel III brings this down to two types of Tier capital. This goes along with a new definition of what kind of capital can be qualified under which tier. Tier 1 can be split up into 'Common equity tier 1' and 'Additional tier 1' capital. Tier 1 and Tier 2 capital under Basel III look as follows:

#### *Common Equity Tier 1*

- Common shares issued by the bank.
- Stock surplus/share premium.
- Retained earnings.
- Accumulated other comprehensive income and other disclosed reserves.

- Common shares issued by consolidated subsidiaries of the bank and held by third parties.
- Non-controlling interests.

#### *Additional Tier 1 capital*

- Preference shares.
- Innovative Tier 1 securities.
- Tax on the excess of expected losses over provisions.

#### *Tier 2 capital*

- Term subordinated debt.
- Perpetual subordinated debt.
- Collective impairment provisions.
- Certain loan loss provisions.
- Revaluation reserves.
- Hybrid instruments.

**Higher capital ratios.** As mentioned earlier in the report, the recent financial crisis demonstrated that only high quality capital is useful to absorb unexpected losses. The tightened capital definition showed in the previous section helps to increase the amount of high quality capital. Because it would be too hard and sudden to introduce much stronger capital demands in a sudden, a phase-in process is used to slowly increase the capital demands. Through this way, banks will be able to work towards a more steady capital base that will make them more loss absorbing and therefore more reliable and stable in the future. The most important capital ratios are the CET 1 capital ratio and the Tier 1 capital ratio.

Table 2.2 shows how the phase-in process looks like. It also shows how much the capital ratios have changed compared to how they were in the previous Basel accord.

We observe that the minimum levels for the CET 1 and Tier 1 ratios have been raised to 4.5% and 6%, respectively. Figure 2.2 shows how this capital ratio transition looks like throughout the whole phase-in period. The 'total capital ratio' line in the figure includes (common equity) tier 1 capital, tier 2 capital and the capital conservation buffer.

Ratio	Year	Basel II	Basel III
CET 1 ratio	2012	2.0%	2.0%
	2013	2.0%	3.5%
	2014	2.0%	4.0%
	2015-2019	2.0%	4.5%
Tier 1 ratio	2012	4.0%	4.0%
	2013	4.0%	4.5%
	2014	4.0%	5.5%
	2015-2019	4.0%	6.0%

Table 2.2: Capital ratio's in BII and BIII

Common equity tier 1 ratio	Min. capital conservation ratio
4.5% - 5.125%	100%
5.125% - 5.75%	80%
5.75% - 6.375%	60%
6.375% - 7.0%	40%
> 7.0%	0%

Table 2.3: Individual bank min capital conservation standards

Ratio	Year	Basel II	Basel III
Capital conservation buffer	2012-2015	-	-
	2016	-	0.625%
	2017	-	1.250%
	2018	-	1.875%
	2019	-	2.500%
Countercyclical buffer	2012-2019	-	≤ 2.500%

Table 2.4: Capital buffers in BII and BIII

**Capital Conservation Buffer.** Outside of stress periods, banks should hold buffers of capital above the regulatory minimum. When buffers are down, banks can rebuild them through reducing discretionary distributions of earnings or by raising new capital from the private sector as an alternative. In addition, Basel III introduces the Capital Conservation Buffer of 2,5%, which should consist of CET 1 capital.

The distribution constraints imposed on banks when their capital levels fall into the range increase as the banks' capital levels approach the minimum requirements, as table 2.3 shows.

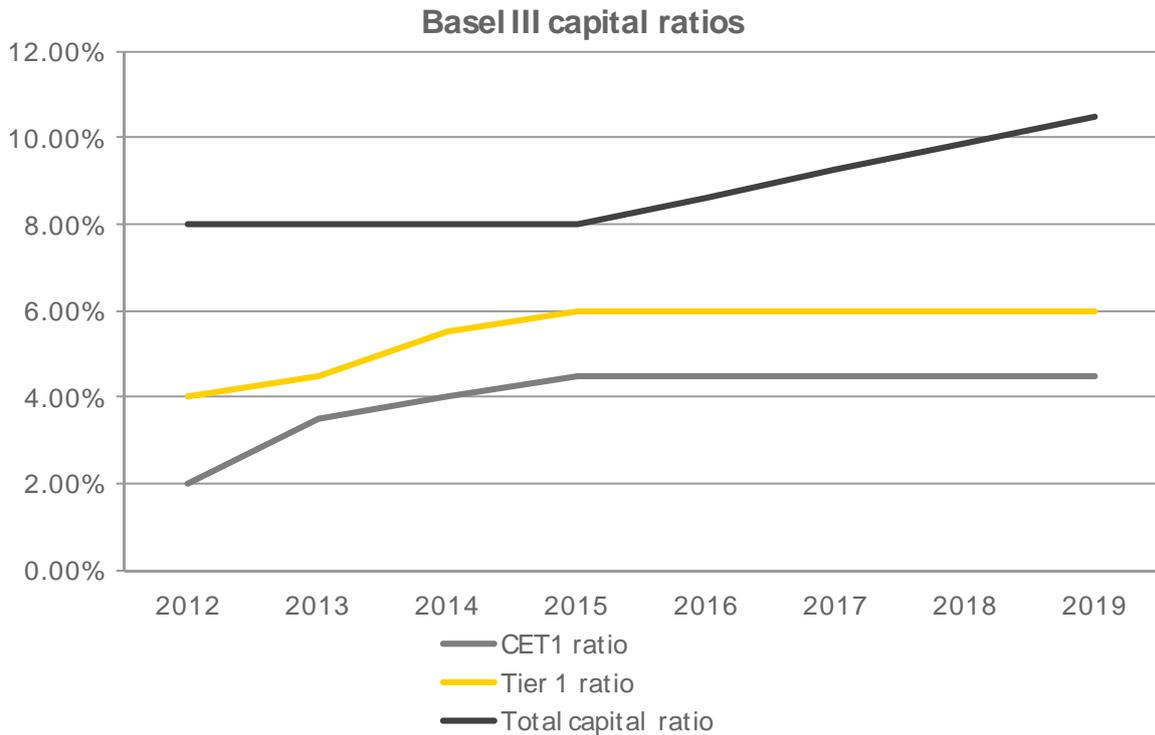


Figure 2.2: Phase-in process of the Basel III capital ratios

**Countercyclical Capital Buffer .** In times of financial downturn the risk of default and bankruptcy increases, and therefore banks are required to hold more capital. This also brings along that banks will provide less credit which stimulates the downturn even more. On the other hand, in times of economic boom, banks possibly provide too much credit. This process is visualized in figure 2.3. The BCBS stated that the main four reasons for introducing a countercyclical buffer are as follows:

- Dampening any excess cyclicity of the minimum capital requirement.
- Promoting more forward-looking provisions.
- Conserving capital to build buffers at individual banks and the banking sector to be used in times of stress.

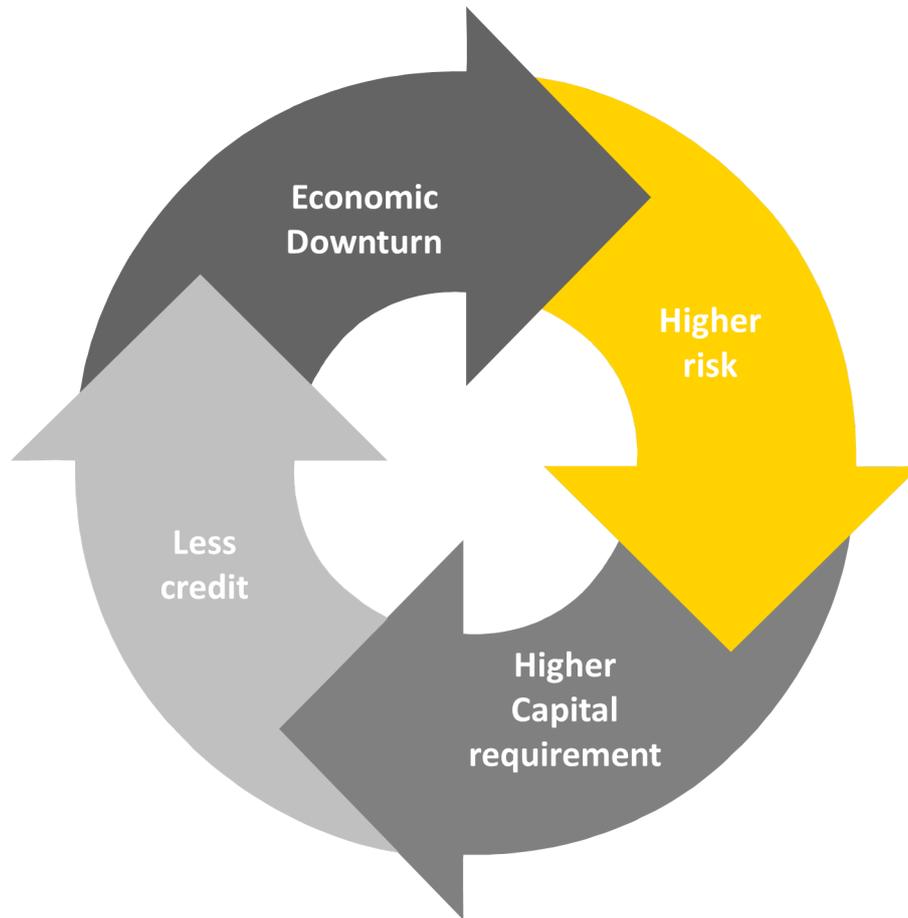


Figure 2.3: Countercyclicity

- Achieving the broader macro prudential goal of protecting the banking sector from periods of excess credit growth.

See table 2.4 for an overview of the countercyclical and capital conservation buffer, as treated in Basel II and Basel III. A more thorough description of the Basel III capital base and related things can be found in the Basel III accord [1].

### 2.3.2 Leverage

The Basel Committee will introduce a leverage ratio as a supplementary measure to the Basel II risk-based framework. The leverage ratio measures the ratio between the size of the balance sheet and the capital

held, where no risk-weighting is applied. With the proposed calibration of 3%, the leverage ratio will help to contain the build up of excessive leverage in the banking system. It will also introduce additional safeguards against attempts to game the risk based requirements, and help to address model risk. It could be called a function as a backstop for the risk-weighted requirements.

**Introduction of a leverage ratio.** The transition phases of the adoption of the leverage ratio are as follows:

*Monitoring (starting January 1st 2012)*

Monitoring period will focus on developing templates which can be used to determine components of the leverage ratio in a consistent way.

*Testing (starting January 1st 2013)*

Testing period will be used to analyze the desirability of the effect of the leverage ratio on on specific internal models and the relation with the risk-weighted capital requirements.

*Adjusting (starting January 1st 2017)*

In the adjustment period, some possible adjustments will be made and there will be worked towards a Pillar I implementation in January 2018.

*Implementation (starting January 1st 2018)*

Scheduled implementation.

It has to be mentioned that there is still a lot of uncertainty on how the leverage ratio implementation will exactly look like. There is a lot of discussion going on about whether the leverage ratio as it is planned now will work the way it should. These discussions hope to track down flaws in the current set-up of the introduction of a leverage ratio. The necessity of the ratio is not a point of discussion though, since it is considered as something of big importance for the contribution to a stable financial system in the coming years.

### 2.3.3 Liquidity

Liquidity risk is inseparably linked with the transformation function of banks: raise funds with short maturities (e.g. savings) and convert

them into long-term loans (e.g. mortgages). During the most recent crisis, financial markets faced large shortages of liquidity. Therefore, the BIS requires an individual bank to apply more stringent standards to reflect that bank's liquidity risk profile.

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

**LCR.** The LCR aims to ensure that a bank maintains an adequate level of unencumbered, high-quality liquid assets that can be converted into cash to meet its liquidity needs for a 30 calendar day time horizon under a significantly severe liquidity stress scenario specified by supervisors. At a minimum, the stock of liquid assets should enable the bank to survive until day 30 of the stress scenario. After 30 days, it is assumed that appropriate corrective actions can be taken by management and/or supervisors, and/or the bank.

Highly liquid assets is a quite ambiguous term when considered out of context. As Basel III introduced the LCR and all its corresponding definitions, it is helpful to show how Basel III [1] characterizes high quality liquid assets:

*Fundamental characteristics*

- **Low credit and market risk:** assets that are less risky tend to have higher liquidity. High credit standing of the issuer and a low degree of subordination increases an asset's liquidity. Low duration, low volatility, low inflation risk and denomination in a convertible currency with low foreign exchange risk all enhance an asset's liquidity.
- **Ease and certainty of valuation:** an asset's liquidity increases if market participants are more likely to agree on its valuation. The pricing formula of a high quality liquid asset must be easy to calculate and not depend on strong assumptions. The inputs into the pricing formula must also be publicly available. In practice, this should rule out the inclusion of most structured or exotic products.

- **Low correlation with risky assets:** the stock of high-quality liquid assets should not be subject to wrong-way (highly correlated) risk. For example, assets issued by financial institutions are more likely to be illiquid in times of liquidity stress in the banking sector.
- **Listed on a developed and recognized exchange market:** being listed increases an asset's transparency.

*Market-related characteristics:*

- **Active and sizable market:** the asset should have active outright sale or repurchase agreement (repo) markets at all times (which means having a large number of market participants and a high trading volume). There should be historical evidence of market breadth (price impact per unit of liquidity) and market depth (units of the asset that can be traded for a given price impact).
- **Presence of committed market makers:** quotes will most likely be available for buying and/or selling a high-quality liquid asset.
- **Low market concentration:** a diverse group of buyers and sellers in an asset's market increases the reliability of its liquidity.
- **Flight to quality:** historically, the market has shown tendencies to move into these types of assets in a systemic crisis.

This desired adequate liquidity level is trying to be achieved by introducing the liquidity coverage ratio, that looks as follows:

$$\frac{\text{Stock of high quality liquid assets}}{\text{Net cash outflows over a 30 day period}} \geq 100\% \quad (2.7)$$

For more specific information, we refer the reader to the Basel III BIS document that is specially made for liquidity risk measurement, standards and monitoring [2].

**NFSR.** To promote more medium and long-term funding of the assets and activities of banking organizations, the Committee has developed the Net Stable Funding Ratio (NSFR). This metric establishes a minimum acceptable amount of stable funding based on the liquidity characteristics of an institution's assets and activities over a one year

horizon. The NSFR is defined as the available amount of stable funding, divided by the amount of required stable funding. This ratio must be greater than 100%.

Basel III [2] identifies the main objective of the NSFR as follows:

To promote more medium and long-term funding of the assets and activities of banking organizations, the Committee has developed the NSFR. This metric establishes a minimum acceptable amount of stable funding based on the liquidity characteristics of an institution's assets and activities over a one year horizon. This standard is designed to act as a minimum enforcement mechanism to complement the LCR and reinforce other supervisory efforts by promoting structural changes in the liquidity risk profiles of institutions away from short-term funding mismatches and toward more stable, longer-term funding of assets and business activities.

In particular, the NSFR standard is structured to ensure that long term assets are funded with at least a minimum amount of stable liabilities in relation to their liquidity risk profiles. The NSFR aims to limit over-reliance on short-term wholesale funding during times of buoyant market liquidity and encourage better assessment of liquidity risk across all on- and off-balance sheet items. In addition, the NSFR approach offsets incentives for institutions to fund their stock of liquid assets with short-term funds that mature just outside the 30-day horizon for that standard.

The NSFR looks as follows:

$$\frac{\text{Available amount of stable funding}}{\text{Required amount of stable funding}} \geq 100\% \quad (2.8)$$

Where stable funding is defined as follows:

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

- The portion of wholesale funding with maturities of less than a year that is expected to stay with the institution for an extended period in an idiosyncratic stress event.

Also for more specific information about NSFR, we refer the reader to the Basel III BIS document that is specially made for liquidity risk measurement, standards and monitoring [2].

## Chapter 3

# Modeling the BS

There has been much published on strategic balance sheet management and the modeling of balance sheets in a smart way. A quite recent work that treats a very similar subject to this report's one was written by Kruger [13]. The paper proposes a multi-objective approach to move from the current balance sheet to the 'optimal' balance sheet, whilst taking Basel Pillars 1 and 2 regulatory capital limits into account. A somewhat older but very interesting work that discusses a linear programming approach for bank balance sheet management is covered in the following paper [10].

This report describes the modeling of a stylized balance sheet, where the goal is to maximize profit for a bank given the Basel III constraints it has to be compliant to. This is done by using a smart optimization technique that will be described in chapter four. As regards the scope of the problem, the type of bank that is modeled is a non-investment bank that has its main operations in the retail sector. This means the stylized balance sheet will not include derivative instruments, and will have the largest exposure in instruments that concern products intended for the retail market.

Synchronously with the modeling, a bank balance sheet optimization tool was developed during the internship period, that can be used as a decision support system in banks. It is a user-friendly customizable tool that uses default starting values and gives the user the opportunity to input a large number of parameters, properties and other things in order to calibrate the tool as much as possible. By doing this, the tool is being set up in a way that it fits the profile and preferences of

the bank that it attempts to model and optimize. The tool was built in excel, using VBA, Crystal Ball and Solver, which are very necessary elements that made it possible to program the tool exactly the way that is desired for this problem. Crystal Ball provided an optimization environment that was set up in such a way that the tool is able to find the best balance sheet composition given the profile, preferences, strategy and other properties of a bank.

This chapter describes how the balance sheet was modeled. This also includes the modeling of a risk profile in the tool, the inclusion of a penalty function to preserve the feasibility of the tool, a description of how stochasticity is used to capture volatility and uncertainty in time, and some words on how the regulations were formalized. This chapter hereby attempts to show how modeling the thesis problem in this way makes it possible to develop a tool that can be very useful for strategic balance sheet management, especially at the time being where many banks have no clearly developed plan on how to deal with Basel III. The tool developed is a strategic level decision supportive program that can be used to advise banks on what direction for their balance sheet would be best to choose, given the incorporated endogenous and partially exogenous variables. We will start with describing the various components of the model.

### **3.1 Components of the model**

Since the model is so extensive, it is necessary to cut it in to pieces in order to secure a structural way of describing the model. Therefore, this section describes the many components the model exists of. The tool described earlier is the tangible reflection of the model, since it contains all the components of the model, together with the possibility to optimize this model. Since the structure of the model is mostly shaped by the structure of the tool, we will hold on to this structure when describing the model.

The most important and central part of the thesis problem is of course the balance sheet (section 3.1.1). The goal is to optimize the composition of the balance sheet, in order to maximize profits under Basel III, keeping in mind the risk profile, strategic goals and other preferences and properties of the bank that are being optimized. The exact composition of each asset and liability type is also specified and can be

modified in the model (section 3.1.2), together with the current different types of capital the bank possesses (section 3.1.4). The expected income and expenses are discussed as well (section 3.1.5). In this model, we define a stylized balance sheet, representing a non-investment retail bank, and input all relevant parameters, choices and preferences of the bank (section 3.1.3), and run the optimization. The expected growth/decline of each BS position (section 3.1.6) and its corresponding risk weights (section 3.1.7) can also be entered by the user.

With regard to regulation, the bank has to deal with the imposed Basel III constraints, which have to be formalized in the model (section 3.2). Because the balance sheet is inseparably interconnected with the bank's risk profile, a clear and thorough representation of this profile is incorporated in to the model (section 3.3). Then, a bank deals with a lot of uncertainty and volatility, and therefore the model has to find a way to represent this uncertainty of certain parameters in time as good as possible. This is done by the inclusion of stochasticity (section 3.4). By taking in to account all these important things, the model and tool will represent reality very closely, and therefore will support a bank's management in taking important decisions on what direction the bank has to follow. This is a smart substantiated way of strategically managing your balance sheet.

### 3.1.1 The balance sheet

The balance sheet composition is the central part of the thesis subject, since it is the element that is being optimized. This section includes the formalization of the stylized balance sheet positions. Figure 3.1 shows the stylized balance that is used in the model.

The total assets exposure looks as follows:

$$\begin{aligned}
 X_{AssetsTotal} = & X_{Cash}(T) + X_{RetMort}(T, m_i) \\
 & + X_{LoansAdv}(T, t_i, m_i) + X_{OtherRec}(T, t_j, m_i) \\
 & + X_{GovBonds}(T, m_i, c_i) + X_{CorpBonds}(T, m_i, c_i)
 \end{aligned} \tag{3.1}$$

with

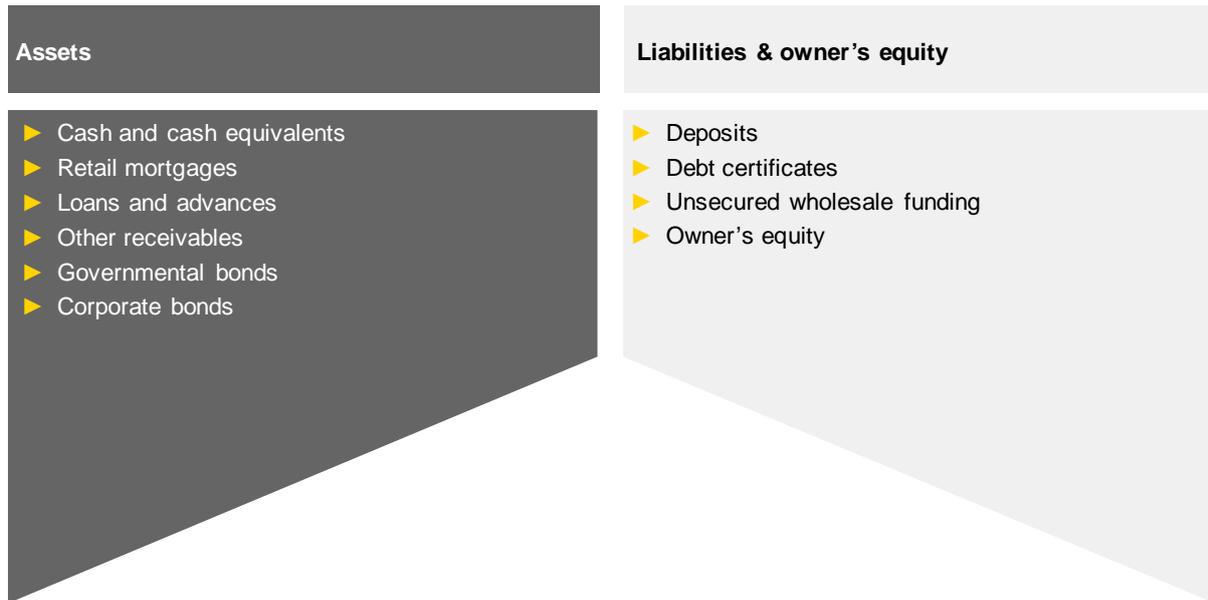


Figure 3.1: The stylized balance sheet

$X_{Cash}(T)$	Cash and cash equivalents exposure
$X_{RetMort}(T, m_i)$	Retail mortgages exposure
$X_{LoansAdv}(T, m_i)$	Loans and advances exposure
$X_{OtherRec}(T, t_j, m_i)$	Other receivables exposure
$X_{GovBonds}(T, m_i, c_i)$	Government bonds exposure
$X_{CorpBonds}(T, m_i, c_i)$	Corporate bonds exposure
$m_i$	Maturity of the position of length i
$t_i$	Type of the position of type i
$t_j$	Type of the position of type j
$c_i$	Credit rating of the position of rating i
$T$	Year

The type of maturities ( $m_i$ ), types ( $t_i$ ), types ( $t_j$ ) and credit ratings ( $c_i$ ) will be discussed more specifically in section 3.1.2.

An important part of balance sheet management is the banks strategy of how the balance sheet roughly looks like. This means that the bank has its ideas on how big each position should be, in other words between which two bounds should the total exposure of a certain position be. Therefore banks specify a left and a right bound that defines the minimum and maximum exposure of a certain position. By doing this, a bank steers its strategy by regulating on what type of exposure

with its corresponding risk a bank wants to lay its focus, and what positions should be smaller. In the model, these caps and floors for the asset side of the balance sheet are defined as follows:

$$\begin{aligned}
X_{Cash}^{MIN} &\leq X_{Cash} \leq X_{Cash}^{MAX} \\
X_{RetMort}^{MIN} &\leq X_{RetMort} \leq X_{RetMort}^{MAX} \\
X_{LoansAdv}^{MIN} &\leq X_{LoansAdv} \leq X_{LoansAdv}^{MAX} \\
X_{OtherRec}^{MIN} &\leq X_{OtherRec} \leq X_{OtherRec}^{MAX} \\
X_{GovBonds}^{MIN} &\leq X_{GovBonds} \leq X_{GovBonds}^{MAX} \\
X_{CorpBonds}^{MIN} &\leq X_{CorpBonds} \leq X_{CorpBonds}^{MAX}
\end{aligned}$$

The total liabilities exposure looks as follows:

$$\begin{aligned}
X_{LiabilitiesTotal} &= X_{Dep}(T, s_i, m_i) + X_{DebtCer}(T, m_i) \\
&\quad + X_{UnsWF}(T, s_i, t_k, m_i)
\end{aligned} \tag{3.2}$$

with

$X_{Dep}(T, s_i, m_i)$	Deposits exposure
$X_{DebtCer}(T, m_i)$	Debt certificates exposure
$X_{UnsWF}(T, s_i, t_k, m_i)$	Unsecured wholesale funding exposure
$s_i$	Stability of the position of stability i
$m_i$	Maturity of the position of length i
$t_k$	Type of the position of type k
$T$	Year

The type of stabilities ( $s_i$ ), maturities ( $m_i$ ) and credit types ( $t_k$ ) will be discussed more specifically in the next section.

In the model, the caps and floors for the liability & equity side of the balance sheet are defined as follows:

$$\begin{aligned}
X_{Dep}^{MIN} &\leq X_{Dep} \leq X_{Dep}^{MAX} \\
X_{DebtCer}^{MIN} &\leq X_{DebtCer} \leq X_{DebtCer}^{MAX} \\
X_{UnsWF}^{MIN} &\leq X_{UnsWF} \leq X_{UnsWF}^{MAX}
\end{aligned}$$

### 3.1.2 Assets & Liabilities composition

The previous section introduced the model's stylized balance sheet. This section specifies the composition of the assets and liabilities, in order to see how the stylized products look like when we cut them in to parts according to their maturities, credit ratings and stability level. The  $m_i$ ,  $t_i$ ,  $c_i$  and  $s_i$  parameters introduced in the previous section are necessary to distinguish the properties of the asset and liability positions. The maturity classes ( $m_i$ ), the credit rating types ( $c_i$ ) and the stability levels ( $s_i$ ) are the same for each of the positions, and is therefore described once. The type ( $t_i$ ) differs, and therefore we will describe the  $t_i$  parameter separately for the different position the parameter applies to.

The following positions contain a maturity component:

$$X_{RetMort}(T, m_i), X_{LoansAdv}(T, t_i, m_i), X_{OtherRec}(T, t_j, m_i), X_{GovBonds}(T, m_i, c_i), X_{CorpBonds}(T, m_i, c_i), X_{Dep}(T, s_i, m_i), X_{DebtCer}(T, m_i) \text{ and } X_{UnsWF}(T, s_i, t_k, m_i).$$

with

$$m_i \quad \text{Maturity of type } i, \quad i = \left\{ \begin{array}{l} \leq 1 \text{ month} \\ 1 \text{ month} - 3 \text{ month} \\ 3 \text{ months} - 1 \text{ year} \\ 1 \text{ year} - 5 \text{ years} \\ > 5 \text{ years} \end{array} \right\}$$

The following positions contain a credit rating component:

$$X_{GovBonds}(T, t, m_i) \text{ and } X_{CorpBonds}(T, (m_i, c_i))$$

with

$$c_i \quad \text{Credit rating of type } i, \quad i = \left\{ \begin{array}{l} AAA \\ AA \\ A \\ BBB \\ \text{Below } BBB \end{array} \right\}$$

The following positions contain a stability level component:

$$X_{Dep}(T, s_i, m_i) \text{ and } X_{UnsWF}(T, s_i, t_i, m_i)$$

with

$$s_i \quad \text{Stability level of type } i, \quad i = \left\{ \begin{array}{l} \text{Stable} \\ \text{Less stable} \end{array} \right\}$$

Now we have covered the BS position properties that have the same vector for all positions it applies to, we will cover the fourth component, where each of the positions it applies to, has a different vector. There are three BS positions that contain a type component.

The three positions with a type component are:

$$X_{LoansAdv}(T, t_i, m_i), X_{OtherRec}(T, t_j, m_i) \text{ and } X_{UnsWF}(T, s_i, t_k, m_i)$$

with

$$\begin{array}{ll}
 t_i & \text{Position type } i, \\
 t_j & \text{Position type } j, \\
 t_k & \text{Position type } k,
 \end{array}
 \quad
 \begin{array}{l}
 i = \left\{ \begin{array}{l} \text{Retail loans} \\ \text{Corporate loans} \\ \text{Loans to financial institutions} \end{array} \right\} \\
 j = \left\{ \begin{array}{l} \text{Non fin. wholesale counterparties} \\ \text{Financial institutions} \end{array} \right\} \\
 k = \left\{ \begin{array}{l} \text{Small business customers} \\ \text{Small corporate wholesale} \\ \text{Large corporate wholesale} \\ \text{Financial institutions} \end{array} \right\}
 \end{array}$$

### 3.1.3 The input

Figure 3.2 shows the main input parameters of the model, besides the most important input covered in the previous section: the balance sheet. The tool gives the user the opportunity to choose values for all these parameters, to fit the model to the bank's preferences and properties. In the tool, all these input parameters are collected on one sheet, which makes it very user friendly, therefore the user does not have to browse through the whole excel document and find the right places for inputting the parameters and preferences.

This section will show how these parameters are modeled. We will follow the yellow boxes in figure 3.2, chronologically from left to right.

**Choosing a starting BS date.** The user of the tool has to set the year, on which it wants to optimize the balance sheet. The model distinguishes the following possible starting years:

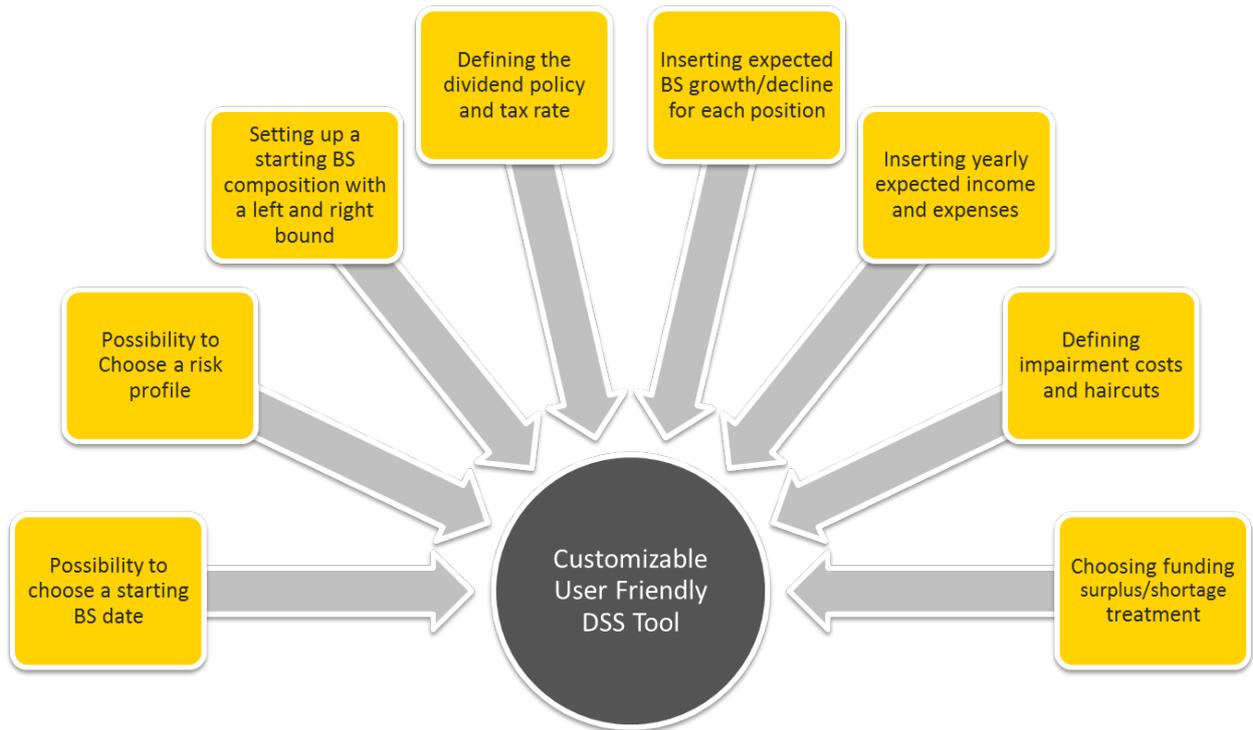


Figure 3.2: The main input parameters of the model

$$T_t \quad \text{Starting balance sheet year } t, \quad t = \left. \begin{array}{c} 2012 \\ 2013 \\ 2014 \\ 2015 \\ 2016 \\ 2017 \\ 2018 \\ 2019 \end{array} \right\}$$

These dates were chosen due to the fact that in this period, the Basel III constraints will change (phase-in process).<sup>1</sup> After 2019, there will not be any increase in the constraints. This means if one wants to optimize the balance sheet for a year after 2019, the user simply has to select 2019.

**Choosing a risk profile.** As the risk profile requires more explanation before we can move on to the notation and formulation, a separate

<sup>1</sup>For the sequel of the report, by year ' $t$ ', it is meant as defined at the beginning of section 3.1.3.

section is devoted to this input component, namely section 3.3.

**Choosing a starting BS with left and right position bounds.** This input component was treated thoroughly in section 3.1.1. The reader that wants to consult this is therefore referred to the second last section.

**Choosing a dividend policy and tax rate.** Each bank has its own dividend policy. We could define this as follows:

**Definition.** The dividend policy is something a company uses to decide how much it will pay out to shareholders in dividends. Once the company decides on whether to pay dividends they may establish a somewhat permanent dividend policy, which may in turn impact on investors and perceptions of the company in the financial markets. What they decide depends on the situation of the company now and in the future. It also depends on the preferences of investors and potential investors.

Besides the dividend policy, the bank deals with a fixed tax rate, that determines how much percent of the retained profits has to be handed in to the authorities, and how much will be left. The dividend policy tells what to do with the amount left. These two components are modeled as follows:

$$\begin{array}{ll} \delta_t & \text{Percentage paid to stockholders in year } t, \\ \vartheta_t & \text{Percentage written to ret. profit in year } t, \\ \tau_t & \text{Tax rate in year } t, \end{array} \quad \delta_t + \vartheta_t = 1$$

**Choosing expected BS positions growth/decline.** Since the model contains a time aspect that makes sure the Basel constraints of the coming years are also accounted for, we are dealing with a balance sheet that evolves over time. In order to correctly model this balance sheet transition in time, the user needs to input an expected growth or decline for each of the balance sheet positions. The input sheet of the tool provides this possibility.

The balance sheet position's growth/decline parameters also can be made stochastic if wanted by making the parameters normally distributed and attaching a desired standard deviation to it in order to

represent uncertainty in time. This stochastic part of the model will be treated in section 3.4. For now, we will show the model notation for the growth/decline parameters for each position.

For the asset side of the balance sheet, the growth/decline notation looks as follows:

$g(X_{RetMort})_t$	Percentage of new retail mortgages in year $t$
$d(X_{RetMort})_t$	Percentage of retail mortgages attrition in year $t$
$g(X_{LoansAdv})_t$	Percentage of new loans and advances in year $t$
$d(X_{LoansAdv})_t$	Percentage of loans and advances attrition in year $t$
$g(X_{OtherRec})_t$	Percentage of new other receivables in year $t$
$d(X_{OtherRec})_t$	Percentage of other receivables attrition in year $t$
$g(X_{GovBonds})_t$	Percentage of new government bonds in year $t$
$d(X_{GovBonds})_t$	Percentage of government bonds attrition in year $t$
$g(X_{CorpBonds})_t$	Percentage of new corporate bonds in year $t$
$d(X_{CorpBonds})_t$	Percentage of corporate bonds attrition in year $t$

For the liability side of the balance sheet, the growth/decline notation looks as follows:

$g(X_{Dep})_t$	Percentage of new deposits in year $t$
$d(X_{Dep})_t$	Percentage of deposits attrition in year $t$
$g(X_{DebtCer})_t$	Percentage of new debt certificates in year $t$
$d(X_{DebtCer})_t$	Percentage of debt certificates attrition in year $t$
$g(X_{UnsWF})_t$	Percentage of new uns. wholesale funding in year $t$
$d(X_{UnsWF})_t$	Percentage of uns. wholesale funding attrition in year $t$

**Choosing expected income and expenses.** The income and expenses a bank occurs are reported on the profit & loss account. The user of the tool can input an expected amount for each separate income and loss component of the P&L account. Also these components can be set stochastic if wanted, more on that in section 3.4.

The notation for the income components in the model looks as follows:

$m^{INC}(X_{RetMort})_t$	Interest income on retail mortgages in year $t$
$m^{INC}(X_{LoansAdv})_t$	Interest income on loans and advances in year $t$
$m^{INC}(X_{OtherRec})_t$	Interest income on other receivables in year $t$
$m^{INC}(X_{GovBonds})_t$	Interest income on government bonds in year $t$
$m^{INC}(X_{CorpBonds})_t$	Interest income on corporate bonds in year $t$
$F^{INC}_t$	Fee and commission income in year $t$
$O^{INC}_t$	Other operating income in year $t$

The notation for the expenses components in the model looks as follows:

$m^{EXP}(X_{Dep})_t$	Interest expense on deposits in year $t$
$m^{EXP}(X_{DebtCer})_t$	Interest expense on debt certificates in year $t$
$m^{EXP}(X_{UnsWF})_t$	Interest expense on uns. wholesale funding in year $t$
$F^{EXP}_t$	Fee and commission expense in year $t$
$O^{EXP}_t$	Other operating expense in year $t$
$D^{EXP}_t$	Depreciation and amortization of fixed assets in year $t$
$S^{EXP}_t$	Staff costs in year $t$

**Choosing impairment costs and haircuts.** Two other important input components are the expected impairment costs and the expected haircuts. They are defined as follows:

**Definition.** A special, nonrecurring charge taken to write down an asset with an overstated book value. Generally an asset is considered to be value-impaired when its book value exceeds the future net cash flows expected to be received from its use. An impairment write-down reduces an overstated book value to fair value.

With regard to the impairment costs; they apply to three of the positions of the asset side of the balance sheet, namely:

$$X_{RetMort}(T, m_i), X_{LoansAdv}(T, t_i, m_i), X_{OtherRec}(T, t_j, m_i)$$

In the model, they are represented as follows:

$l(X_{RetMort})$	Loan impairment percentage of retail mortgages
$l(X_{LoansAdv})$	Loan impairment percentage of loans and advances
$l(X_{OtherRec})$	Loan impairment percentage of other receivables

**Definition.** The difference between prices at which a market maker can buy and sell a security. In other words, the percentage by which an asset's market value is reduced for the purpose of calculating capital requirement, margin and collateral levels.

With regard to the haircuts; they apply to three of the positions of the asset side of the balance sheet, namely:

$$X_{GovBonds}(T, t, m_i) \text{ and } X_{CorpBonds}(T, m_i, c_i)$$

In the model, they are represented as follows:

$\kappa(X_{GovBonds})$	Applied haircut percentage on government bonds
$\kappa(X_{CorpBonds})$	Applied haircut percentage on corporate bonds

**Choosing funding surplus/shortage treatment.** Every year, a funding shortage or surplus might arise. The model also gives the user the opportunity to choose what happens with this surplus or shortage of funding. Suppose at some year, a bank attracts more funding than it can set out in assets. This means it has to attribute this surplus to its balance sheet. It can choose how much of this amount is hold as cash reserve and how much gets set out as a government bond. In the case a shortage of funding arises, the bank has to decide whether the shortage is absorbed by cash or by government bonds. This input component provides room for this preference. It is modeled as follows:

$\zeta$	Perc. absorbed by/attribution to cash	$\zeta + v = 1$
$v$	Perc. absorbed by/attribution to government bonds	
$f_t$	Funding surplus/shortage in year $t$	

### 3.1.4 Capital

Another input component not included in figure 3.2 is the input of the capital of the bank. Because we are dealing with a stylized, the capital definition is also modeled in a stylized way. Therefore we distinguish the following capital types in the model:

- **Common equity tier 1 capital:** Existing of starting core capital and retained earnings that are added to this group each year.
- **Additional tier 1 capital:** Each year, an expected growth and deduction percentage determine the additional tier 1 capital growth / decline.
- **Tier 2 capital:** Each year, an expected growth and deduction percentage determine the tier 2 capital growth / decline.

The user specifies the starting amount of each of the three groups, and the corresponding expected growth and deduction percentages. For the CET 1 capital, the earnings determine the growth/decline of the core capital. This looks as follows:

$C_{CET1_t}$	Amount of common equity tier 1 capital in year $t$
$C_{AddT1_t}$	Amount of additional tier 1 capital in year $t$
$C_{T2_t}$	Amount of tier 2 capital in year $t$
$g(C_{AddT1})_t$	Expected additional tier 1 capital growth perc. in year $t$
$d(C_{AddT1})_t$	Expected additional tier 1 capital decline perc. in year $t$
$g(C_{T2})_t$	Expected tier 2 capital growth perc. in year $t$
$d(C_{T2})_t$	Expected tier 2 capital decline perc. in year $t$

### 3.1.5 P&L account

On the profit and loss account, the retained profit is calculated. They result from the income and expenses, and of course the tax rate and dividend pay out percentage influences how much remains for reinvestment in the balance sheet. This section shows how earlier introduced notation results in the amount of retained profit.

The income calculation looks as follows:

$$I_t = m^{INC}(X_{RetMort})_t + m^{INC}(X_{LoansAdv})_t + m^{INC}(X_{OtherRec})_t \\ + m^{INC}(X_{GovBonds})_t + m^{INC}(X_{CorpBonds})_t + F^{INC}_t + O^{INC}_t$$

The expenses calculation looks as follows:

$$E_t = m^{EXP}(X_{Dep})_t + m^{EXP}(X_{DebtCer})_t + m^{EXP}(X_{UnsWF})_t \\ + F^{EXP}_t + O^{EXP}_t + D^{EXP}_t + S^{EXP} \\ + \iota(X_{RetMort}) * X_{RetMort}(T) + \iota(X_{LoansAdv}) * X_{LoansAdv}(T) \\ + \iota(X_{OtherRec}) * X_{OtherRec}(T) \\ + \kappa(X_{GovBonds}) * X_{GovBonds}(T) + \kappa(X_{CorpBonds}) * X_{CorpBonds}(T)$$

Therefore the retained profit in year  $t$  looks as follows:

$$RP_t = \vartheta_t * [(1 - \tau_t) * (I_t - E_t)] \quad (3.3)$$

### 3.1.6 Risk weighted assets

The RWA is not modeled as an input, but the user has the possibility to choose a value for the RWA factor for each position. For now, the standard method is used to calculate the RWA, but it can be easily modified to an internal approach when desired. This section shows how the RWA factors are chosen for each asset position:

$RWA_t(X_{Cash})$	RWA factor for cash in year $t$
$RWA_t(X_{RetMort})$	RWAfactor for ret. mortgages in year $t$
$RWA_t(X_{LoansAdv})$	RWAfactor for loans and advances in year $t$
$RWA_t(X_{OtherRec})$	RWAfactor for other receivables in year $t$
$RWA_t(X_{GovBonds})$	RWAfactor for gov. bonds in year $t$
$RWA_t(X_{CorpBonds})$	RWAfactor for corp. bonds in year $t$

For the first four, the standard approach percentage is assigned to the factor. For exposure that is composed of multiple credit rating groups (government bonds and corporate bonds), the percentages are calculated as follows:

$$\begin{aligned}
 RWA_t(X_{GovBonds}) = & 0.0 * X_{GovBonds}(T, m_i, AAA) & (3.4) \\
 & +0.0 * X_{GovBonds}(T, m_i, AA) \\
 & +0.2 * X_{GovBonds}(T, m_i, A) \\
 & +0.5 * X_{GovBonds}(T, m_i, BBB) \\
 & +1.0 * X_{GovBonds}(T, m_i, Below B)
 \end{aligned}$$

$$\begin{aligned}
 RWA_t(X_{CorpBonds}) = & 0.2 * X_{CorpBonds}(T, m_i, AAA) & (3.5) \\
 & +0.2 * X_{CorpBonds}(T, m_i, AA) \\
 & +0.5 * X_{CorpBonds}(T, m_i, A) \\
 & +1.0 * X_{CorpBonds}(T, m_i, BBB) \\
 & +1.5 * X_{CorpBonds}(T, m_i, Below B)
 \end{aligned}$$

Given the notation above, the total RWA in year  $t$  can be calculated as follows:

$$\begin{aligned}
RWA_t(Total) &= RWA_t(X_{Cash}) + RWA_t(X_{RetMort}) & (3.6) \\
&+ RWA_t(X_{LoansAdv}) + RWA_t(X_{OtherRec}) \\
&+ RWA_t(X_{GovBonds}) + RWA_t(X_{CorpBonds})
\end{aligned}$$

### 3.1.7 Balance sheet transition

The model contains a time-line, which shows the development of the balance sheet through time. More specifically, it shows the transition of the balance sheet from the chosen starting balance sheet year till seven years later. So taking 2012 as a starting year, the user of the tool can optimize the current balance sheet in order to maximize return on equity this year under the Basel III constraints of the next 7 years, given the expected growth/decline of the balance sheet as explained in section 1.3.

Now that we have showed the notation of the input parameters, we will be able to show how the transition of the balance sheet looks like from year ' $t - 1$ ' to year  $t$ . The components that make the balance sheet change are:

- The expected growth/decline percentages for each BS position.
- The expected growth/decline percentage of the capital
- The funding surplus/shortage
- The retained profit (or loss).

Therefore the transition on the asset side of the balance sheet for the different positions looks as follows:

$$\begin{aligned}
X_{Cash}(T) &= X_{Cash}(T - 1) + \zeta * f_t \\
X_{RetMort}(T) &= [1 + g(X_{RetMort})_t - d(X_{RetMort})_t] * X_{RetMort}(T - 1) \\
X_{LoansAdv}(T) &= [1 + g(X_{LoansAdv})_t - d(X_{LoansAdv})_t] * X_{LoansAdv}(T - 1) \\
X_{OtherRec}(T) &= [1 + g(X_{OtherRec})_t - d(X_{OtherRec})_t] * X_{OtherRec}(T - 1) \\
X_{GovBonds}(T) &= [1 + g(X_{GovBonds})_t - d(X_{GovBonds})_t] * X_{GovBonds}(T - 1) + v * f_t \\
X_{CorpBonds}(T) &= [1 + g(X_{CorpBonds})_t - d(X_{CorpBonds})_t] * X_{CorpBonds}(T - 1)
\end{aligned}$$

The transition on the liability side of the balance sheet for the different positions looks as follows:

Basel constraint	2012	2013	2014	2015	2016	2017	2018	2019
Leverage ratio	0.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
CET 1 ratio	2.0%	3.5%	4.0%	4.5%	4.5%	4.5%	4.5%	4.5%
Tier 1 ratio	4.0%	4.5%	5.5%	6.0%	6.0%	6.0%	6.0%	6.0%
Total capital ratio	8.0%	8.0%	8.0%	8.0%	8.625%	9.25%	9.875%	10.5%
LCR	0.0%	0.0%	0.0%	100%	100%	100%	100%	100%
NSFR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	100%

Table 3.1: Basel III constraints in a time-line

$$\begin{aligned}
 X_{Dep}(T) &= [1 + g(X_{Dep})_t - d(X_{Dep})_t] * X_{Dep}(T - 1) \\
 X_{DebtCer}(T) &= [1 + g(X_{DebtCer})_t - d(X_{DebtCer})_t] * X_{DebtCer}(T - 1) \\
 X_{UnsWF}(T) &= [1 + g(X_{UnsWF})_t - d(X_{UnsWF})_t] * X_{UnsWF}(T - 1)
 \end{aligned}$$

As regards the owners equity, the transition looks as follows:

$$\begin{aligned}
 OE_t &= C_{CET1_{t-1}} + [g(C_{AddT1})_{t-1} - d(C_{AddT1})_{t-1}] * C_{AddT1_{t-1}} \\
 &\quad + [g(C_{T2})_{t-1} - d(C_{T2})_{t-1}] * C_{T2_{t-1}} + RP_{t-1}
 \end{aligned} \tag{3.7}$$

## 3.2 BIII constraints formalization

In order to be compliant to the Basel III constraints, they need to be formalized. This section shows how the incorporated ratios are modeled. The Basel III ratios that apply to the model were discussed in section 2.3. Table 3.1 summarizes the required ratio of all constraints at the moment the phase-in process has fully completed. The values in the table therefore show where to banks need to work as regards regulation. The notation of the different ratios will be discussed here.

**Leverage ratio.** The leverage ratio puts a cap on the balance sheet size. The actual leverage ratio of the bank in year  $t$  is modeled as follows:

$$\begin{aligned}
LR_t &= \frac{\text{Total (core) tier 1 capital}}{\text{Balance sheet size}} & (3.8) \\
&= \frac{C_{CET1_t} + C_{AddT1_t}}{X_{AssetsTotal}} \\
&= \frac{C_{CET1_t} + C_{AddT1_t}}{X_{LiabilitiesTotal} + OE_t}
\end{aligned}$$

**Capital ratios.** The capital ratios put a cap on the amount of risk weighted assets a bank may be exposed to. In the model, we distinguish three different capital ratios:

- Common equity tier 1 ratio.
- Tier 1 ratio.
- Total Capital (tier 1&2 and capital conservation buffer) ratio.

They are modeled as follows:

$$\begin{aligned}
CET1R_t &= \frac{\text{Total core tier 1 capital}}{\text{Total RWA}} & (3.9) \\
&= \frac{C_{CET1_t}}{RWA_t(\text{Total})}
\end{aligned}$$

$$\begin{aligned}
T1R_t &= \frac{\text{Total (core) tier 1 capital}}{\text{Total RWA}} & (3.10) \\
&= \frac{C_{CET1_t} + C_{AddT1_t}}{RWA_t(\text{Total})}
\end{aligned}$$

$$\begin{aligned}
TCR_t &= \frac{\text{Total capital}}{\text{Total RWA}} & (3.11) \\
&= \frac{C_{CET1_t} + C_{AddT1_t} + C_{T2_t}}{RWA_t(\text{Total})}
\end{aligned}$$

**Liquidity ratios.** The liquidity ratios force banks to hold more short-term and long-term funding. The LCR and NSFR were discussed in section 2.3. The modeling of the LCR and NSFR is discussed here.

The LCR in year  $t$  looks as follows:

$$LCR_t = \frac{\text{Stock of high quality liquid assets}}{\text{Net cash outflows over a 30 day period}} \quad (3.12)$$

For a better understanding of how the stock of highly liquid assets looks like in the model, we refer the reader to appendix A.1. Also the factors that correspond to each of the high quality liquid assets are covered there.

The NSFR in year  $t$  looks as follows:

$$NSFR_t = \frac{\text{Available amount of stable funding}}{\text{Required amount of stable funding}} \quad (3.13)$$

For a better understanding of how the stable funding looks like in the model, we refer the reader to appendix A.2. Also the factors that correspond to each of the types of stable funding are covered there.

### 3.3 Risk profile

It is important that risk is actively managed prior to any (possible) crisis, to ensure that earnings and other performance indicators are robust enough to cope with adverse conditions. There are clear links between earnings stability and capital adequacy, ratings resilience and market confidence. As the recent crisis has shown, having a clear plan for managing risk and reducing earnings volatility can be a key factor behind the relative performance of banks. Because of the relevance of this topic, the first part of this section is devoted to the explanation of how risk profiles are organized and why they are important. Afterwards we will show how the risk profile is incorporated in to the model.

A recent survey from the IIF (Institute of International Finance) showed that risk appetite is at the top of the agenda of most major banks globally. The biggest challenges in this are:

- Cascading and translating high level objectives into business level guidelines.
- Embedding a culture of risk within the wide business.
- Linking risk appetite to the behavior of mid-level staff.

Every bank that managed to retain an AA-category rating prior to the crisis, also managed to record a profit (no matter how small) in each year during the crisis. Their strong risk management functions and cultures enabled them to reduce their vulnerability to adverse market changes.

**Characteristics that can be common to those banks that fail.** The following bullet points show characteristics a bank can have that may lead to serious problems:

- Dependence on short-term wholesale funding or lack of liquidity.
- Growth versus risk culture (strategic errors).
- Low capital reserves.
- Investment banking activities (volatility in earnings).
- Management & governance.
- Remuneration (the total compensation that an employee receives in exchange for the service they perform for their employer).

**Rating strength.** Maintaining a strong rating strength is very important for banks. Therefore banks need to think of a strategy that enables them to make sure they do everything in their power to achieve and maintain this important goal. We could define four pillars linked to rating strength:

1. **Capital adequacy**
  - (a) RWA management
  - (b) Capital allocation
  - (c) Stressed ratios
  - (d) Leveraged ratios

A risk profile is defined by choosing similar or somewhat higher capital ratios than the ones defined in Basel III. An example could be: The bank should target a 9-10% core tier 1 capital ratio, and become confident of a CET 1 ratio of at least 7% under extreme stress scenarios.

## 2. Stable earnings growth

- (a) Earnings volatility
- (b) VaR (value at risk)
- (c) Credit volatility

Important linkages between 'earnings volatility' and other parts of the Risk Appetite framework:

- Rating agencies clearly view stable earnings as a fundamental pillar of their credit assessment.
- Positive earnings enable year-on-year capital accumulation and contribute significantly to the ability to manage more stable capital ratios during periods of stress.
- Positive earnings enables the ongoing payment of dividends during periods of stress, and helps to maintain market confidence.
- Relative performance and Peer Group comparisons are important to market confidence and risk differentiation. Markets dislike volatile earnings as they are a key indicator of attitudes towards higher risk by management and more volatile outcomes. The valuation of banks typically reflects the volatility of earnings, with lower value multiples attributed to banks with more volatile earnings.

Measures that could be taken are: making sure that even in a mild, severe or extreme stress scenario, the bank remains profitable. This can be done by introducing a maximum earnings volatility of 100%.

## 3. Stable and efficient access to funding and liquidity

- (a) Cost of funding
- (b) Leverage ratio
- (c) Stressed measures

Maturity mismatch can not be eliminated, therefore sufficient resources must be available to meet funding needs at times of stress by:

- Improving the liquidity profile (e.g. increasing its retail deposit base).
- Building up a liquidity reserve.
- Being within the upper quantile of your peers (e.g. have a lower perceived funding riskiness than others).

Measures that can be taken, formally spoken, could be:

- Minimum Loan to Deposit ratio.
- Minimum liquidity reserve.
- Maximum amount of short-term wholesale funding.

#### 4. Stakeholder confidence

- (a) AA category rating
- (b) Reputation risk

50% of a rating agency assessment is qualitative, therefore there are a lot of qualitative factors that can set a Stakeholder Confidence Risk Appetite:

- Franchise value: Ability to withstand stress better than peers, measured by business mix, revenue stability, market share and customer mix.
- Management & strategy: Strategic competence, operational effectiveness and risk tolerance. Measured by strategic positioning and governance.
- Risk positioning: Management's effectiveness at risk management relative to peers, measured by managed growth, risk concentrations and portfolio diversification.
- Regulatory & reputation risk: Maintaining healthy relationships with regulators and other stakeholders. Measured by adverse publicity, customer complaints and regulatory breaches.

**Modeling the risk profile.** Now we showed that the risk profile is vital for a well functioning bank, we can show how the risk profile looks like in the tool and model. Figure 3.3 shows the three risk profiles incorporated in to the model. The user can pick between a risk seeking, a risk neutral or a risk averse profile. If the user prefers something in

<b>Risk seeking</b>	▶ Leverage ratio	≥	3.0 %
	▶ Common Equity Tier 1 ratio	≥	4.5 %
	▶ Tier 1 ratio	≥	6.0 %
	▶ Total Capital ratio	≥	10.5 %
	▶ LCR ratio	≥	100.0 %
	▶ NSFR ratio	≥	100.0 %
	▶ Loan : Deposit ratio	≠	110.0 %
	▶ BS modification willingness	=	High
<b>Risk neutral</b>	▶ Leverage ratio	≥	3.3 %
	▶ Common Equity Tier 1 ratio	≥	5.5 %
	▶ Tier 1 ratio	≥	7.0 %
	▶ Total Capital ratio	≥	11.5 %
	▶ LCR ratio	≥	115.0 %
	▶ NSFR ratio	≥	115.0 %
	▶ Loan : Deposit ratio	≠	100.0 %
	▶ BS modification willingness	=	Medium
<b>Risk averse</b>	▶ Leverage ratio	≥	3.6 %
	▶ Common Equity Tier 1 ratio	≥	6.5 %
	▶ Tier 1 ratio	≥	8.0 %
	▶ Total Capital ratio	≥	12.5 %
	▶ LCR ratio	≥	130.0 %
	▶ NSFR ratio	≥	130.0 %
	▶ Loan : Deposit ratio	≠	90.0 %
	▶ BS modification willingness	=	Low

Figure 3.3: The three incorporated risk profiles in the model

between the default profiles or something totally different, the tool can be easily modified.

Now what makes these profiles differ in risk tolerance? This can be explained by looking at the desired performance ratios the bank wants to maintain.

For the risk seeking profile, the bank has no aversity to risk at all and therefore only wants to do the absolute necessary what concerns regulations. This means they adopt the Basel III demands, which is legally required, and nothing more. Besides that, its balance sheet modification willingness is high. The bank will have no problems changing its balance sheet when necessary, since it is not risk averse and therefore not conservative. Changing your balance sheet brings along certain risk, but when you seek risk, you do not mind.

When looking at the performance indicators of the risk neutral profile, we see that the bank trying to live up to this profile, wants to have some margin over the Basel III constraints. This margin is meant for absorbing risks in stressful times, which is made possible by the buffer. The thorough explanation of risk profiles above argues how this exactly works. The BS modification willingness is somewhat lower here,

and therefore the penalty of modifying your balance sheet in a short time interval will be higher than when choosing a risk seeking profile. More on this penalty function in section 4.1.1.

The third profile, the risk averse profile, is the most conservative one. The buffers over the Basel III constraints are again larger, showing that the bank wants to focus on achieving and maintaining high and solid ratios over maximized return. This profile would fit to a bank that looks at the Basel III implementation period as a survival period. It wants to remain conservative, hold more capital, hold more short and long term funding and does not want to become too leveraged. Its balance sheet modification willingness is the lowest of the three profiles, meaning the highest penalty function for moving away from each balance sheet exposure of the three profiles.

### 3.4 Stochasticity

In order to capture volatility in time, the tool gives the user the possibility to make some parameters stochastic. These parameters are hard to estimate, since they fluctuate each year. The tool gives the option to make them normally distributed, attaching a mean and a standard deviation to them. Figure 3.4 gives an overview of the parameters of the model that can be made stochastic, in our case normally distributed.

In the model, the stochasticity of the BS growth/decline parameters looks as follows:

$$\begin{array}{ll}
 g(X_{RetMort})_t \sim N(\mu_{a1}, \sigma_{a1}^2) & d(X_{RetMort})_t \sim N(\mu_{a2}, \sigma_{a2}^2) \\
 g(X_{LoansAdv})_t \sim N(\mu_{b1}, \sigma_{b1}^2) & d(X_{LoansAdv})_t \sim N(\mu_{b2}, \sigma_{b2}^2) \\
 g(X_{OtherRec})_t \sim N(\mu_{c1}, \sigma_{c1}^2) & d(X_{OtherRec})_t \sim N(\mu_{c2}, \sigma_{c2}^2) \\
 g(X_{GovBonds})_t \sim N(\mu_{d1}, \sigma_{d1}^2) & d(X_{GovBonds})_t \sim N(\mu_{d2}, \sigma_{d2}^2) \\
 g(X_{CorpBonds})_t \sim N(\mu_{e1}, \sigma_{e1}^2) & d(X_{CorpBonds})_t \sim N(\mu_{e2}, \sigma_{e2}^2) \\
 \\ 
 g(X_{Dep})_t \sim N(\mu_{f1}, \sigma_{f1}^2) & d(X_{Dep})_t \sim N(\mu_{f2}, \sigma_{f2}^2) \\
 g(X_{DebtCer})_t \sim N(\mu_{g1}, \sigma_{g1}^2) & d(X_{DebtCer})_t \sim N(\mu_{g2}, \sigma_{g2}^2) \\
 g(X_{UnsWF})_t \sim N(\mu_{h1}, \sigma_{h1}^2) & d(X_{UnsWF})_t \sim N(\mu_{h2}, \sigma_{h2}^2)
 \end{array}$$

The stochasticity of the expected costs and income parameters looks as follows:

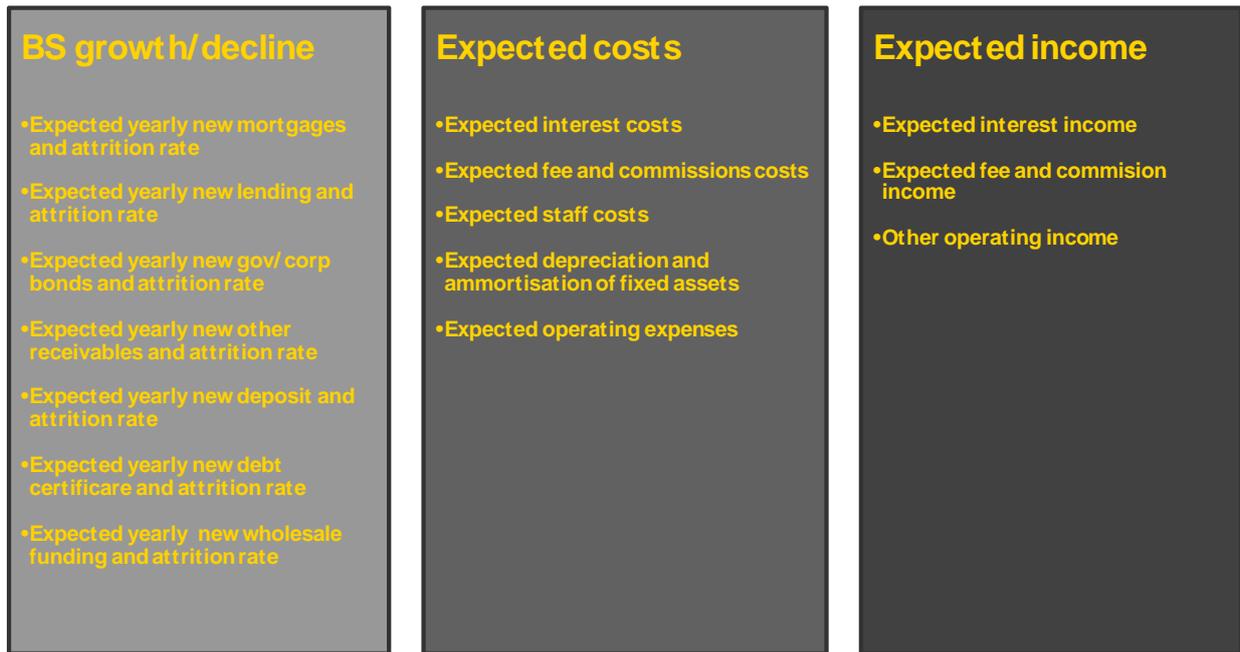


Figure 3.4: Stochasticity in the model

$$\begin{aligned}
 m^{EXP}(X_{Dep})_t &\sim N(\mu_i, \sigma_i^2) & m^{INC}(X_{RetMort})_t &\sim N(\mu_p, \sigma_p^2) \\
 m^{EXP}(X_{DebtCer})_t &\sim N(\mu_j, \sigma_j^2) & m^{INC}(X_{LoansAdv})_t &\sim N(\mu_q, \sigma_q^2) \\
 m^{EXP}(X_{UnsWF})_t &\sim N(\mu_k, \sigma_k^2) & m^{INC}(X_{OtherRec})_t &\sim N(\mu_r, \sigma_r^2) \\
 F^{EXP}_t &\sim N(\mu_l, \sigma_l^2) & m^{INC}(X_{GovBonds})_t &\sim N(\mu_s, \sigma_s^2) \\
 O^{EXP}_t &\sim N(\mu_m, \sigma_m^2) & m^{INC}(X_{CorpBonds})_t &\sim N(\mu_u, \sigma_u^2) \\
 D^{EXP}_t &\sim N(\mu_n, \sigma_n^2) & F^{INC}_t &\sim N(\mu_v, \sigma_v^2) \\
 S^{EXP}_t &\sim N(\mu_o, \sigma_o^2) & O^{INC}_t &\sim N(\mu_w, \sigma_w^2)
 \end{aligned}$$

For a very interesting work on how to incorporate stochasticity in decision making models by Dash and Kajiji [8]. It discusses a stochastic nonlinear goal program. The model simultaneously treats nonlinear demand relationships and a complex option hedge to help resolve uncertainty in a two-stage decision-making environment.

Another interesting work on balance sheet management under uncertainty is the following one [14].

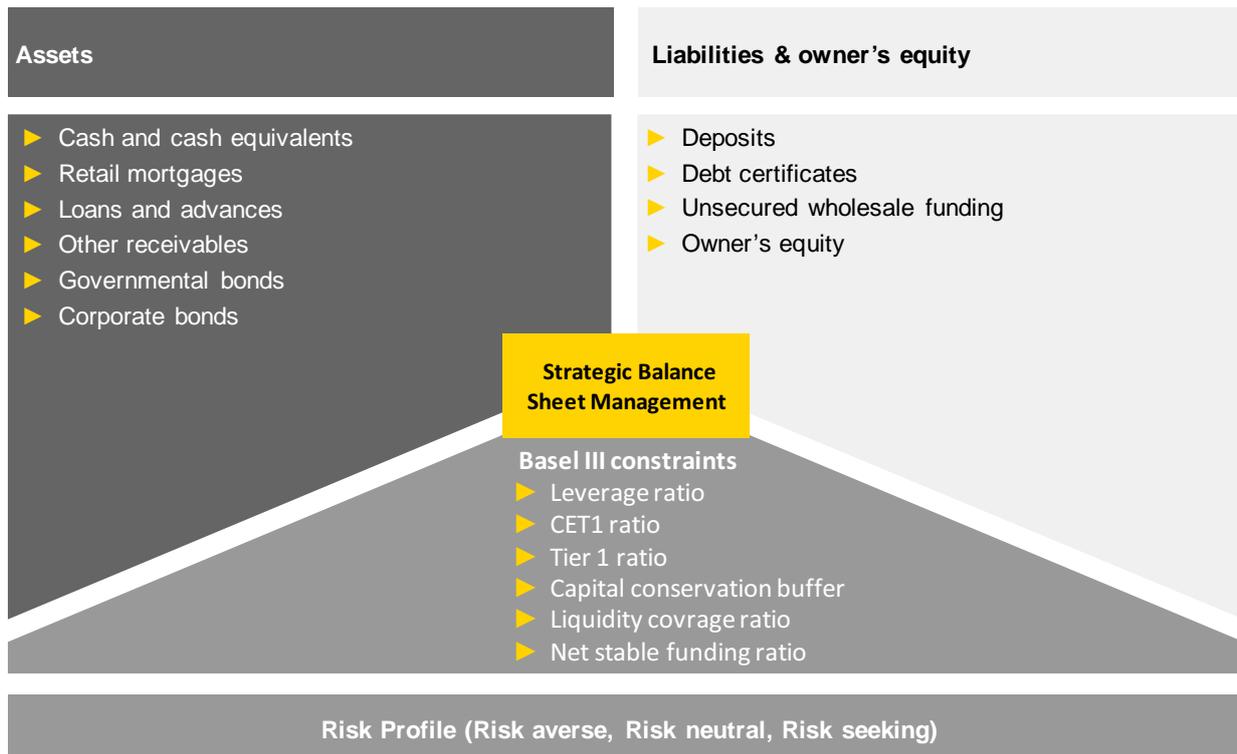


Figure 3.5: Context of strategic balance sheet management

### 3.5 Strategic BS management

The model described, implemented in excel using VBA to program the model to serve the desired goal results in a very interesting tool that can support management in taking strategic decisions on balance sheet management. Of course, the output of a model is often as good as the input, and therefore adequate calibration is a crucial part of the successful management of a bank's balance sheet. The good thing about the model is that it leaves most of the input and therefore a large part of the calibration process open. The best party to find the right input is the bank itself. After all, who else knows the strategic goals, (risk) preferences, assumptions, focus and properties of a bank better than the bank itself. So when the input and calibration process are performed in continuous communication with the bank and if enough data is available to estimate certain parameters, the model will be a very good representation of the situation of the bank.

As soon as the input is correct, the most important aspects of the model are the balance sheet, the risk profile and the Basel III constraints. These aspects have to be modeled correctly in order to be able to strategically manage a bank's balance sheet. Figure 3.5 visually shows this strategic BS management environment, where the stylized balance sheet, the different risk profiles and the incorporated Basel III ratios are placed in a context.

Making a good balance sheet management model is one thing, but thinking of a smart way to optimize the balance sheet and thereby the model is another very interesting thing. The incorporation of a smart optimization technique is what converts the model in to a smart decision support system; a tool that can show the dynamics of a bank's metrics. Moreover, it shows what the optimal way is of composing the bank's balance sheet, given its strategic goals, (risk) preferences and other properties. Chapter four will explain more on the optimization technique and related things.

## Chapter 4

# Optimization technique

### 4.1 Optimization problem

Now that we have described the bank balance sheet model, we will treat how the optimization part fits in to the model. Earlier in the report we mentioned that the bank balance sheet optimization tool was built in Excel, making use of VBA (visual basic for applications) to program the optimization in the right way. We also mentioned that we make use of Solver and Crystal Ball's OptQuest.

Excel Solver is an optimization add-in of Excel. It falls under the category of what-if analysis. This means that Solver determines what happens with the outcome of a problem if one parameter is changed. Within a spreadsheet, solver makes use of three types of cell ranges, namely:

- **Target function range:** This is typically one cell in a spreadsheet. It is usually a function that inputs other values that are found within the same spreadsheet. These cells fall within the next two categories. The goal is to maximize, minimize or set equal the value of this cell.
- **Adjustable Cells:** These cells must be given an initial value. When Solver is run, it will change the values of these cells in order to reach the optimum solution in the target cell.
- **Constraint Cells:** These are set values that will restrict values that Solver will use. They can refer to other cells in the spreadsheet.

OptQuest is an optimization tool that runs with Crystal Ball. As an add-in to Crystal Ball, OptQuest enhances simulation models by automatically searching for and finding optimal solutions. At the basic level, OptQuest selects a value for each decision variable, enters those values into a spreadsheet, runs a Monte Carlo simulation on the spreadsheet, records the results, and repeats the process. One could manually perform this sort of analysis, but as you increase the number of decision variables, the number of possible variable combinations becomes unwieldy.

On a more advanced level, OptQuest does a much better job at finding optimal solutions than is possible with manual calculations. OptQuest surpasses the limitations of genetic algorithm optimizers because it uses multiple, complimentary search methodologies, including advanced tabu search and scatter search, to help find the best global solutions. To gain more understanding about this way of optimizing, we refer the reader to a book that discusses ordinal optimization [11]. This book discusses how ordinal optimization works and why it is effective. It was an inspiring source for the optimization choices made throughout the research period of the internship.

Before we go further in to detail on why we use these two tools, what distinguishes them and how we exactly use them (section 4.2), we will formulate the optimization problem. Section 4.3 treats the discussion of constraints choice, since this is a very relevant part of the optimization technique. But more on that later, this section presents the optimization problem.

**The optimization problem.** One could consider the problem as a linear programming (LP) problem. This would seem the most logical choice, since we are dealing with an optimization problem where we want to maximize the return on equity (target function) by changing the balance sheet composition (decision variables), under Basel III (constraints). When we look at the model, there are no non-linear components in the modeling framework.

But there is one reason why we may not consider the problem as a LP problem, and that is the incorporation of the earlier mentioned penalty function. This penalty function influences the optimization such, that it loses the properties of a LP problem. The penalty function, that will be discussed in the next section, includes a quadratic

component, which means the problem becomes a non-linear programming problem. The penalty function puts a cap on the extent to which each position on the balance sheet may change by applying a penalty for increasing or decreasing a certain position in a short time interval. After all, changing your balance sheet is not for free. There are transaction costs involved when lowering the exposure of a certain position, and the interest margin of a product has to be decreased to attract more clients and thereby increasing the exposure. Section 4.1.1 shows how this penalty function looks like. First we will formulate the optimization problem. Before we can do that, we need to formalize the return on equity, since this is the function we want to maximize:

$$\begin{aligned}
 roe_t &= \frac{\text{Retained profit in year } t}{\text{Average capital over year } t - 1 \text{ and year } t} & (4.1) \\
 &= \frac{RP_t}{\frac{(C_{CET1_{t-1}} + C_{AddT1_{t-1}} + C_{T2_{t-1}} + RP_{t-1}) + (C_{CET1_t} + C_{AddT1_t} + C_{T2_t})}{2}}
 \end{aligned}$$

As equation 4.1 shows, the return on equity takes the retained profit in year  $t$  over the average amount of owner's equity of the last two years. Now we can formulate the optimization problem:

$$\begin{aligned}
 \max \quad & roe_t \\
 \text{s.t.} \quad & LR_{t>2012} \geq 0.03 \\
 & CET1R_{t=2012} \geq 0.02 \\
 & CET1R_{t=2013} \geq 0.035 \\
 & CET1R_{t=2014} \geq 0.04 \\
 & CET1R_{t>2014} \geq 0.045 \\
 & T1R_{t=2012} \geq 0.04 \\
 & T1R_{t=2013} \geq 0.045 \\
 & T1R_{t=2014} \geq 0.055 \\
 & T1R_{t>2014} \geq 0.06 \\
 & TCR_{t=2012-2015} \geq 0.08 \\
 & TCR_{t=2016} \geq 0.08625 \\
 & TCR_{t=2017} \geq 0.0925 \\
 & TCR_{t>2018} \geq 0.09875 \\
 & TCR_{t>2019} \geq 0.105 \\
 & LCR_{t>2014} \geq 1 \\
 & NSFR_{t>2018} \geq 1 \\
 & X_{Cash}^{MIN} \geq X_{Cash} \geq X_{Cash}^{MAX} \\
 & X_{RetMort}^{MIN} \geq X_{RetMort} \geq X_{RetMort}^{MAX} \\
 & X_{LoansAdv}^{MIN} \geq X_{LoansAdv} \geq X_{LoansAdv}^{MAX} \\
 & X_{OtherRec}^{MIN} \geq X_{OtherRec} \geq X_{OtherRec}^{MAX} \\
 & X_{GovBonds}^{MIN} \geq X_{GovBonds} \geq X_{GovBonds}^{MAX} \\
 & X_{CorpBonds}^{MIN} \geq X_{CorpBonds} \geq X_{CorpBonds}^{MAX} \\
 & X_{Dep}^{MIN} \geq X_{Dep} \geq X_{Dep}^{MAX} \\
 & X_{DebtCer}^{MIN} \geq X_{DebtCer} \geq X_{DebtCer}^{MAX} \\
 & X_{UnsWF}^{MIN} \geq X_{UnsWF} \geq X_{UnsWF}^{MAX} \\
 & X_{AssetsTotal} = X_{LiabilitiesTotal}
 \end{aligned} \tag{4.2}$$

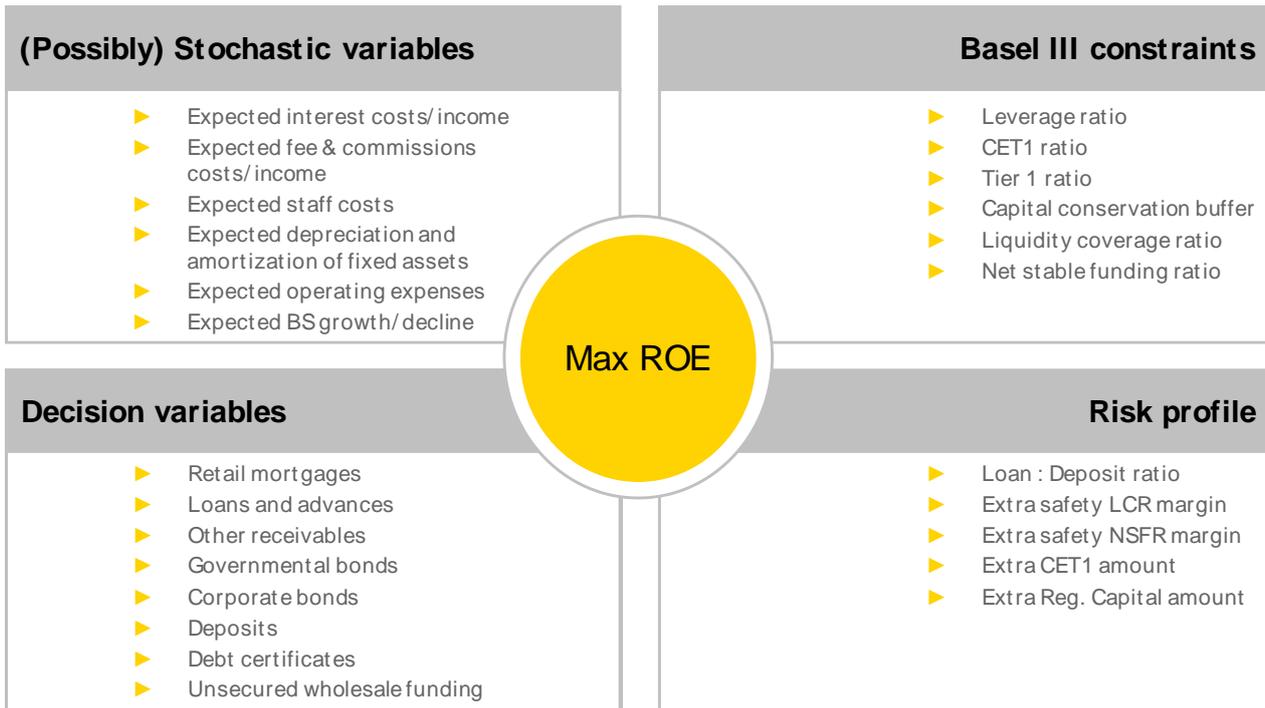


Figure 4.1: The optimization environment with ROE as the target function

with the decision variables being:

$X_{Cash}$	Cash and cash equivalents exposure
$X_{RetMort}$	Retail mortgages exposure
$X_{LoansAdv}$	Loans and advances exposure
$X_{OtherRec}$	Other receivables exposure
$X_{GovBonds}$	government bonds exposure
$X_{CorpBonds}$	Corporate bonds exposure
$X_{Dep}$	Cash and cash equivalents exposure
$X_{DebtCer}$	Retail mortgages exposure
$X_{UnsWF}$	Loans and advances exposure

This optimization equation includes the Basel III constraints of not just year  $t$ , but also from the seven following years. One could ask if it would not be better to only consider the Basel III ratios of year  $t$  when optimizing year  $t$ ? Section 4.3 discusses this thought experiment.

Figure 4.1 shows the optimization environment belonging to the optimization equation. We see the return on equity as the central component that we want to maximize, with the most important components

around it. Of these surrounding components the decision variables are the most important ones, since they represent the balance sheet exposures for each position and therefore the composition that we want to improve. The Basel III constraints is something we can not ignore, and have to fulfill at each point in time. The risk profile ensures the risk preferences of the bank, that form a safety buffer over the Basel III constraints to capture shocks. And last, the (possibly) stochasticity can be added to certain parameters to capture uncertainty.

### 4.1.1 Penalty function

An important property of the optimization is the incorporation of a penalty function. This penalty function was introduced and described briefly earlier in the report. This section provides a better understanding of this function that tries to keep the optimization from choosing a balance sheet that is too much different from the starting balance sheet. By doing this, unrealistically large balance sheet modifications can be prevented by attaching a higher penalty to a larger balance sheet modification on a position level.

How can this penalty be explained? Why do you have to apply a penalty to the modification of a position? To explain this, we will consider two ways of modifying a balance sheet position:

1. **Increasing a position:** Let us say we want to increase the amount of retail mortgages exposure. In order to do this, banks need to make it more attractive for clients to choose their bank. The way to do this is by making it more lucrative for the client to close a mortgage with that bank. Banks will have to decrease their interest margin on retail mortgages in order to attract more customers and thereby increasing the retail mortgages exposure. This interest rate decrease means a lower earning on this BS position. But if increasing this position is better, a bank is going to want to expand on their retail mortgages exposure, even if it brings along a small decrease in interest income. This example shows that it is not for free to increase a balance sheet position in a short time interval.
2. **Decreasing a position:** Now let us consider the situation where it would be better to decrease the exposure of a certain position. Let us take corporate loans as an example. If it seems better to lower on this position, a bank will have to pay transaction costs

to achieve this in a short time interval. The corporates receiving their loans will not be willing to participate for free after all.

These two examples explain why the penalty function is a logical representation of dealing with balance sheet modification. The tool contains such a penalty function. This means that the tool tries to find an optimal balance sheet that has a higher return on equity, fulfills all the risk preferences and strategic goals of the bank, and is compliant to all Basel III constraints throughout the whole implementation period, without having to modify the balance sheet too much.

The penalty function makes it that the optimization problem is not a linear programming problem, but a non-linear one. Leaving the penalty function out would cause the optimization to suggest a balance sheet that is very different from the starting one, creating an absolutely unrealistic balance sheet composition meaning that the bank would have to make enormous transaction costs and interest rate losses to come to this 'optimal balance sheet'. It is logical to see that this would be a bad strategy since the costs the bank would need to make to modify the balance sheet so much, would take away the win that could be made with a smarter balance sheet composition.

The penalty function in the tool can be found in appendix 6.2. As the appendix shows, the penalty applied depends on four variables:

- **Base exposure:** The current exposure of a certain position.
- **Actual (optimal) exposure:** The exposure that the optimization finds for a certain position.
- **Margin:** The current interest margin of the position.
- **Risk appetite:** The willingness to move away from the current balance sheet composition.

These four variables determine the penalty. After all, the difference between the actual exposure and the base exposure is the amount of modification you apply on a certain position. The interest rate margin is used to make a position more attractive and the risk appetite defines how willing the bank is to move away from its current exposure per position.

To be more specific; in the case of moving upwards from a certain position, the penalty is the decrease in interest income. The severity of the penalty is determined by the 'actual optimal exposure', the optimal

exposure for a certain position. This property causes the optimization function not to be linear anymore. In the case of moving downwards from a certain position, the penalty function is the transaction fee that needs to be paid to be able to lower the exposure of that certain position.

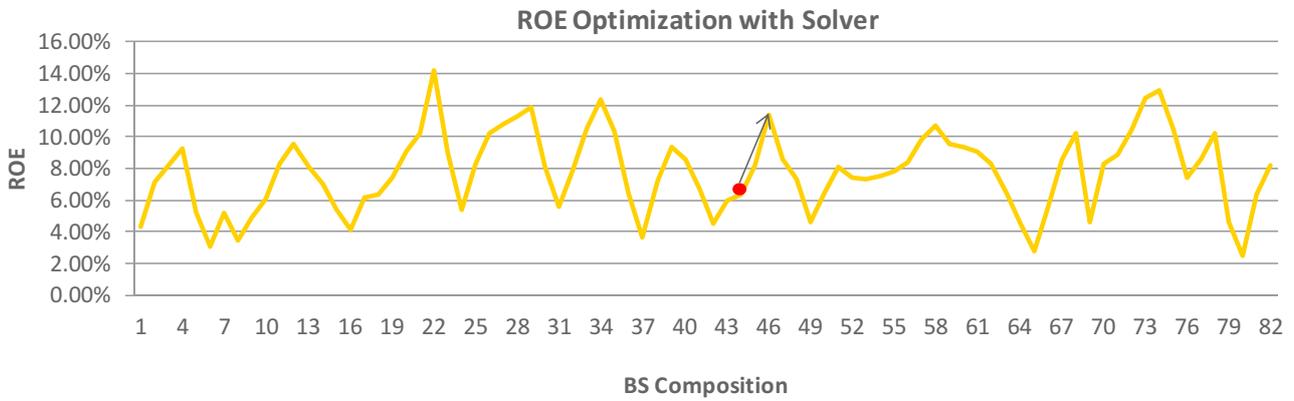
## 4.2 Solver vs OptQuest

At the beginning of this chapter, Solver and OptQuest were discussed briefly. This section compares the techniques and shows why combining them in a smart way, enables one to find an optimal way of seeking for the best balance sheet composition given all your preferences, properties and constraints.

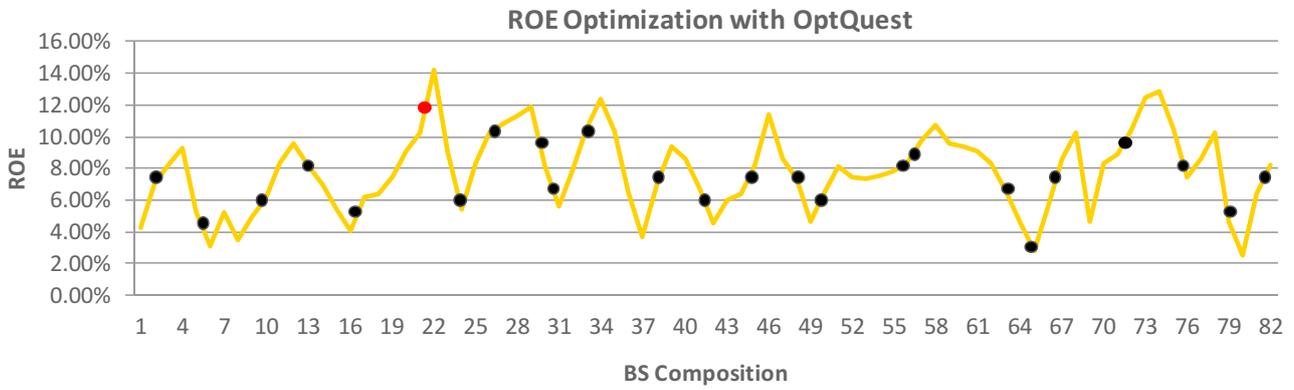
**Optimization Under Uncertainty.** OptQuest is a global optimization software tool that works with Crystal Ball models to find an optimal choice for a given decision. If you want to minimize costs or maximize profits, OptQuest can assist in making the best decisions despite conditions of uncertainty.

Excel Solver uses classical linear programming and nonlinear programming methods designed for problems where every locally optimal solution is also globally optimal. In contrast, OptQuest uses a combination of meta heuristic procedures from methods such as Tabu Search, Neural Networks, and Scatter Search. All of these methods are effective for models that Excel Solver can solve, as well as for models with local solutions that are not globally optimal, which is usually true in the real world.

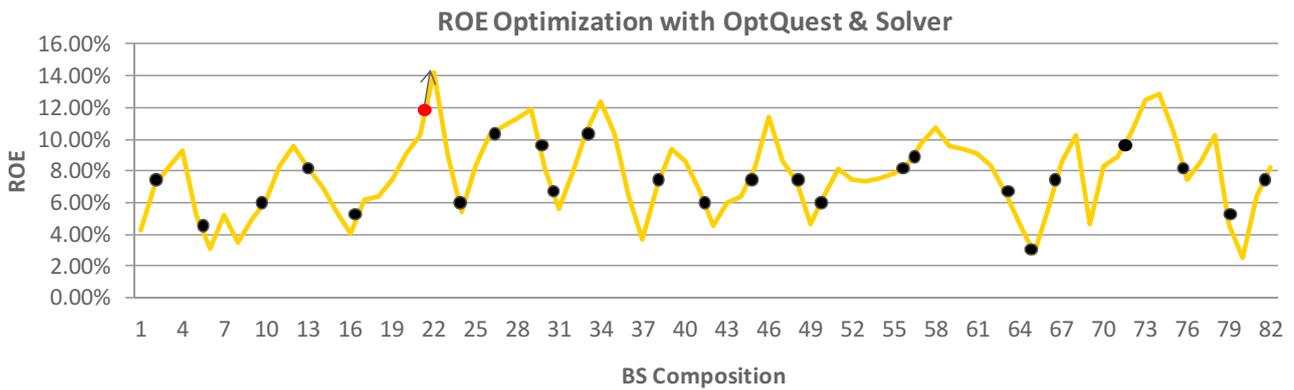
Figure 4.2a shows how Solver seeks for an optimal balance sheet. The horizontal axis gives a random draw from different type of balance sheet compositions (a sample space). The vertical axis shows the corresponding return on equity. The red dot shows the current balance sheet composition (composition 43) with a return on equity of about 7%. This is a simplified two dimensional optimization problem, since displaying a nine-dimensional one as in our problem would not be possible. What Solver does, is finding the best local optimum (best local balance sheet). It is a good but not good-enough solution. Using Solver to simulate multiple starting BS compositions is too exhaustive. Omitting this gives a poor local optimum.



(a) Optimizing with solver only



(b) Optimizing with OptQuest only



(c) Optimizing using both Solver and OptQuest

Figure 4.2: The two used optimization techniques in the model

Figure 4.2b shows what OptQuest does to find the best balance sheet composition. The black dots are possible starting balance sheets that fulfill all Basel constraints. The horizontal and vertical axis represent the same unit as in the figure above it. OptQuest has three advantages over the Excel Solver:

- OptQuest thoroughly searches the sample space in an environment of uncertainty.
- OptQuest will not get trapped in local optimal solutions.
- OptQuest can handle complex nonlinear relationships.

The disadvantage is that OptQuest does not actually look for the optimum. It searches a great part of the sample space and every time it finds a better solution (read better balance sheet composition) it saves this one over the last best solution. In our tool, we take 1000 drawings from the sample space. So OptQuest simulates multiple starting BS compositions and thereby reduces the complexity tremendously and gives a global but sub-optimal solution.

So what we want to do is combine both techniques; first we use OptQuest to search a great enough number of possible balance sheet compositions that are not too far away from our starting balance sheet. The penalty function would make a too far away balance sheet composition too expensive and therefore not optimal anyway. For all of these possible starting balance sheets (samples) it checks whether it fulfills all Basel constraints and whether the corresponding return on equity is higher than the last best solution. After we found the best of the 1000 balance sheet compositions, we take the best solution and run Solver to pull the solution up to the global best solution with the highest return on equity. Therefore using OptQuest first and Solver afterwards combines best of both worlds in order to find the best possible composition for the balance sheet. Figure 4.2c shows how this looks like.

### 4.3 Choice of constraints

In our optimization function (4.2) we see that the Basel constraints of each of the years from 2012 to 2019 are used. An interesting thought could be whether it would be better to choose the Basel III constraints

Balance sheet date	2012	2013	2014	2015	2016	2017	2018
Basel III Event				<b>LCR</b>			<b>NSFR</b>
(in € million)							
ASSETS							
Cash & cash equivalents	3,877	4,917	7,550	<b>23,248</b>	26,682	33,692	<b>51,005</b>
Retail mortgages	116,000	142,240	152,188	134,968	142,523	147,547	142,446
Loans and advances	18,099	14,888	12,239	10,395	9,065	7,865	3,579
Other receivables	6,710	5,787	4,135	3,626	2,654	2,316	2,325
Government bonds	32,323	11,424	2,130	<b>20,489</b>	21,318	15,733	<b>26,764</b>
Corporate bonds	7,380	4,209	2,249	5,012	7,231	6,153	10,135
LIABILITIES AND OWNERS EQ.							
Deposits	84,963	71,955	74,347	7,916	81,755	82,802	89,431
Debt certificates	54,002	73,875	79,782	88,408	97,241	104,163	117,534
Unsecured WF	28,924	30,072	28,340	22,884	21,390	16,634	16,898
Owners equity	7,565	8,023	8,529	9,089	9,707	10,390	11,291
<b>ROE (%)</b>	14,72	15,82	16,63	<b>7,30</b>	10,32	9,59	<b>5,88</b>

Table 4.1: Thought experiment on constraints choice

of only year  $t$  instead of for the whole phase-in period when optimizing the balance sheet of year  $t$ . It would be nice to check this.

Table 4.1 shows seven optimized stylized balance sheets that were optimized (maximizing ROE) under the Basel III constraints of only the corresponding year. So first the 2012 BS was optimized under the 2012 BIII constraints, then the expected growth was applied on that BS to come to the expected 2012 BS, which we then optimized over only the 2012 BIII constraints. We iterated this process till 2018 and the result is shown in the table. It also contains the corresponding ROE values for each year.

We observe that we have a nice increase in ROE the first three years, until suddenly in 2015 the LCR comes into play. Since we did not take the future BIII constraints in to account, we suddenly have to re-compose our balance sheet so drastically, the associated transaction costs are so high that the ROE becomes less than half the ROE of 2014. The bold exposures show that in 2015, we need to triple our cash position, and ten times increase our government bonds position to be able to be LCR and thereby BIII compliant in 2015.

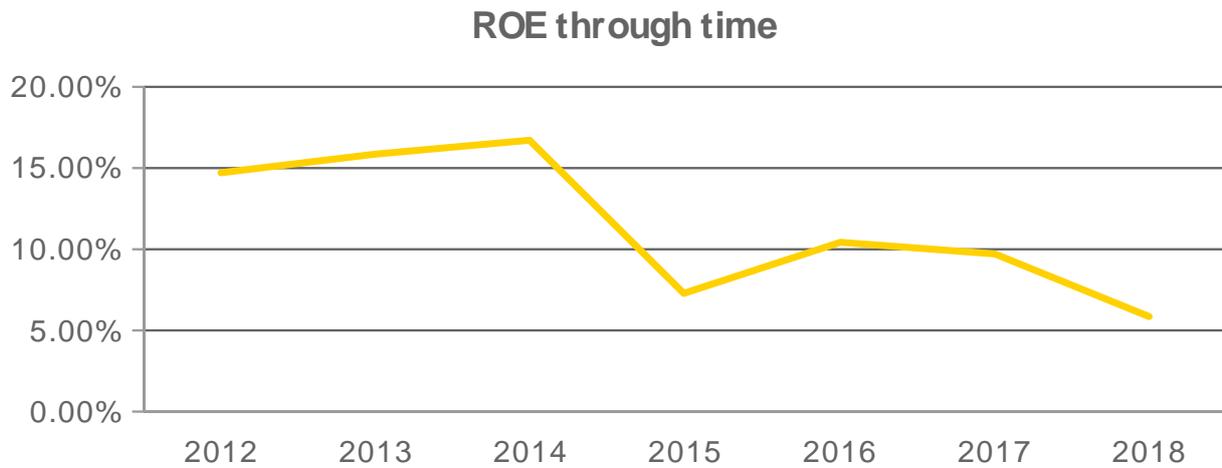


Figure 4.3: ROE development with yearly BIII constraints

The same happens in 2018, where we suddenly have to cope with the NSFR, forcing us to increase our liquid balance sheet position such, that again our ROE drops significantly.

This shows that we can not close our eyes but need to take the future BIII in to account right now, in order to be able to start building extra liquid capital with more speed to be able to have enough liquid capital to be LCR and NSFR compliant in respectively 2015 and 2018. If we do not do this we will walk against a wall that is too expensive to overcome within just one year for this method to be a good alternative. Figure 4.3 confirms this. It shows the development of the ROE through time, with large declines in 2015 and 2018.

## Chapter 5

# Results

This section discusses the results of the research. It shows what kind of interesting facts can be obtained by using the balance sheet optimization tool in the right way. The whole way of modeling and optimizing the research problem of course is already ‘a result’ on its own, since it is the way we have tackled the problem. Therefore the tool that has been developed during the research is the most interesting result of the internship. Nevertheless it is definitely interesting to show some nice results that have been generated by the use of the tool.

To be able to produce results, it is necessary to choose default values for the parameters in the model. Therefore we will start with showing which default values we will use. See appendix A.4.

The appendix might be overwhelming, but we provide it for the sake of reproduction concerns. When using these default values, we can see how much the tool can improve the current situation of the default bank. By improving we mean, achieving a higher return on equity, meeting all Basel III constraints throughout the whole BIII phase-in period, and simultaneously making sure the strategic goals of the bank are also secured.

### 5.1 Base versus optimal balance sheet

The main question answered in this section is: how does the optimized balance sheet look like, compared to the starting balance sheet, and

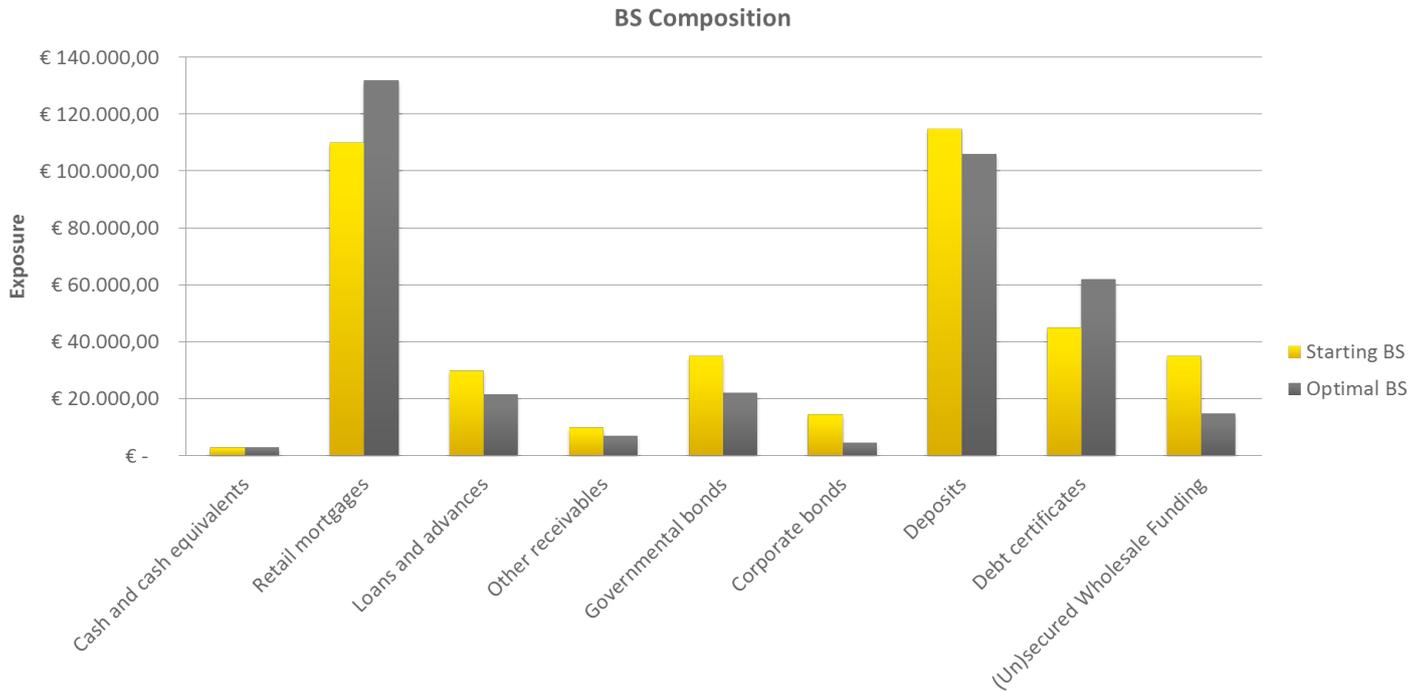


Figure 5.1: Optimal versus starting balance sheet

in what way has it improved. Of course, as described in chapter 4, feasibility is a very important property the outcome of the tool needs to include. The penalty function section (4.1.1) sees this feasibility is achieved. Figure 5.1 is a bar graph that shows how much the optimal balanced sheet, found by the tool, differs from the starting balance sheet. We use the default parameter values defined in appendix A.4. The risk profile used here is 'risk seeking'.

We see that the optimal balance sheet composition is close to the starting balance sheet composition. This means the optimal balance sheet does not differ too much from the starting one, but seems to be better. Now what does 'better' mean? Let us look at some performance metrics to answer that question (table 5.1 and table 5.2). We see that the optimal balance sheet brings along a return on equity that is more than 3,5 % higher. Besides that, the starting balance sheet was not fully compliant to Basel III, while the optimal one is. And all of this is achieved by some small modifications of the balance sheet positions. So why would one not want a better performing bank with a higher return on equity and BIII compliancy, when all that needs to happen is a bit modification? A very interesting result.

Balance sheet composition	Return on equity	Basel III compliant
Starting balance sheet	13.69 %	No
Optimal balance sheet	17.27 %	Yes

Table 5.1: Performance of starting and optimal BS

Basel III ratio	2012	2013	2014	2015	2016	2017	2018
STARTING BS							
$LR_t$	2.65%	2.87%	3.02%	3.25%	3.51%	3.82%	4.11%
$CET1R_t$	5.17%	5.92%	6.45%	7.01%	7.66%	7.94%	8.20%
$T1R_t$	7.38%	7.65%	7.96%	8.32%	8.76%	9.02%	9.55%
$TCR_t$	7.58%	8.21%	8.86%	9.31%	9.57%	9.85%	10.24%
$LCR_t$	82.26%	91.27%	89.26%	95.62%	97.94%	103.72%	101.27%
$NSFR$	88.18%	93.35%	90.65%	96.17%	99.26%	108.36%	105.35%
OPTIMAL BS							
$LR_t$	2.68%	3.00%	3.27%	3.55%	3.77%	3.95%	4.15%
$CET1R_t$	3.89%	5.01%	5.96%	6.94%	7.75%	8.40%	9.19%
$T1R_t$	6.92%	7.80%	8.51%	9.27%	9.89%	10.35%	10.98%
$TCR_t$	9.11%	9.811%	10.34%	10.95%	11.43%	11.76%	12.28%
$LCR_t$	95.35%	102.42%	99.47%	100.10%	106.12%	100.00%	108.26%
$NSFR$	114.25%	116.11%	115.25%	118.28%	121.27%	120.25%	122.26%

Table 5.2: Basel III ratios comparison

## 5.2 How to find the optimal BS

Of course, the main result of the research is not a single return on equity improvement percentage. It is more than that. The most difficult thing in the research is the development of a steady and robust model that incorporates all relevant parameters, risk preferences and strategic goals of a bank, and provides the user the possibility to produce an optimal way of working towards Basel III. The central component of course is the balance sheet, which forms the kernel of the capital base of the bank, and shows where the money goes and where the money comes from. Modifications on the balance sheet influence the performance of the whole bank, and therefore it is crucial that the bank knows it can build their decisions on secure quantitative models and tools.

The tool built throughout the research therefore hopefully will prove to become an important part of the balance sheet management period

towards and throughout Basel III. It is therefore a result itself. This section contains a short overview of the most important elements of the modeling and the tool that made it possible to come to this result:

- **Penalty function:** A function that assures that the outcome of the tool is a balance sheet composition a bank can achieve in a realistic way. It is a vital component of the optimization, described in section 4.1.1.
- **Customizability:** If the tool would not be customizable, it would mean that it would be calibrated for one specific situation, and therefore hard to adjust to a different one. This means it could only be used for one specific bank. Since almost all components of the model are built in such a way that it is very easy for the user to change them, the tool can be calibrated to different banks, and can therefore be used in a wider context. A disadvantage is that it might be less specific on some detail-level parts, but there is always room for working out further details such as the incorporation of an IRB RWA calculation approach in stead of a SA. Section 3.1.3 discussed this.
- **Optimization technique:** A big part of the research was devoted to the quest for the best possible way to optimize the balance sheet composition. The outcome of it was that the best possible way is to use a combination of Solver and Crystal Ball's OptQuest. This ordinal way of optimization as worked out in [11] seems to be the best way of dealing with this nine-dimensional optimization problem. Section 4.2 described this problem.
- **Constraint choice:** The thought experiment worked out in section 4.3 shows how one should deal with the choice of the constraints. It is the result of an analysis in which different ways of choosing constraints were compared in order to find the most optimal, efficient and feasible way of doing this. It is a very important part of the balance sheet modeling solution this report presents.

### 5.3 Sensitivity analysis

It is also interesting to perform some sensitivity analysis on the balance sheet, in order to gain more understanding in the dynamics of the different positions. Besides that it shows what positions have most influence on what metrics. In this section, we will look at the influence of each balance sheet on the return on equity, the most important

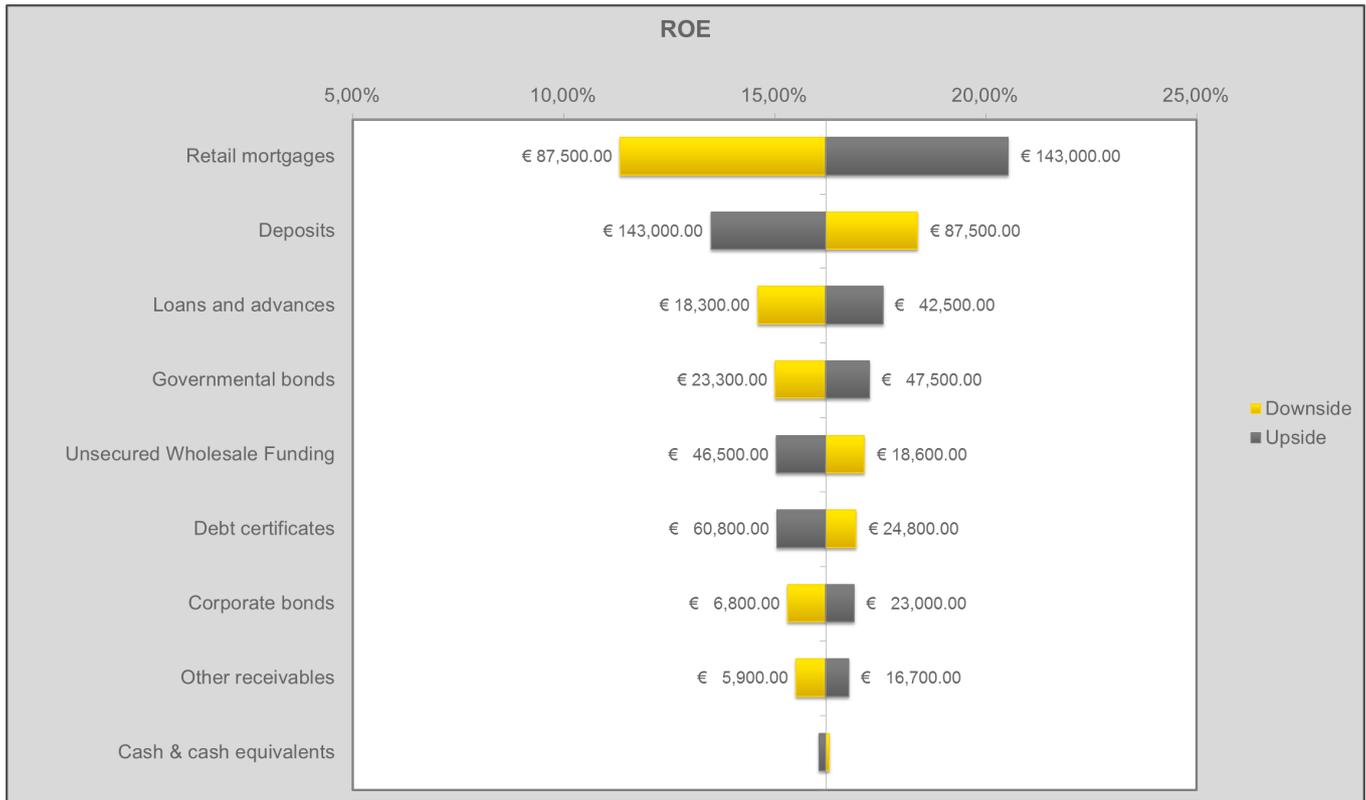


Figure 5.2: Sensitivity analysis on return on equity

metric in the research of this thesis. Figure 5.2 shows this sensitivity analysis.

We see to what extent the modification of one balance sheet position, *caeteris paribus*<sup>1</sup>, influences the profitability metric of the bank. Besides giving insight in to the composition of the balance sheet and the exposure weights, it shows how much can be achieved by playing around with one position. What needs to be mentioned of course is that it is not free to change your balance sheet a lot in a short time interval. This means that the actual return on equity would be lower than in the figure, since the costs of modification (penalty function) is not included in this graph. Nevertheless it is a very useful graph.

<sup>1</sup>*Caeteris paribus* is a Latin phrase, literally translated as "with other things the same," or "all other things being equal or held constant."

Risk profile	Return on equity	Basel III compliant
Risk seeking bank	17.27 %	Yes
Risk neutral bank	15.81 %	Yes
Risk averse bank	14.05 %	Yes

Table 5.3: Impact of risk profile modification

## 5.4 Impact of risk profile modification

Another interesting thing is to see what the impact would be when the bank would change its risk profile. For example, consider a risk-seeking bank that does not mind incorporating risk in their strategy and actions. Given the heavier regulations coming up, this bank might want to consider whether it could be smart or even necessary to take a somewhat more conservative attitude in its operations. This would mean that the bank would redefine its profile to become more risk neutral or even risk averse. But before a bank would undertake such an action, it would be interested in seeing how much profitability it would hand in to be more safe.

This section shows what happens to the profitability metric when the default bank we consider would choose a different risk profile. The outcome of this tells us how costly it is to apply a higher level of conservatism. We will use the default risk profiles that are defined in the model, as in figure 3.3. The impact on the return on equity is shown in table 5.3.

We see that taking a more conservative stand, by pursuing a more risk averse profile in order to be better prepared for unforeseen events, does not hurt the profitability of the bank too much. This means that it might be interesting for a bank to consider this strategy. It is definitely not a bad idea given the current view on the economy of a lot of banks: "At this moment, surviving is higher on the agenda than making as much profit as possible."

## 5.5 Scenarios

This section discusses a small number of scenarios that are incorporated in the tool. The scenarios are interesting to see what kind of

Situation	Performance metric						
	$LR_t$	$CET1R_t$	$T1R_t$	$TCR_t$	$LCR_t$	$NSFR$	$roe_t$
$d(X_{Dep})_t = 2.5\%$ , $t = 2016$ (default)	3.77%	7.75%	9.89%	11.43%	106.12%	121.27%	15.06%
$d(X_{Dep})_t = 10.0\%$ , $t = 2016$	3.80%	7.59%	9.75%	11.30%	70.79%	113.15%	12.44%
$d(X_{Dep})_t = 15.0\%$ , $t = 2016$	3.82%	7.45%	9.63%	11.20%	45.79%	110.09%	10.50%
$d(X_{Dep})_t = 20.0\%$ , $t = 2016$	3.84%	7.34%	9.54%	11.13%	24.76%	106.60%	8.56%

Table 5.4: Influence of a bank run scenario

performance metrics are affected most by what type of scenario. Besides that it is interesting to see how much return it costs to optimize under a few stress scenarios. The scenarios incorporated in the tool are a bank run scenario, a credit downgrade scenario and an unexpected large loss scenario. This section describes these three scenarios and their impact, and concludes with showing how costly it is to incorporate them in to the optimization.

**Bank run.** Let us first consider a bank run scenario. Suppose that at some point in time, the deposit attrition rate  $d(X_{Dep})_t$  goes up. What is the impact of this on the optimized balance sheet? We take 2016 for  $t$ . We consider three levels of attrition. The results are shown in table 5.4. We only consider the year 2016, since we chose that date as the year where the extreme event happens.

We see that a bank run scenario has the highest impact on the return on equity and the LCR ratio. The other performance metrics remain quite stable.

**Credit downgrade.** Now let us consider a credit downgrade scenario. This means that at some point in time, the RWA of government bonds  $RWA_t(X_{GovBonds})$  will increase significantly. What is the impact of this on the optimized balance sheet? We take 2014 for  $t$  this time. Table 5.5 shows the result of running this scenario on the optimal balance sheet in three levels of severity.

We see that this scenario mostly affects the capital ratios. The other ratios remain quite stable.

Situation	Performance metric						
	$LR_t$	$CET1R_t$	$T1R_t$	$TCR_t$	$LCR_t$	$NSFR$	$roe_t$
$RWA_t(X_{GovBonds}) = 17.3\%$ , $t = 2014$ (default)	3.27%	5.96%	8.51%	10.34%	99.47%	126.00%	16.51%
$RWA_t(X_{GovBonds}) = 45.0\%$ , $t = 2014$	3.27%	5.60%	7.99%	9.71%	99.47%	126.00%	16.51%
$RWA_t(X_{GovBonds}) = 75.0\%$ , $t = 2014$	3.27%	5.25%	7.50%	9.11%	99.47%	126.00%	16.51%
$RWA_t(X_{GovBonds}) = 100.0\%$ , $t = 2014$	3.27%	5.00%	7.13%	8.67%	99.47%	126.00%	16.51%

Table 5.5: Influence of a credit rating downgrade scenario

Situation	Performance metric						
	$LR_t$	$CET1R_t$	$T1R_t$	$TCR_t$	$LCR_t$	$NSFR$	$roe_t$
No unexpected large loss, $t = 2017$ (default)	3.94%	8.39%	10.34%	11.75%	102.77%	127.40%	13.64%
Unexpected large loss of 0.6 Bn, $t = 2017$	3.89%	8.26%	10.21%	11.61%	102.21%	127.32%	12.32%
Unexpected large loss of 1.2 Bn, $t = 2017$	3.84%	8.12%	10.07%	11.48%	101.65%	127.25%	10.99%
Unexpected large loss of 1.8 Bn, $t = 2017$	3.79%	7.98%	9.94%	11.34%	101.09%	127.17%	9.66%

Table 5.6: Influence of an unexpected large loss scenario

Type of optimization	Return on equity	Basel III compliant
Optimizing without scenarios	17.27 %	Yes
Optimizing with scenarios	13.82 %	Yes

Table 5.7: Impact on ROE when incorporating stress in optimization

**Unexpected large loss.** The third and last scenario is called the unexpected large loss scenario. At some point in time, the bank will experience a large unexpected loss. What is the impact of this on the optimized balance sheet? This time, we take 2017 for  $t$ . The results are shown in table 5.6.

When we look at the effect of this scenario on the performance of the bank, we see that the return of equity is most effected, while the other metrics are only slightly effected.

**Optimizing with stress.** One more interesting question regarding scenarios is: how much return on equity loss do we have to accept when we want to incorporate these three scenarios in the optimization? Table 5.7 answers this question.

We see that we would have to hand in almost 3.5% return on equity when we want to optimize with the above stress scenarios. This is

not a small percentage. Therefore the bank has to decide what is most important for the bank. The severity of the incorporated scenarios is at its maximum in this case. So if we choose less severe levels for some or all scenarios the return on equity loss will be higher, but the level of severity we keep in to account is lower then. This result gives a good view on the dynamics of optimizing with or without stress.

## Chapter 6

# Conclusion

This report started with a description of the main research question. Throughout the report, the model that was necessary to answer this research question was worked out thoroughly. The assumptions and hurdles were addressed, and eventually the results were presented. In order to summarize the most important results and related conclusions, this chapter is incorporated.

### 6.1 The optimal balance sheet

Many thoughts have passed throughout the internship period on how the difficult task of strategic balance sheet management under Basel III could best be tackled with as goal to find an optimal balance sheet. Of course, this optimal balance sheet has to fit in the strategy framework and risk preferences of the bank as well. Some important findings that were made when building this model are summarized here. Also important components of the model and tool are highlighted.

**Modeling.** In order to find the optimal balance sheet, there are many things to take in to account when modeling and tackling this problem. Chapter three showed how this difficult problem can be formalized, and discussed the software needed to support the modeling framework. It also described why it is very important that in order to make a tool that is interesting for banks, a large number of parameters should

be made customizable. This is a vital thing in order to be able to assure the tool can be practically interesting.

Besides the fact that a customizable model is of much higher practical value than one that is only made for a specific situation, defining and incorporating a smart risk-profile is also extremely important. When this would be ignored, the risk preferences of a bank would not be captured and the optimization would not find a balance sheet that fits to the risk averseness of the bank. Also the possibility to add stochasticity to the model is a useful feature that allows the user of the tool to capture volatility and uncertainty in time.

**Optimization.** With regard to the optimization, we showed that the use of Solver and OptQuest in the right way is the best way to find an optimal balance sheet under Basel III. Since we are dealing with a nine-dimensional optimization problem we have a quite complex and large sample space. Therefore we showed that the use of ordinal optimization is a smart and efficient way to tackle this complexity and come to a much better balance sheet.

Another very important thing is the use of a penalty function that prevents the tool from finding an optimal balance sheet that is unfeasible to achieve. Transaction costs would simply be too high for a bank. The penalty function therefore makes the use of the modeling framework and tool (that follow from the research) will provide banks with a realistic solution for the difficult task of strategic balance sheet management under Basel III.

A third thing we can conclude about the optimization, is that the best way to choose the constraints is by fitting them in a time-line. By doing this, one can prevent enormous transaction costs in the future that would be necessary to achieve the required LCR and NFSR in respectively 2015 and 2018. Closing your eyes till then and only doing what is optimal at current would mean that a bank would run into a wall that is too high to overcome. By optimizing over the Basel III constraints of all coming years therefore is the best way to deal with the difficult regulations that are coming up.

**Performance.** We have shown that when using the described way of modeling, a very interesting balance sheet optimization tool can result. When we used the tool on a default bank with parameters as in

appendix A.4, we can improve the profitability of a bank quite a lot, without the need of modifying the balance sheet unrealistically much. In our example, the return on equity grew from 13.69 percent to 17.27 percent. Besides this profitability improvement, the tool took care of the risk preferences and strategy of the bank, and made sure that with the given optimal strategy and expected balance sheet growth, the bank will be sure of being Basel III compliant during the whole phase-in period. Therefore the tool can form a part in the answer to banks that are not sure how to react on Basel III yet.

We also showed that a bank does not have to hand in too much profitability when applying a higher level of conservatism. Risk profile modification could therefore be an interesting way of strategic balance sheet management.

The scenario analysis discussed showed us what performance metrics are most affected by what kind of scenario. We showed that:

- A 'Bank run scenario' affects the LCR and the return on equity of the bank most.
- A 'Credit rating downgrade' affects the capital adequacy of the bank most.
- An 'Unexpected large loss scenario' affects the profitability of the bank most.

Besides this, we showed that it would cost about 3.5 percent when one would optimize a bank with incorporated stress scenarios. Whether this is a big sacrifice or not depends on what is most important for a bank. But it is definitely a way to apply a higher level of conservatism when a bank seeks a more risk averse profile.

## 6.2 Further research

As with all kinds of research, a research problem is always restricted. This is a good thing, in order to prevent that it would lose its focus. It also means that there is room for other problems and questions in the same field, which gives the opportunity for further work.

The same is the case with the research performed during the internship period worked out in this report. A complex problem has been

partially tackled by this thesis, nevertheless a lot of components of the problem can be worked out more in to depth, in order to come to an even more precise modeling and optimization framework. The feedback by banks where the balance sheet optimization tool that was designed as a result of the research, gave a lot of insight in what questions are answered and what questions not. Also some questions arose after the demonstration of the tool.

One thing that could be done is the incorporation of an IRB approach for calculating the RWA, instead of a SA as the current model contains. This would make the calculation of the RWA and thereby the capital ratios more accurate.

As regards the balance sheet; the model contains a stylized balance sheet. This has a big advantage, namely that the problem remains clear and possible to model. The advantage is that actual balance sheets are not stylized but more specified. Therefore a possible extension of the model would be to replace the stylized balance sheet by a much more specified larger balance sheet. This also has a big disadvantage though. The optimization would become much more-dimensional and therefore very complex. The current tool already takes about twenty minutes to optimize the nine-dimensional problem with 1000 draws from the sample space, so it is not hard to understand that the extension of the balance sheet would increase this complexity a lot.

Another thing concerns the stochasticity in the model. In the current model, the user of the tool has the opportunity to optimize over a stochastic path of the parameters indicated in section 3.4, instead of keeping them deterministic. The advantage of this is that the development of the volatility of these parameters in time is captured better than in a deterministic context. The disadvantage though is that the stochastic path used in the optimization is only one possible path, drawn from a large sample space. It would be very interesting to use stochastic optimization here. This would mean that one would have to run much more optimizations over different stochastic parameter paths. It would increase the complexity of the problem tremendously, but it would provide a more accurate outcome.

With regard to the scenarios; it would be interesting to dig deeper into this component of the framework. One way to do this is working out the current scenarios more specifically. Also the addition of new scenarios would be a nice enhancement.

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# Appendix

## A.1

The stock of highly liquid assets exists of two type of assets. Basel III defines them as level 1 and level 2 assets, of which level 1 assets are more liquid and therefore stronger.

Both type of assets exist of different types of liquid assets, cash and bonds. To what extent they can be seen as highly liquid assets is determined by a percentage that is attached to each type of asset group that falls under the stock of highly liquid assets.

<b>Stock of high quality liquid assets</b>	
<b>Asset</b>	<b>Factor</b>
LEVEL 1 ASSETS	
Cash and cash equivalents	100%
Sovereign debt with 0% risk-weight (AAA & A)	100%
LEVEL 2 ASSETS	
Sovereign debt with 20% risk-weight (A)	85%
Qualifying corporate bonds rated AA- or higher	85%

The net cash outflows over a 30 day period is the sum of the total cash outflows minus the sum of the total cash inflows. Also here, there is a percentage attached to each type of outflow as defined by Basel III, in order to fine tune the LCR.

<b>Cash outflows</b>	
<b>Asset</b>	<b>Factor</b>
RETAIL DEPOSITS	
Stable deposits	5%
Less stable deposits	10%
UNSECURED WHOLESALE FUNDING	
Stable small business customers	5%
Less stable small business customers	10%
Small corporate wholesale	100%
Large corporate wholesale	100%
Financial institutions	100%
OTHER OUTFLOWS	
Debt certificate	100%

<b>Cash inflows</b>	
<b>Asset</b>	<b>Factor</b>
RETAIL RECEIVABLES	
Mortgages receivable from retail counterparties	5%
Loans receivable from retail counterparties	10%
NON-RETAIL RECEIVABLES	
Amounts receivable from non-financial wholesale	5%
Amounts receivable from financial institutions	10%

## A.2

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### Available stable funding

---

<b>Asset</b>	<b>Factor</b>
Cash and cash equivalents	5%
Guaranteed sovereign debt with 0% risk weight	5%
Corporate bonds (AA or higher & $\geq 1$ year)	20%
Non-financial corp. bonds (A & $\geq 1$ year)	50%
Non-financial corp. Counterparties loans ( $< 1$ year)	50%
(Mortgage) loans to retail customers ( $\geq 1$ year)	65%
Other loans to retail and small businesses ( $< 1$ year)	85%
All other assets	100%

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### Required stable funding

---

<b>Liability &amp; equity</b>	<b>Factor</b>
Tier 1	100%
Liabilities with effective maturity ( $> 1$ year)	100%
Stable retail&small customer deposits ( $< 1$ year)	90%
Less stable retail&small customer deposits ( $< 1$ year)	80%
Wholesale funding by non-financial firms ( $< 1$ year)	50%
All other liabilities	0%

---

### A.3

The penalty function for increasing a certain balance sheet position looks as follows:

```
Function penalty(base, actual, margin, riskPref)
  Dim factor As Double
  If riskPref = 1 Then
    factor = 0.05
  ElseIf riskPref = 2 Then
    factor = 0.125
  ElseIf riskPref = 3 Then
    factor = 0.2
  End If
  If actual >= 1.2 * base Then
    penalty = Abs((actual - 1.2 * base) / (0.5
      * base)) * (factor * margin)
  Else
    penalty = 0
  End If
End Function
```

The penalty function for decreasing a certain balance sheet position looks as follows:

```
Function penalty2(base, actual, margin, riskPref)
  Dim factor As Double
  If riskPref = 1 Then
    factor = 0.1
  ElseIf riskPref = 2 Then
    factor = 0.175
  ElseIf riskPref = 3 Then
    factor = 0.25
  End If
  If actual <= 0.8 * base Then
    penalty2 = Abs((actual - 0.8 * base) / (0.5
      * base)) * (factor * margin)
  Else
    penalty2 = 0
  End If
End Function
```

## A.4

Default parameter values:

$X_{Cash}$	=	3.0 Bn	$X^{MIN}_{Cash}$	=	2.0 Bn
$X_{RetMort}$	=	110.0 Bn	$X^{MIN}_{RetMort}$	=	80.0 Bn
$X_{LoansAdv}$	=	30.0 Bn	$X^{MIN}_{LoansAdv}$	=	15.0 Bn
$X_{OtherRec}$	=	10.0 Bn	$X^{MIN}_{OtherRec}$	=	5.0 Bn
$X_{GovBonds}$	=	35.0 Bn	$X^{MIN}_{GovBonds}$	=	20.0 Bn
$X_{CorpBonds}$	=	14.5 Bn	$X^{MIN}_{CorpBonds}$	=	5.0 Bn
$X_{Dep}$	=	115.0 Bn	$X^{MIN}_{Dep}$	=	80.0 Bn
$X_{DebtCer}$	=	45.0 Bn	$X^{MIN}_{DebtCer}$	=	20.0 Bn
$X_{UnsWF}$	=	35.0 Bn	$X^{MIN}_{UnsWF}$	=	15.0 Bn
$X^{MAX}_{Cash}$	=	5.0 Bn	$X^{MAX}_{Dep}$	=	150.0 Bn
$X^{MAX}_{RetMort}$	=	150.0 Bn	$X^{MAX}_{DebtCer}$	=	65.0 Bn
$X^{MAX}_{LoansAdv}$	=	45.0 Bn	$X^{MAX}_{UnsWF}$	=	50.0 Bn
$X^{MAX}_{OtherRec}$	=	18.0 Bn	$X_{AssetsTotal}$	=	202.5 Bn
$X^{MAX}_{GovBonds}$	=	50.0 Bn	$X_{LiabilitiesTotal}$	=	202.5 Bn
$X^{MAX}_{CorpBonds}$	=	25.0 Bn			
$C_{CET1_{2012}}$	=	3.2 Bn	$\delta_t$	=	55%
$C_{AddT1_{2012}}$	=	2.5 Bn	$\vartheta_t$	=	45%
$C_{T2_{2012}}$	=	1.8 Bn	$\tau_t$	=	30%
$\iota(X_{RetMort})$	=	2%	$\kappa(X_{GovBonds})$	=	10%
$\iota(X_{LoansAdv})$	=	3%	$\kappa(X_{CorpBonds})$	=	15%
$\iota(X_{OtherRec})$	=	2%			
$g(C_{AddT1})$	=	6.0%	$d(C_{AddT1})$	=	4.5%
$g(C_{T2})$	=	6.0%	$d(C_{T2})$	=	4.5%
$\zeta$	=	25%	$T_t$	=	2012
$v$	=	75%			
$RWA_t(X_{Cash})$	=	0.0%	$RWA_t(X_{OtherRec})$	=	85.0%
$RWA_t(X_{RetMort})$	=	35.0%	$RWA_t(X_{GovBonds})$	=	17.3%
$RWA_t(X_{LoansAdv})$	=	65.0%	$RWA_t(X_{CorpBonds})$	=	45.6%

$$\begin{aligned}
g(X_{RetMort})_t &= N(0.200, 0.011) \\
g(X_{LoansAdv})_t &= N(0.180, 0.01) \\
g(X_{OtherRec})_t &= N(0.100, 0.007) \\
g(X_{GovBonds})_t &= N(0.155, 0.009) \\
g(X_{CorpBonds})_t &= N(0.160, 0.009)
\end{aligned}$$

$$\begin{aligned}
d(X_{RetMort})_t &= N(0.065, 0.004) \\
d(X_{LoansAdv})_t &= N(0.055, 0.004) \\
d(X_{OtherRec})_t &= N(0.06, 0.006) \\
d(X_{GovBonds})_t &= N(0.070, 0.006) \\
d(X_{CorpBonds})_t &= N(0.040, 0.002)
\end{aligned}$$

$$\begin{aligned}
g(X_{Dep})_t &= N(0.120, 0.005) \\
g(X_{DebtCer})_t &= N(0.190, 0.011) \\
g(X_{UnsWF})_t &= N(0.180, 0.012)
\end{aligned}$$

$$\begin{aligned}
d(X_{Dep})_t &= N(0.025, 0.002) \\
d(X_{DebtCer})_t &= N(0.05, 0.004) \\
d(X_{UnsWF})_t &= N(0.090, 0.006)
\end{aligned}$$

$$\begin{aligned}
m^{EXP}(X_{Dep})_t &= N(0.029, 0.000) \\
m^{EXP}(X_{DebtCer})_t &= N(0.025, 0.000) \\
m^{EXP}(X_{UnsWF})_t &= N(0.027, 0.000) \\
F^{EXP}_t &= N(250, 25) \\
O^{EXP}_t &= N(400, 40) \\
D^{EXP}_t &= N(200, 20) \\
S^{EXP}_t &= N(100, 10)
\end{aligned}$$

$$\begin{aligned}
m^{INC}(X_{RetMort})_t &= N(0.052, 0.000) \\
m^{INC}(X_{LoansAdv})_t &= N(0.042, 0.000) \\
m^{INC}(X_{OtherRec})_t &= N(0.038, 0.000) \\
m^{INC}(X_{GovBonds})_t &= N(0.031, 0.000) \\
m^{INC}(X_{CorpBonds})_t &= N(0.036, 0.000) \\
F^{INC}_t &= N(830, 83) \\
O^{INC}_t &= N(450, 45)
\end{aligned}$$

