ECONOMIC CAPITAL FOR DUTCH RETAIL BANKING BOOKS

A STUDY ON THE EFFECTS OF EMBEDDED OPTIONS IN DUTCH RETAIL BANKING BOOKS ON INTEREST RATE RISK AND ECONOMIC CAPITAL

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PROEFSCHRIFT

ter verkrijging van
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door

Theodorus Petrus Gerardus van Mullem
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Dit proefschrift is goedgekeurd door

de promotoren: prof. dr. ir. A. Bruggink
prof. dr. J. Bilderbeek

Voorwoord

Hoewel helemaal voorin het proefschrift, is het voorwoord een van de laatste delen, zo niet hét laatste deel dat geschreven wordt. En wat mij betreft is het ook een van de moeilijkste onderdelen. Die moeilijkheid zit hem niet zo zeer in de opzet. Zoals een van mijn voorgangers al constateerde lijkt het voorwoord aan enkele ongeschreven regels gebonden (zie ook Bos, 1999b, p. 7). Zoals hij stelt, volgt na een dankwoord aan de promotoren en anderen die inhoudelijk hebben bijgedragen aan het proefschrift, steevast een lijst met personen die het leven van de promovendus dragelijk hebben gemaakt.

Om nu terug te komen op die moeilijkheid: hoewel bovenstaand stramien op zichzelf het schrijven van het voorwoord makkelijk maakt, wordt het tegelijkertijd moeilijk om daarin toch nog enigszins creatief voor de dag te komen. Sommigen doen dat met de nodige dosis humor en al dan niet wetenschappelijk verantwoorde stellingen (zie bijvoorbeeld Van Triest, 2000). Weer anderen hebben hun naam mee (zie bijvoorbeeld Van den Tillaart, 2003).

Voor mij persoonlijk is de ontdekkingstocht die promoveren heet echter het best te vergelijken met het wielrennen, een sport die mij na aan het hart ligt. Mijn carrière begon wat dat betreft in 1998. Na een overwinning in een belangrijke amateur-koers - het behalen van mijn doctoraal Technische Bedrijfskunde - werd het tijd voor een nieuwe uitdaging. Die bestond wat mij betreft uit het rijden van andere amateur-koersen in het "buitenland", wat wil zeggen het voortzetten van mijn studententijd aan wat toen nog de Katholieke Universiteit Brabant heette om Rechten en Bedrijfseconomie te gaan studeren. Echter, tijdens die laatste koers werd ik door mijn "ploegleider" Bert Bruggink gevraagd om een profcontract te overwegen. Mijn programma voor de komende seizoenen zou ik zelf nader mogen bepalen. Hoewel ik er even over moest nadenken was het feitelijk een aanbod dat ik niet kon laten lopen. Toen vervolgens de tweede ploegleider van mijn beoogde ploeg, Jan Bilderbeek, ook enthousiast bleek, was de beslissing toch nog snel genomen.

Zo kwam het dus dat ik eind 1998 begon met de training voor het grote werk, dat uiteindelijk begin 1999 begon. Het programma had ik toen ook al bepaald. Ik zou vooral koersen gaan rijden in het gebied dat "economic capital" heet. Al gauw bleek dat echter een wel erg groot gebied te zijn en werd het onderzoek ingekaderd tot een studie naar de effecten van zogenaamde embedded options in producten in het retail bank bedrijf. Om het in gewoon Nederlands te stellen: hoe kunnen we nu de risico's die verbonden zijn aan optie-achtige constructies in producten voor de particuliere sector zo goed mogelijk in kaart brengen.

Om dat onderzoek te doen, werd ik opgenomen in een ploeg die de vakgroep Financieel Management en Bedrijfseconomie (kortweg FMBE) van de Universiteit Twente heette. Zeer regelmatig echter werd ik als gastrenner opgenomen in het ALM-team van mijn sponsor, de Rabobank. Zodoende was het mogelijk om het beste van twee werelden te combineren. Enerzijds zat ik bij de bank natuurlijk bovenop de praktijk, anderzijds was het mogelijk om de rust van de universiteit op te zoeken om een en ander nader te bestuderen en op te schrijven.

Derhalve werd mijn promotietraject net zoiets als een Tour de France. Na een aantal vlakke etappes waarin het onderzoeksgebied en onderzoeksdoel helder gesteld werden, begon de koers feitelijk pas echt, toen de bergen zich aandienden. In mijn geval bestonden die bergen uit het ontwikkelen en schatten van enkele modellen. Wie het wielrennen enigszins volgt, weet dat de kopman dit niet alleen kan, maar dat hij helpers nodig heeft. In mijn geval waren de "waterdragers" diegenen die een sfeer creëerden waarin het prettig werken was. Ik denk dan met name aan mijn voormalige collega's aan de universiteit en binnen het ALM-team van Control Rabobank Groep. Daarnaast zijn ook enkele "meesterknechten" nodig die de kopman tot bijna bij de top brengen met hun inhoudelijke commentaren en aanmoedigingen. Ik denk daarbij met name aan Pieter Emmen en Jacco Wielhouwer. Met hun hulp en de steun van de beide ploegleiders, Bert Bruggink en Jan Bilderbeek, was het mogelijk een goede uitgangspositie te krijgen in het algemeen klassement.
Na de reeks van bergetappes was er in feite nog één grote uitdaging: de individuele tijdrit. In mijn geval: de race tegen de klok om het proefschrift op tijd bij de drukker te krijgen. Gelukkig bleek deze hindernis minder zwaar dan gedacht en was het zodoende mogelijk om met het geel om de schouders de laatste etappe in te gaan.
Die laatste etappe doet er in de wielerwereld meestal niet zo toe, alhoewel er aan het einde toch nog meestal heel hard gereden wordt. Wie kent de rondjes door hartje Parijs niet? In een promotietraject gaat het eigenlijk net zo. De officiële verdediging begint pas in de middag, maar dan gaat het ook 45 minuten lang heel hard. Echter, de voldoening aan het eind is groot en de moeite waard.

Rest mij om aan het eind van dit voorwoord nog een dankwoord te richten aan mijn "fanclub". In de eerste plaats denk ik dan aan Pieter Verbraeken en mijn broer Hugo, die mij in die laatste etappe tot steun waren als paranimf. Ook wil ik mijn ouders en schoonouders bedanken, die regelmatig vroegen hoe het nu eigenlijk ging. Op de een of andere manier was dat vaak op een moment waarop het even niet liep in het traject. Maar ja, als sportman wil je nu eenmaal niet opgeven en zeker niet in het aangezicht van je fans, dus eigenlijk stimuleerde dit om toch nog een tandje bij te zetten en te proberen het probleem (of liever: uitdaging) te tackelen.
Tenslotte denk ik aan mijn vrouw Andrea en onze dochter Mariëlle. Zoals zo vaak blijft de invloed van de directe omgeving van de sporter op zijn prestatie onderbelicht. Zonder hun steun is een topprestatie echter onmogelijk. Andrea, je hebt geen idee hoe groot jouw invloed was, maar ik durf de stelling wel aan dat dit proefschrift er niet gekomen was zonder jouw steun en peptalk zo af en toe. Daarvoor heel hartelijk dank. En Mariëlle, je ben nog te klein om te beseffen hoe gelukkig jij me maakt. Maar als je later groot bent moet je dit maar eens lezen: als jij naar me lacht, schijnt de zon in mij, hoe slecht het weer ook is.

Fedor van Mullem
Arnhem, 9 januari 2004

Contents

1

Introduction, problem definition, methodology and summary

1.1 Introduction to interest rate risk in the banking book

This thesis is about interest rate risk in Dutch retail banking books and its economic capital. An important concept in these fields is capital regulation. In the banking environment an important shift in capital regulation and risk measurement can be observed. This shift has two main components. The first one is a shift towards economic capital calculation. This means that capital regulation more and more reflects "real risk" and allows banks to use internal models to measure risks. Secondly, more risk types will be included in capital regulation. For example, one could think of interest rate risk in the banking book, liquidity risk and operational risk.

Therefore new or improved methods for calculating the risk exposure and the amount of economic capital required by these 'new' types of risk are needed. Furthermore, since economic capital is based on the actual risks in a portfolio, it can be used for risk adjusted performance measurement and management control. More about risk adjusted performance measurement can be found in Bos (1999a and 1999b). The theory of management control is studied in more detail in, for example, De Leeuw (1990), Kramer & De Smit (1991), Bos & Bruggink (1996), Pape (1999), Van den Tillaart (2003) and Scheffer (2004).

At present banks have to hold equity for their credit risk and market risk exposures. The capital charge for its credit risk exposure is calculated using a standardised method. To calculate the capital charge for its market risk exposure a bank is allowed, under some conditions, to use an internal model.

In 1999 the Basel Committee[1] proposed a major upgrade to the current regulation by issuing a consultative paper with a new credit risk approach. In that paper the Committee also mentioned that it wants to incorporate more types of risk in the capital adequacy regulation. Mentioned were interest rate risk in the banking book and operational risk.

Since interest rate risk in the banking book is one of the "new" risk types in the capital adequacy framework, the focus in this thesis will be on this type of risk.

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[1] The Basel Committee on Banking Supervision consists of representatives of the central banks and supervisory authorities of the Group of Ten countries (Belgium, Canada, France, Germany, Italy, Japan, The Netherlands, Sweden, Switzerland, United Kingdom, United States) and Luxembourg. The Committee meets at the Bank for International Settlements in Basel, Switzerland and therefore is sometimes abbreviated as BIS.

What is interest rate risk in the banking book? For now, we will define it as the risk of losses in the banking book[2] due to unexpected changes in interest rates.
In order to calculate a capital charge for interest rate risk in the banking book, it is necessary to quantify it first. Currently, banks use a number of different methods to quantify interest rate risk in the banking book. In section 2.3.3 these techniques will be studied in greater detail.
The problem with interest rate risk in the banking book is the numerous assumptions necessary for a number of products that influence the outcome of the risk quantification process. These are required because most of the typical (retail) banking book products have so-called embedded or implicit options. This means that products have option-like features. An example may clarify this. A normal product or product category in the retail banking book is savings accounts. A typical feature of this product is that clients can determine at any time to withdraw money from that account. However, usually, there will be some amount present in that account at all times. Furthermore, the rate paid on that account is determined by the bank and can mostly be adjusted at any time. Because of this, some banks regard these products as short-term. Other banks however argue that the interest rate paid on these accounts is on average adjusted annually. Therefore, these banks regard these products to be medium term. So, because embedded options can influence the cash flows in the banking book, they also have an effect on the risk exposure and therefore the economic capital requirement of the book. Currently, the way in which a bank treats these accounts can have a big impact on the outcome of economic capital calculation. Not much is known about the effects of these embedded options. However, the need for a more objective economic capital model which captures these effects is clear.
We have already introduced several concepts and will use more. Section 1.2 will contain the definitions of the core concepts of this thesis. This section also gives the problem statement and research questions. The general outline of the thesis will be presented in section 1.3. Section 1.4 summarises the thesis.

1.2 Problem statement & methodology

1.2.1 Introduction

This section states the aim of this research (section 1.2.2). After that will we give the research questions in 1.2.3. Answering these questions enables us to reach the research goal. Core definitions will be given in section 1.2.4 to clarify the most important concepts of this thesis. Finally, section 1.2.5 ends this section with some methodological considerations.

1.2.2 Research goal

Verschuren and Doorewaard (1998) define a number of different phases to come from the defined problem to the research questions. Others summarise these phases and call it the formulation of the problem statement. Examples are De Leeuw (1996, p. 81) and Van der Zwaan (1995, p. 28).

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[2] A definition of the banking book follows later.

A problem statement exists of two different parts. The first one is the definition of the research goal. The second part is the definition of the research questions. Following Van der Zwaan (1995, p. 29): "*The research goal gives the 'why' of the research, or in other words, the answer the researcher wants to find. The research question gives the 'what' of the research, or in other words, the exact knowledge that has to be gathered to find the answer*". Verschuren and Doorewaard state that the research environment usually is too big to study as a whole. Therefore the research goal has to give direction to the research. It has to define that part of the environment the researcher wants to study.

De Leeuw (1996, p. 82) states that an adequate problem statement requires "*relevance, feasibility and efficiency*". This means that a research goal must satisfy these requirements too. Verschuren and Doorewaard (1998, p. 31) also set some requirements to the research goal. Their view is that a research goal has to be "*useful, feasible, unequivocal and informative*". These concepts are more or less equal. A relevant or useful research goal means that it could actually contribute to the present knowledge in the problem field. A feasible research goal means that the researcher must be able to perform the research within the limitations set by time, money, data availability, and so on. An unequivocal and informative research goal tells the researcher what he wants to achieve and roughly how he thinks he can achieve it.

In section 1.1 we briefly mentioned the concept of economic capital. As we will see later on, the concept of economic capital theoretically comprises all types of risk present within a bank, which makes it a very broad field to study. Therefore in this thesis the focus will be on economic capital for only one type of risk within a bank. This is interest rate risk in the banking book, since this is one of the 'new' risks in the capital adequacy regulation. However, the banking book is still a wide concept and can include both the wholesale and retail banking book. We are particularly interested in the effects of so-called embedded options on interest rate risk and economic capital. Since most embedded options are present in the retail banking book, as we will see later on, the focus will be on this part of the banking book.

Accordingly the goal of this research will be **to study the effects of embedded options in the retail banking book on interest rate risk and economic capital**.

1.2.3 Research questions

From the research goal it follows that knowledge is required on, at least, the type of embedded options found in the retail banking book, interest rate risk and economic capital. In order to gather knowledge on interest rate risk, we shall first study the risk types typical in banking and see how interest rate risk fits in. Secondly, we shall study the specific concepts of interest rate risk (in the banking book). This yields the following questions:

1. What risks can be identified in banking?
2. What is interest rate risk in the retail banking book and how is it measured?

We will see that embedded options are part of interest rate risk in the banking book. We will, however, first focus on economic capital and postpone the study on embedded option effects to research question four. Research questions three and four therefore read:

3. What is economic capital and why is it important?
4. In what way can the effects of embedded options in the retail banking book be measured?

Finally, our last question brings us to our research goal:

5. What are the effects of embedded options in the retail banking book on interest rate risk and economic capital?

1.2.4 Core definitions

Throughout the thesis we will define and use several concepts. Below we give the definitions of the most important concepts. Unless stated otherwise, when we use these concepts, we use them in the context of the definitions below.

- Risk
  In general risk is defined as uncertainty. Since this thesis focuses on economic capital, which looks at the downside of risk, we define risk in this thesis as the chance that a contract or process has an unfavourable outcome.
- Trading book
  In the trading book the bank tries to benefit from differences between the buying and selling prices of the instruments in the trading book.
- Retail banking book
  In the banking book the bank tries to profit from the margin between what is earned on assets and paid on liabilities. The retail banking book is a part of the banking book that focuses on private persons and small businesses.
- Interest rate risk in the retail banking book
  Negative effects in accrual income and/or negative value changes in on- and off-balance-sheet positions in the retail banking book due to unexpected changes of interest rates.
- Option
  An option is a financial contract which gives the holder the right, but not the obligation, to exercise the terms of the contract at a certain date or during a certain period.
- Embedded option
  An embedded option is an option, which is "built into" a financial product.
- Embedded options risk
  Embedded options risk is an aspect of interest rate risk in the retail banking book, where the negative effects on earnings are caused by embedded options.
- Withdrawal option
  The withdrawal option is an embedded option in savings products which gives the holder the right, but not the obligation, to withdraw credits on his account at any time for free.
- Prepayment option
  The prepayment option is an embedded option in a mortgage contract, which gives the mortgagor the right, but not the obligation, to prepay (part of) his loan for free. In the Netherlands, this option is limited to only 10% to 20% of the original contractual amount per calendar year.

- Interest rate consider period option
  An interest rate consider period option is an embedded option in a mortgage contract, which gives the mortgagor the right but not the obligation to reconsider the interest rate fixed period during the last *y* years of the current interest rate fixed period. During these *y* years, the mortgagor can change the interest rate fixed period for free.
- Embedded life cap/floor
  An embedded life cap/floor is an embedded option in a mortgage contract, which sets an upper/lower limit to the contract rate. Actually, this is not really an option, although it is usually included in embedded options risk.
- Embedded period cap/floor
  An embedded period cap/floor is an embedded option in a mortgage contract, which sets an upper/lower limit to the maximum contract rate increase/decrease at interest rate fixing dates. As above, this is not really an option, although it is usually included in embedded options risk.
- Quotation rate option
  The quotation rate option is an embedded option in a mortgage commitment, which gives the holder the right, but not the obligation, to get a mortgage for the terms specified in the commitment, at the lowest mortgage rate during the commitment period.
- Choice option
  The choice option is an embedded option in a mortgage contract, which gives the mortgagor the right, but not the obligation, to chose another fixed period at interest rate fixing dates.
- Economic capital
  Amount of equity that is required to cover for unexpected losses within a certain confidence level and a certain time period.
- Accounting capital
  Amount of equity in the balance sheet. Based on accounting principles.
- Regulatory capital
  Amount of equity prescribed by capital regulation. Also known as solvency.
- Fair value
  Fair value is the amount for which an asset could be exchanged, or a liability settled, between knowledgeable, willing, parties in an arm's length transaction.

1.2.5 Methodological considerations

In sections 1.2.2 and 1.2.3 we specified the goal of this research and its research questions respectively. In this section we will outline the methodology used to find answers to our questions and thus to reach the goal of this research.

In answering research questions one, two and three we mainly used a study of available literature. That is, we found the risks inherent to banking from relevant literature as well as several methods for measuring interest rate risk. We also used literature to study the concept of economic capital in more detail. We clearly found evidence of the increasing interest in this subject, since the amount of literature on this subject grew during the time of this research.

The methodology used for answering research question four was slightly different. Again, we studied relevant literature in order to find methods to measure the effects of embedded options in the retail banking book. From this study we concluded that available information about the prepayment option in Dutch mortgages has increased and can be used in our study, especially the study of Alink (2002). We also found some literature on the withdrawal option, although mostly based on American products, which are (slightly) different from the products found in the Dutch market. We therefore decided to estimate our own models. We also decided to use data of the Dutch Central Bureau of Statistics (CBS) where possible.

Based on discussions with specialists at the bank, we concluded that a retail bank's liabilities mainly consists of four parts: equity, retail liabilities, interbank liabilities and wholesale liabilities. Retail liabilities consist of demand deposits, savings accounts and term deposits. The withdrawal option is present in the first two categories, which are currently the biggest in volume.

We then estimated a model for the total demand of these retail liabilities. Basically, we started with variables that intuitively should explain demand. Insignificant variables were excluded from the model, which was then re-estimated. We continued this procedure until all remaining variables were significant.

Although the resulting model of total demand explained demand quite well, the structure of the model could cause highly inaccurate forecasts. We therefore estimated models for the separate items in the retail liabilities as well. Basically, we took the approach of starting with the models simplest possible and tried to increase the explanatory power by adding more variables.

Because we want to forecast with the demand models, we also required a model for the interest rate. We decided to use the well known Cox, Ingersoll & Ross (CIR) one-factor interest rate model and the less known three-factor model of De Feijter (2002), because we wanted to see the effect of different interest rate models on the outcome. We estimated the parameters of the CIR model on our data, but decided to use the parameters as estimated by De Feijter, because her model is already based on Dutch interest rate data.

With regard to the other embedded options we identified, the interest rate consider period option, embedded caps and floors, the quotation rate option and the choice option, we found little literature. However, as we regard the impact of these options to be small, we did not estimate their effect in much detail.

Our final step in reaching the goal was to measure the impact. We did this in detail for the withdrawal option. Based on the estimated models, we did a forecast of demand and derived a value for these products by applying the valuation procedure of Jarrow and Van Deventer. In total we ran 100,000 scenarios using Monte Carlo techniques. From the resulting value distribution we can take a certain confidence level from which economic capital is derived.

Regarding prepayment risk, we explained how the prepayment models can be used to determine the magnitude of the risk. For this we used a simplified example. Basically, although the models differ in the variables they use, they all produce forecasts of the expected monthly prepayment. One variable that is present in all models is the refinance incentive, which basically measures the financial gain the mortgagor can have by prepaying. The refinance incentive is dependent on the interest rate. By simulating interest rates, one can simulate various prepayment patterns. Since prepayment alters the cash flow scheme and thus the value of the mortgage, the result is a value distribution from which economic capital can be derived.

Again, we did not pay much attention to the other embedded options, although we specified some methods on how to determine economic capital for these options.
Finally, we looked at portfolio effects, since it is highly likely that the effects are correlated and can show a mitigating effect. Unfortunately, we lacked data to do a detailed study on portfolio effects and therefore used a simplified example, with some assumptions to show the effects of all options combined.

1.3 Outline

After a summary in the next section we will provide some theoretical background for this research. In chapter 2 we will start with a description of the risk types inherent to banking, followed by a study of interest rate risk in the banking book. We will identify the different types of interest rate risk and also describe methods commonly used to measure the size of the risk.
We look at both economic capital and economic capital models in that chapter as well. Finally, chapter 2 will also provide a short summary of the relevant regulation. The regulation is split into capital regulation and accounting regulation. With regard to capital regulation, we will, after a brief general introduction, focus on capital regulation relating to interest rate risk. Regarding accounting regulation, we focus briefly on International Accounting Standards (IAS) 32 and 39. Since these accounting guidelines have a major impact on the way derivatives have to be presented in the balance sheet, they may affect interest rate risk management as well. At the end of chapter 2 research questions one, two and three will be answered.
Based on our literature study in chapter 2 we conclude that basically six types of embedded options can be identified in products typical for the retail banking book. They are the withdrawal options, the prepayment option, the interest rate consider period option, embedded caps and floors, the quotation rate option and the choice option. Finding ways to measure the effects of these embedded options was the focus of research question four. We will answer this question in chapters 3 to 5.
We consider the withdrawal option and the prepayment option to cause the biggest risks. We therefore study these options separately in chapter 3 and 4 respectively. The other options will be discussed in chapter 5.
Chapter 6 will then answer research question five, which focused on the effects of the embedded options on interest rate risk and economic capital. Finally, in chapter 7 we conclude and give recommendations for further research.

1.4 Summary

In this thesis we study the effects of embedded options in the retail banking book on interest rate risk and economic capital. In chapter 1 we give an introduction to the field. Further we define some core concepts and describe the research goal and research questions in that chapter. The goal of this research is to study the effects of embedded options in the retail banking book on interest rate risk and economic capital. To reach this goal, we start with a study of banking risks in general in chapter 2. At the end of that study we provide a general risk typology, thereby answering research question one.

We then focus on interest rate risk in the retail banking book; the definition we use for this type of risk throughout this thesis is:

Negative effects in accrual income and/or negative value changes in on- and off-balance-sheet positions in the retail banking book due to unexpected changes of interest rates.

Our findings are that interest rate risk in the banking book is caused by four factors, which are mismatch and yield curve risk, which are caused by a mismatch between assets and liabilities; basis risk, which is caused by failing correlations between yield curves; and embedded options risk, which is the risk due to embedded options. We will define six types of embedded options, namely:

- withdrawal option;
- prepayment option;
- interest rate consider period option;
- embedded caps and/or floors;
- quotation rate option;
- choice option.

Furthermore, we will describe numerous methods of measuring interest rate risk. We split the measurement methods by their approach. Methods can be value based or earnings based. Further methods can be static or dynamic. We notice a trend towards more sophisticated approaches, that is dynamic value based methods. At the end of this study we have answered research question two.

Having looked in detail at interest rate risk in the retail banking book, we will focus on economic capital. We note capital can be defined in three ways, resulting in accounting, regulatory and economic capital. The latter defines capital as the amount of equity that is required to cover unexpected losses within a certain confidence level and a certain time period. We have also studied economic capital models and derived a general economic capital model from this study.

To explain why economic capital is getting more and more attention, we describe some (recent) regulations, both capital adequacy as well as accounting regulations. In capital adequacy regulation we can see a shift towards internal models, which should reflect the economic risks. We see more or less the same in accounting regulations, where the focus is getting more and more on the real economic value (fair value). This study answers research question three.

We then finally start with our study on the effects of embedded options on interest rate risk and economic capital. We first study methods to measure the effects (chapters 3, 4 and 5), before focussing on the actual effects (chapter 6).

We start with a study of the effects of the withdrawal option in chapter 3. This option is present in non-maturing instruments on the liability side of the balance sheet, viz. demand deposits and savings accounts. Therefore, we conclude that we need to explain saving behaviour before we can measure the effects. We briefly study Keynes' theory on liquidity-preference, according to which an individual basically makes two decisions (Keynes, 1936).

The first decision is how much of his income he will consume and thus how much remains for saving. The second decision is how he will invest that amount. Depending on his liquidity-preference the individual will keep this money in cash, on some account and/or invest it in the stock market, for example.

When this is applied with respect to the withdrawal option, we can identify the same three classes. First of all, “saving” by individuals to pay for their bills is done on a demand deposit. Interest on these accounts is low or zero. The amounts on these accounts are expected to be relatively interest rate insensitive – people have to pay for their bills anyway. A second class of savings are the “normal” savings. People save on their savings accounts for later big consumptions. Savings in this category are expected to be moderately interest rate sensitive.

The above two categories of savings are typically done on products, which include the withdrawal option. The third category, that is the speculative savings, is somewhat different. It is not the immediate availability of money without the risk of loosing some that is important here, but the return. In this category, people are expected to switch relatively quicker between products. In this category investments in stocks or stock options are located as are investments in term deposits or ordinary savings accounts, depending on the expected return.

Since we concluded that economic capital should be calculated using a value approach, our final goal in chapter 3 is to find a valuation procedure for Dutch demand deposits, savings accounts and term deposits. The latter product does not include the withdrawal option, but is regarded as an important replacement product.

We have found some valuation procedures in literature and decide to use the Jarrow-Van Deventer approach. The reason being that this model has been used in other studies as well.

Since the Jarrow-Van Deventer approach requires demand models, we then focus on modelling savings demand. We have also found several demand models in literature, but decided to model our own. One of the reasons for not choosing an existing model is that most of them use previous month’s volume (and other variables) to estimate this month’s volume. Whilst volume from month to month shows a large correlation, there is the danger of a unit root in the series, causing the series to be non-stationary. Due to this non-stationarity general assumptions of least squares regression do not hold and the resulting statistics of the regression must be handled with care. In our data, we also find unit roots. This was the case for both savings volume and term deposits volume.

Before estimating our own models, we first study the determinants of saving behaviour. Based on several studies the following indicators are identified:

- household income;
- the level of interest rates on savings accounts;
- expected return on the stock market;
- the marginal tax rate; and
- several demographic factors such as:
    - age;
    - social background;
    - family composition; and
    - region.

Unfortunately, we don't have detailed data on the above indicators. As a result we have to limit ourselves to a more aggregate level and specify models to the total demand of demand deposits, savings accounts and term deposits. Nevertheless we have found models with reasonable explanatory power and forecasting capabilities.
The Jarrow-Van Deventer valuation procedure requires interest rates as well, first to calculate the interest payments, and second to use for discounting. We assume interest rates on demand deposits to be zero, and therefore do not estimate a model for it. On the other hand we do estimate models for both the savings rate and the term deposits rate. Both models have reasonable explanatory power and good forecasting performance. Finally, we have estimated models for the risk-free rate which is used for discounting. We have estimated parameters for the well-known Cox, Ingersoll & Ross (1985) model, as well as a multi-factor model to overcome the disadvantages of a one-factor model (De Feijter, 2002). The multi-factor model is capable of capturing the most important empirical phenomena that have been observed: (1) the yield curve is increasing on average; (2) the term structure of volatilities is decreasing on average; (3) yield lie on a smooth curve, hence yield with little time to maturity are highly correlated; (4) interest rates are more volatile when the interest rate level is high; and (5) mean-reversion is stronger in cases where the interest rate level is further away from the mean-reversion level. With the estimated models we are able to calculate a value for the different savings products. That is, we find an answer to research question four on how to measure the effects of embedded options with regard to the withdrawal option.
Methods for measuring the effect of the prepayment option, are the subject of chapter 4. Research on the prepayment option is vast in the USA. However, due to the differences between the Dutch and American mortgage market, American models can not be applied directly to the Dutch situation. Nevertheless, after a brief introduction on the Dutch mortgage market, we start with a description of the well-know study of Kang and Zenios (1992), which is known as the Wharton-model. This model is more or less the basis for all subsequent research on mortgage prepayment, including Dutch research. The model explains prepayment by four factors, which are the refinance incentive, seasoning, burnout and seasonality. The first variable captures the financial motives for prepayment. Seasoning and burnout are aging effects and in fact each others opposites, whilst seasonality captures seasonal changes in prepayment rates.
After the study of the Wharton model, we focus on Dutch research. Most of this research is empirical. Basically, these empirical models predict monthly prepayment rates. Based on these studies, it can be concluded that the prepayment option is valuable. However, it has to be taken into account that most of the prepayment models are based on a relatively short history, during which mortgage rates decreased most of the time. Nevertheless, the models can help to measure the effects of the prepayment options.
Finally, we answer research question four for the other embedded options, viz. interest rate consider period option, embedded caps and floors and the quotation rate option as well as the choice option in chapter 5.
Regarding the interest rate consider period option, we conclude that there are basically three approaches to model the effects, which are constructing a replicating portfolio, regard the interest rate consider period options as a penalty-free prepayment option during the last two years of the interest rate fixed period or by simulation. We conclude that we can best use simulation. The reasons are the differences between the interest rate consider period option and the prepayment option as well as the difficulty in finding a replicating portfolio, due to

other embedded options in a mortgage. In simulation one can take the effects of these options into account as well, although one needs to make assumptions on the behaviour of mortgagors. The risk of the interest rate consider period option is considered low though. The main cause for this is that the mortgagor needs to pay fees during the fixed period of the mortgage with the embedded interest rate consider period option. Usually this price is 20 basis points. One of the conclusions of Van Mullem (1998) is that this fee is enough to hedge the risk of exercising even if the mortgagor behaves optimal. Furthermore, mortgages with this option embedded are only sold in small numbers.

Embedded caps and floors as such are not common in Dutch mortgages. The only cap that is present in Dutch mortgages is the quotation rate option. Once the mortgagee offers the mortgagor a mortgage, this offer usually contains a quotation rate option. Effectively, this option insures the mortgagor against interest rate increases during the quotation period. On the other hand, the mortgagor profits to a full extent from interest rate decreases. The coupon on the mortgage once the offer is locked in is the lowest between the quotation date and the lock-in date. Although this option is present in all quotes, the risk is fairly small, due to the fact that (1) the quotation often has a maturity of only three months, (2) mortgage rates are usually not that volatile and (3) the risk of this option can be hedged by the bank. Using the lowest mortgage rate in the past three months as the locked-in rate in simulation will probably model the risk of this option well.

Finally, we describe the choice option. We conclude that the risk in this option will be low, since the bank can adjust its funding to the choice of the mortgagor. Furthermore, mortgages are usually funded on a portfolio level, which further mitigates this risk.

Finally, we focus on the last research question, which reads: "what are the effects of embedded options in the retail banking book on interest rate risk and economic capital?" in chapter 6.

We start with a study of each option's individual effect. We argue that only the withdrawal option as well as the prepayment option have a potential large impact on interest rate risk and economic capital.

In chapter 6 we use the models of chapter 3 to simulate the effect of the withdrawal option. We conclude that the choice of the interest rate model, used for discounting and to generate the other interest rates, has a major impact on the calculations. Furthermore, we can conclude that a portfolio of demand deposits, savings accounts and term deposits has a lower economic capital requirement than the sum of the economic capital requirement of the separate items. Finally, we find that the net present value of savings accounts can become negative under unfavourable conditions. This is mainly due to the assumption that total savings accounts volume at the assumed time horizon is paid back. An assumed higher time horizon might change this, although we may expect the volume to increase as well. Furthermore, the bank will have to pay interest for a longer period.

Concluding, we state that the impact on interest rate risk and economic capital due to the withdrawal option is small. This is reflected by most banks' policy to treat demand deposits and savings accounts as partial long-term funding and partial short-term funding, where the long-term part is usually larger. The biggest potential risk is a new competitor who offers an extremely high interest rate on his savings account. Due to the moderate interest rate sensitivity of savings accounts, an outflow of funds might occur.

With the studies described in chapter 4 we estimate the impact on interest rate risk and economic capital of the prepayment option in chapter 6 as well. We use a simplified example to show how the models of prepayment behaviour work. From this example we learn that the change in value of a mortgage portfolio due to prepayment can be substantial. In our example the net present value decreased by 20%, which of course is a substantial amount.
After studying the individual effects, we focus on the joint effect and look at the balance sheet of a typical retail bank. We then apply two simple parallel shock scenarios to this balance sheet using several simplifying assumptions. From the resulting figures we learn that a upward shock causes losses in capital, whereas a downward shock is followed by a gain in capital, despite prepayments in the mortgage portfolio. One should bear in mind that this is just an example, and that other assumptions would have lead to other outcomes, but in general we can state the following: although the withdrawal option is present in two large products on the liability side of the balance sheet, savings accounts and demand deposits, its influence is marginal. In the past ten years we have witnessed declining interest rates in the market, as well as for these products, whereas the volume of savings accounts and demand deposits still grew. Therefore, although the potential risk caused by the withdrawal option is large, since the bank can loose the biggest part of its balance sheet, the actual risk is considered small. As already mentioned the biggest risk occurs when a (new) competitor suddenly offers an extremely high interest rate on comparable savings accounts. Due to the moderate interest rate sensitivity this might lead to a potentially large outflow of funds. So the risk is small, but economic capital should be substantial, since economic capital should cover unexpected events.
Regarding the prepayment option, we can state that this risk is more significant. We have seen in the late 1990's that prepayment rates went up, because of historical low mortgage rates. Since large parts of bank's mortgage portfolios are renewed since then, prepayments are not going to be very likely in the near future. However, when mortgage rates go up again, prepayment might become more important again. The worst case scenario for prepayment is when rates first go up significantly and than decrease again. In this case the opposite of the withdrawal option is true. That is, the risk of the prepayment option is substantial, however economic capital can be lower, since prepayment can be predicted relatively well. Since economic capital is only for unexpected events, expected prepayments should be covered by normal risk management procedures.
Finally, we question whether we reached the goal of our research, which reads: "to study the effects of embedded options in the retail banking book on interest rate risk and economic capital". We can conclude that we reached this goal. For the most important embedded options we have either developed our own models or are able to use models from other researches that are capable of measuring the effects of the embedded options on interest rate risk in the retail banking book as well as economic capital. However, there are still some issues, which we are not able to solve, mostly due to a lack of data.

2

Interest rate risk, economic capital and regulation

2.1 Introduction

In this chapter some theoretical background will be given. At the end of this chapter, we will have answered research questions one, two and three. First we study the risks present in banking (section 2.2). That section will answer research question one. Research question two will be answered in section 2.3. In that section we will study interest rate risk in the banking book more specifically. We will focus on aspects of interest rate risk, and measurement and management tools. Economic capital and economic capital models will be studied in section 2.4. Regulation will be the focus of section 2.5. In these two sections an answer will be given to the question of what economic capital is and why it is so important. Finally, in section 2.6 we will conclude the main findings.

2.2 Risk types

2.2.1 Introduction

At first sight it seems as if there are as many risk types as there are researchers studying them. However, a closer look at the risk typology of some institutes and researchers shows that in general some main types of risk are identified. In section 2.2.2 first some risk typologies found in literature will be studied. A general risk typology will be derived from that in section 2.2.3.

2.2.2 Risk types in literature

Basel Committee

The Basel Committee identifies three main types of risk: credit risk, market risk and other risks. The Committee defines *credit risk* as the risk of counterparty failure[3]. Parts of credit risk are *country risk* and *transfer risk*[4]. Country risk refers to "*risks associated with the economic, social and political environments of the borrower's home country*". Transfer risk occurs when a borrower's

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[3] Basel Committee (1988), p. 2.

[4] Basel Committee (1997b), p. 34.

obligation is not denominated in the local currency. In that case "*the currency of the obligation may become unavailable to the borrower regardless of its particular financial condition*".
Market risk is defined as the risk of losses in on- and off-balance-sheet positions arising from movements in market prices[5]. Market risk is divided into *general market risk* and *specific market risk*. General market risk is the risk of losses in on- and off-balance-sheet positions due to movements of the market as a whole, whereas specific market risk is the risk of losses in on- and off-balance-sheet positions due to movement in one specific security[6]. Furthermore, the Committee recognizes four types of market risk. The first one is *interest rate risk in the trading book*[7]. This is the risk that movements of interest rates cause losses in on- and off-balance-sheet positions in the trading book. Secondly, the Committee defines *equity position risk*. This is the risk of losses in on- and off-balance-sheet positions in the trading book arising from movements in the prices of equity instruments. The third market risk type that the Committee defines, is *foreign exchange risk*. This is the risk of losses in on- and off-balance-sheet positions arising from movements in foreign exchange rates. Finally, the fourth market risk type is *commodities risk*, which is the risk of losses in on- and off-balance-sheet positions due to movements in the prices of commodities.
The Basel Committee's third risk category is the category of *other risks*[8]. These are all risks that are neither credit nor market risk. One of them is *interest rate risk in the banking book*. This is the risk of losses in on- and off-balance-sheet positions in the banking book arising from changes in interest rates. Although the causes of interest rate risk in the banking book are the same as the causes of interest rate risk in the trading book, the two risk types are different. The main reason is that the current accounting principles for the trading and banking book are different, and because of that the way in which the risks are treated differ. Other types of other risk include *liquidity* risk, which is the risk of a bank being unable to get funds in the market at reasonable cost, and *operational risk*, which is the risk of losses arising from operational failure. Operational risk is usually divided into many different categories, among which *business risk*, *fraud risk* and *event risk*. We will not give a definition of these risk types[9]. Two other types of risk are *legal risk* and *reputational risk*[10]. Legal risk is the risk of losses due to changing laws, or lost law-suits. Legal risk is of great importance when a bank enters into a new or complex transaction, such as securitisations. Reputational risk is the risk of a loss in reputation caused by bad publicity.

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[5] Basel Committee (1996), p. 1.

[6] Basel Committee (1996), p. 9.

[7] Instead of using the term interest rate risk in the trading book, in the 1996 amendment the Committee uses the term interest rate risk for this type of risk in the trading book. Because Basel II introduced the term interest rate risk in the banking book, and since the 1996 amendment focused on exposures in the trading book, we will use the term interest rate risk in the trading book here to avoid confusion.

[8] Basel Committee (1999).

[9] The interested reader should refer to the Basel Committee's September 1998 paper "*Operational Risk Management*". Van den Tillaart (2003) is also completely dedicated to operational risk.

[10] Basel Committee (1997b), p. 36.

Bessis (1998)

Bessis also mentions a number of risk types in his 1998 book *Risk management in banking*. He defines risk as the "*adverse impact on profitability*" caused by "*sources of uncertainty*"[11]. In defining risk types Bessis makes a distinction between banking risks, which are financial risks and non-banking risks, which do not necessarily have to be financial. In the first group Bessis defines six different types of risk[12]. The first one is *credit risk*, which is defined as the risk that customers default, that is fail to comply with their obligations.

Secondly, Bessis defines *liquidity risk*. He gives two definitions of liquidity risk. The first one is that short-term assets are not sufficient to match short-term liabilities or unexpected outflows. The second definition of liquidity risk is the risk of having difficulties in raising funds.

The third risk is *interest rate risk*, which is the risk of declines in earnings due to movements of interest rates. Part of interest rate risk is prepayment risk, which is the risk that a customer prepays his loan.

Market risk is the fourth type of risk. It is defined as the risk of adverse deviations of the mark-to-market value of the trading portfolio during the period needed to liquidate the transactions.

The fifth type of risk is *foreign exchange risk*. Bessis also calls it currency risk, and defines it as the risk of observing losses due to changes in exchange rates.

Finally, the last type of banking risks, defined by Bessis, is solvency risk. It is defined as the risk of being unable to cover losses, generated by all types of risk[13], with available equity. Solvency risk is therefore the risk of default of the bank.

Besides banking-risks Bessis also defines a non-banking risk, which is *operational risk*. He defines it as malfunctioning of information systems, reporting systems or internal risk monitoring rules.

Bos & Bruggink (1996)

Four types of risk are defined by Bos and Bruggink[14]. The first one, again, is *credit risk*, which they define as the risk that a counterparty fails to comply with his obligations. Credit risk is divided into four categories[15]. The first one is *debtor-risk*, which is the risk that a client fails on his obligation due to insolvency. The second type of credit risk is *country risk*. In this case the client is another country or a client in another country and fails due to prevailing laws[16]. The third type of credit risk defined by Bos and Bruggink is the so-called *valuer compensé risk*, which is the risk of not knowing at the moment of paying whether the reciprocate in another currency is or will be done. Finally, the last type of credit risk is *settlement risk*. This is the risk that a counterparty does not settle in a forward contract.

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[11] Bessis (1998), p. 5.

[12] Bessis (1998), p. 5-11.

[13] Including non-banking risks.

[14] Bos, J.J. & A. Bruggink, *Management control bij banken*, Amsterdam, 1996.

[15] Bos & Bruggink (1996), p. 55.

[16] This happens when a government decides that no foreign payments are allowed or that no payments in foreign currencies are allowed.

Next to credit risk three other risk types are identified[17]. The first one is *foreign exchange risk*, which is the risk of losses due to movements in exchange rates. Secondly, *liquidity risk* is defined. Liquidity risk is the risk of losses due to mismatches in the liquidity of assets and liabilities. Finally, *interest rate risk* is recognised. They define interest rate risk as the risk that a certain criterion is not met due to unexpected changes in interest rates. The criterion usually is some form of profit. Bos and Bruggink define two types of profit:

1. profit out of interest income; and
2. profits due to changes in market values.

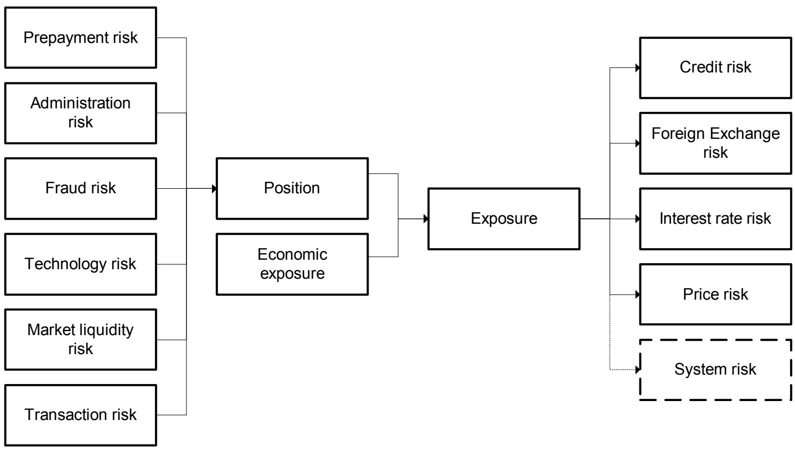
Usually, the first corresponds to interest rate risk in the banking book, because profit or loss in the banking book is usually an interest profit or loss. The second corresponds to interest rate risk in the trading book, because profit or loss in the trading book is usually defined as gains or losses in the market value of the trading book.

Hoekema (1997)

In his thesis, Hoekema, has done some research on risks[18]. He made a distinction between risks that cause a position and therefore an exposure to risk, and risks that arise from an exposure. In Figure 2.1 below the risk types defined by Hoekema are shown.

Figure 2.1 Risk types defined by Hoekema (1997, p. 45)

Hoekema defines risks that can either cause an exposure or are caused by an exposure



[17] Bos & Bruggink (1996), p. 56-58.

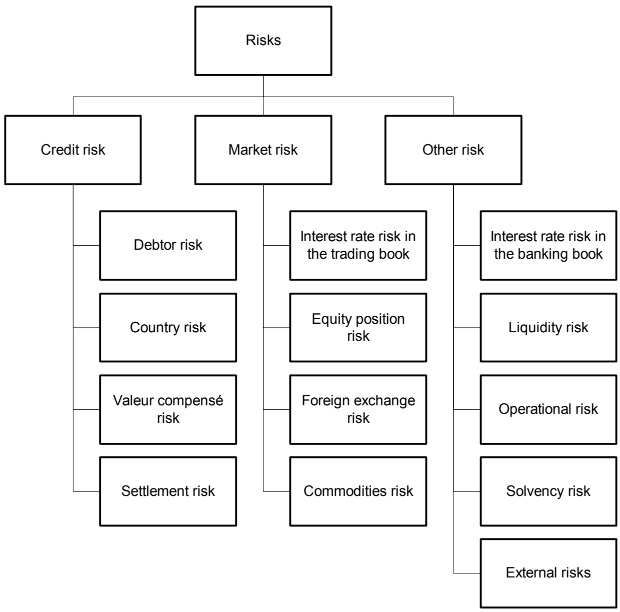
[18] Hoekema, A., *Management control van financiële risico's*, Ph.D. thesis, Twente University, Enschede, 1997.

The risks on the left can cause a position. A position and economic exposure[19] can cause an exposure. This exposure finally can cause the risks shown on the right side of the figure. System risk is the risk of a crash in the economic system, and thus an external risk. Therefore it is dashed. For exact definitions of the risks above, we refer to the second chapter of Hoekema (1997).

2.2.3 A general risk typology

In the previous section four risk typologies have been described. A closer look at the definitions given by the different authors shows that all authors roughly make the same distinction, although they sometimes use different names for the risk types. This is shown in Table 2.1 on page 18. As one can see, all authors make, more or less, a distinction between credit risk, market risk and other risks. The only risk that is missed out is business risk. Although the Basel Committee sees it as part of operational risk, we view operational risk more as the risk that internal processes fail, whereas we see business risk more as the risk caused by external processes, such as disasters, strong competitors and so on. More or less the same holds for reputational and legal risk, which, depending on the definition can be seen as part of operational risk or as separate risk classes. We see these risks as separate risk classes and therefore take them into our general risk typology as external risks (see Figure 2.2 below).

Figure 2.2 General risk typology



[19] Even when an enterprise does not have a position, economic exposure can cause an exposure (Hoekema, 1997, p. 45). An example can be that changes in the economic environment in a country can cause competitive inequality between local and foreign companies, even if the foreign company does not hold a position in the local currency.

Table 2.1 All risk typologies brought together

Basel Committee	Bessis	Bos & Bruggink	Hoekema
Credit risk	Credit risk	Credit risk:	Credit risk
		• Debtor risk	
• Country risk		• Country risk	
• Transfer risk			
		• Valeur compensé risk	
		• Settlement risk	
Market risk[20]:	Market risk		
• Interest rate risk in the trading book		Interest rate risk[21]	Interest rate risk
• Equity position risk			
• Foreign Exchange risk	Foreign exchange risk	Foreign exchange risk	Foreign exchange risk
• Commodities risk			
			Price risk
Other risk:			
• Interest rate risk in the banking book	Interest rate risk	Interest rate risk[22]	Interest rate risk
• Liquidity risk	Liquidity risk	Liquidity risk	
• Operational risk	Operational risk		
• Legal risk			
• Reputational risk			
			Position causing risks[23]
	Solvency risk		

2.3 *Interest rate risk in the retail banking book*

2.3.1 Introduction

In section 2.2.3 we gave a general risk typology. We put interest rate risk in the banking book in the category of other risks. However, we did not consider the concept of risk itself. What is risk? Risk can be defined in a number of ways. For example, one can use a general definition stating that risk is the chance that a process does not have a certain outcome. Using statistical terms, a process is not risk free if the standard deviation is different from zero. Examples of these processes are the tossing of a coin, throwing a dice, and so on. This is the definition normally used for risk and dates back to a 1952 paper by later Nobel prize winner Markowitz (Bernstein, 1996, p. 248).

[20] Both general and specific market risk.

[21] In this case the profit criterion is the change in market value of a portfolio.

[22] In this case the profit criterion is net interest income.

[23] These are the risks that, according to Hoekema, can cause a position.

In stating that the standard deviation of a risky process differs from zero, we imply that one can have an idea of the level of risk of a process, where a higher standard deviation indicates a higher risk. However, a process can also be considered risky when we don't have any way of knowing what the outcome will be. In statistical terms, we don't know the standard deviation, but we do know it is different from zero.
Summarising, risk can be defined as uncertainty, whether it is profitable or unfavourable. Another definition only looks at the downside of risk as defined above. That is, a risk is the chance of an unfavourable outcome. Let's clarify this with an example. Assume that we toss a coin. If heads comes up we win €100,-. Otherwise we earn €10,-. Assume that we can play this game for free. Using the first definition of risk, this game contains risk, since the outcome of the game is not certain. Under the second definition, the game will be risk free, since no matter what happens, we will always make a profit[24]. Now assume, the same game, but now we have to pay €20,- to play the game. Now the process also contains risk under the second condition, since it might happen that, after the game, we are left with less than before. Since the economic capital concept only looks at whether the bank has enough capital to cover for losses, we are only interested in the downside effects of the risk of embedded options and will therefore use the second definition throughout this thesis.

Before we study interest rate risk in the banking book in more detail, we will define it. In defining interest rate risk in the banking book we can divide this concept in two parts. These are interest rate risk and the banking book.
In the previous section, interest rate risk was already briefly discussed. It was defined as the risk of losses in on- and off-balance-sheet positions arising from changes in interest rates. In this section that definition will be somewhat narrowed.
We choose to use a definition of risk that is associated with a negative outcome. A process is thought to contain risk if there is a chance that the outcome will be unfavourable. Relating this to interest rate risk, one can say that the definition given above is accurate. However, expected changes in interest rates do not necessarily have to be unfavourable since the bank can hedge this risk or anticipate it. Therefore, interest rate risk is related to the unexpected changes in interest rates. Thus, the definition of interest rate risk is adjusted as follows:

Losses in on- and off-balance-sheet positions arising from unexpected changes in interest rates.

However, it is not necessary to bear a loss to speak of interest rate risk. A decline in income will also be regarded as interest rate risk. Furthermore, one can argue that a decline in value is also a loss. This alters the definition in the following way:

Negative effects in accrual income of and/or negative value changes in on- and off-balance-sheet positions due to unexpected changes in interest rates.

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[24] Although one can argue that this game also contains risk under the second definition. The expected profit from this game is €55.-. As a result, if we only win €10.-, our gains are lower than expected. Therefore it can be argued that there is a loss.

This is still a broad definition and includes both losses in the trading and the banking portfolio. The trading book is defined by the Basel Committee as follows: "*The bank's trading book contains instruments that are intended to be held for a short term and which are taken by the bank to benefit from actual or expected differences between their buying and selling prices*" (Basel, 1996). From this definition, it follows that the trading book is (often) market value driven.

In the banking book on the other hand the bank tries to profit from the margin between what is earned on assets and paid on liabilities. From this definition it follows that the banking book usually has a longer term focus[25]. It is therefore sometimes referred to as the strategic portfolio. All this results in the banking book often having an accrual focus. An accrual focus has two effects:

1. revenues and costs are divided over the whole maturity of an instrument; and
2. changes in interest rates do not necessarily have an immediate effect on revenues and costs.

A bank's banking book can be split, depending on the bank's activities into a wholesale and a retail part. The main difference between the two parts are the characteristics of the instruments in the book. The difference is due to a different client focus. The wholesale banking book focuses on large enterprises. Therefore, the book usually contains structured, tailor-made, products with explicit options where necessary to create the desired risk profile for the client. As such this part of the banking book has few embedded options.

The retail banking book on the other hand focuses on private persons and small businesses. As a result, products are usually not tailor-made and contain more embedded options. Since most embedded options can be found in the instruments in that part of the banking book, this thesis focuses on the retail banking book.

Bearing the above in mind and with interest rate risk and the retail banking book defined, a definition for interest rate risk in the retail banking book can be given. In this thesis interest rate risk in the retail banking book is defined as:

Negative effects in accrual income of and/or negative value changes in on- and off-balance-sheet positions in the retail banking book due to unexpected changes in interest rates.

Although currently the banking book is usually accounted for on an accrual basis, in the definition market value losses are not excluded. The main reason for this is expected accounting regulation. With the introduction of IAS[26] 39 (IASB, 1998) (see section 2.5.3) it is

[25] This longer term focus does not mean that the average maturity of instruments in the banking book necessarily has to be long term. Instead, the longer term focus means that there is a hold to maturity intent.

[26] IAS stands for International Accounting Standard. These standards are developed by the international Accounting Standards Board (IASB). This Committee was founded in 1973 and is located in the United Kingdom. In December 1998 it comprised representatives of accounting bodies in the following countries: Australia, Canada, France, Germany, India, Japan, Malaysia, Mexico, the Netherlands, South Africa, United Kingdom and the United States of America. Apart from the representatives from the different countries, the following institutions also have representatives in the IASB: the Nordic Federation of Public Accountants, the International Council of Investment Associations, the Federation of Swiss Industrial Holding Companies and the International Association of Financial Executives Institutes.

still possible to account for the banking book on an accrual basis, provided that there is an intent to hold the items in the banking book until maturity. However, in that same standard, more focus is given on the concept of fair value. Therefore, one could expect fair value accounting to be required for all bank portfolios in the future and therefore market value losses, which more or less equal fair value losses, are also included. Another reason is the management information market values can provide. If the position at a moment in time has a very high market value with respect to the market value on the day the position was bought, one could lock in the market value gain by closing the position. This can be very attractive, but is harder as soon as IAS 39 is implemented, because of the hold to maturity condition for accrual accounting.

Now we have a definition of interest rate risk in the retail banking book, we will first describe the different aspects of interest rate risk in the banking book (section 2.3.2), after which we will study methods for the quantification of this risk type in 2.3.3. At the end of this section we will have answered research question two: what is interest rate risk in the banking book and how is it managed?

2.3.2 *Aspects of interest rate risk in the banking book*

Interest rate risk – both in the trading and in the banking book - can be divided in a number of different subtypes. The Basel Committee mentions repricing risk, yield curve risk and basis risk[27]. Bos and Bruggink (1996) split interest rate risk in mismatch risk, which is the same as the Basel Committee's repricing risk, yield curve risk and client option risk. Dholakia (1997) divides interest rate risk into repricing risk, basis risk, run-off risk, embedded options risk and yield curve risk. Hinkle (1997) defines the following four subtypes: mismatch risk, yield curve risk, options risk and basis risk. So, in general interest rate risk is divided in four subtypes, which are:

- repricing risk;
- yield curve risk;
- basis risk; and
- (embedded) option risk.

The first three are all related to negative effects on earnings due to changes in the interest rates, while the fourth, embedded option risk largely depends on client behaviour which may be caused by changes in interest rates, but by other factors as well as we will see. The same holds for Dholakia's run-off risk.

Dholakia relates run-off risk to non-interest bearing products such as demand deposits. A customer bears opportunity costs, because he doesn't receive interest on these accounts. As soon as interest rates increase the costs rise. Therefore he could decide to transfer his money from this account to another, interest bearing account. Since this is disadvantageous to the bank, this is a risk. In fact run-off risk is the risk that a client exercises his option(s). Therefore, this risk type will not be studied separately, but as part of embedded option risk.

[27] Basel Committee (1997c), p. 6-7.

In the remainder of this section we will further clarify the above aspects of interest rate risk (in the banking book).

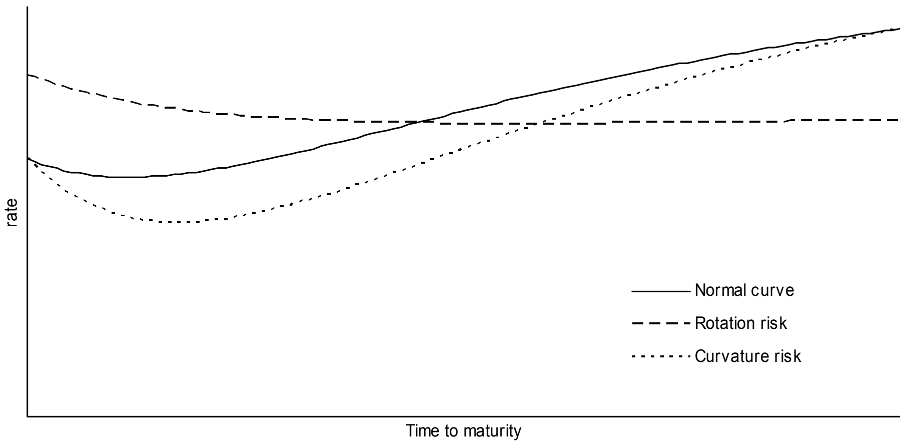
Repricing risk

Repricing risk occurs when the repricing schedules of assets, liabilities and off-balance-sheet items are not identical. For example, if a bank sells a ten year fixed mortgage which it funds with a one year deposit, the bank bears a risk, because the instruments do not reprice at the same moment. If the one year rate increases sharply during the year, it is possible that the bank has to refund the mortgage at a higher rate, thus decreasing the spread on the mortgage. Repricing risk is also referred to as mismatch risk.

Yield curve risk

Yield curve risk is the risk of non-parallel shifts in the yield curve, thus causing a flatter or steeper curve. This type of risk is sometimes referred to as rotation risk. Another type of yield curve risk is curvature risk, where interest rate changes cause the yield curve to show more curvature. Examples of both rotation risk and curvature risk are shown in Figure 2.3 below. The black, continuous line shows a "normal" yield curve. Usually, the yield curve is upward sloping, meaning that interest rates are higher if the time to maturity is longer. The dashed line shows rotation risk. We see that short-term rates increased, whereas long-term rates decreased, resulting in a so-called inverted yield curve. Finally, the dotted line shows curvature risk. Both the short-term and the long-term rate did not change. However, the medium-term rates decreased, resulting in the a yield curve which shows more curvature, than the original one.

Figure 2.3 Examples of yield curve risk



Basis risk

Basis risk is the risk that two yield curves, which normally act together suddenly follow different paths. For example, assume that a bank has bought a ten year floating rate note which is tied to yield curve A and funded it with a ten year variable instrument tied to yield curve B. Normally, yield curves A and B are strongly positively correlated. So, normally if the funding becomes more expensive, this is compensated by higher revenues. Because of the same reprice period, the bank does not bear any reprice risk, but what if the correlation fails? What if yield curve A drops and yield curve B rises? If that happens, it is possible that the bank has to take a loss.

Embedded options risk

Embedded optionality plays an important role in quantifying and setting (economic) capital requirements for interest rate risk in the retail banking book. One could think of numerous forms of embedded options in all sort of products typical for the retail banking book. The most common are:

a) withdrawal option;
b) prepayment option;
c) interest rate consider period option;
d) embedded caps and/or floors;
e) quotation rate option with regard to mortgages; and
f) choice option.

Ad a) Withdrawal option

A common option in typical retail banking book products such as savings accounts and demand deposits is the withdrawal option. Clients can decide to withdraw credits at any time, often without a penalty. Because of this the bank might unexpectedly need new funding, which is usually more expensive than the rate paid on for example savings accounts. We will study the withdrawal option is more detail in chapter 3.

Ad b) Prepayment option

The prepayment option is a very common option. The holder of the option has the right, but not the obligation, to prepay some of the principal before maturity. In the Netherlands usually only 10% to 20% of the original principal of the mortgage can be prepaid freely. If the mortgagor wants to prepay more, a penalty has to be paid. This penalty is normally the difference between the present value of cash flows as they had been if the current rate was maintained and the present value of the new cash flows. The prepayment option will be studied in chapter 4.

Ad c) Interest rate consider period option

In Dutch this option is called a "rentebedenktijd optie". It is sometimes referred to as a $x+y$ option and is present in some mortgages. A mortgage with this option has an interest rate fixing period of $x+y$ years. However, the mortgagor has the right, but not the obligation, to choose a new fixing period during the last y years of the fixing period, which does not necessarily have to be $x+y$ years again.

Therefore, the actual fixing period is not certain but between x and $x+y$ years. The interest rate consider period option will be studied in greater detail in chapter 5.

Ad d) Embedded caps and/or floors

This type of embedded option is a well known product which is also separately sold in financial markets. A cap sets the upper limit to possible interest rates, while a floor sets the lower limit. If both a cap and floor are present, this is sometimes referred to as a collar. A distinction is made between life caps and floors, and period caps and floors. For example, a holder of a mortgage with an embedded life cap of 10% and an embedded period cap of 200 basis points knows for sure that the rate he has to pay will never exceed 10% and will not rise by more than 200 basis points between two fixing periods. In Table 2.2 below some examples are given, where we assume that the life time cap is 10% and the period cap is 200 basis points. In scenario one we see that neither the period cap, nor the life cap is activated, since the increase in interest rates is below 200 basis points and the absolute level of the interest rate is below 10%. In scenario two we see that the new rate is capped to 7% due to the 200 basis points period cap. In scenario three we see that the new rate is capped to 10%, due to the 10% life cap.

Table 2.2 Examples of a life cap of 10% and a period cap of 200 basis points

Scenario	Current rate	Market rate	New rate
1	5%	6%	6%
2	5%	8%	7%
3	9%	10.5%	10%

Embedded life caps are sold in some Dutch adjustable rate mortgages. Life floors and period caps and/or floors are not common in the Dutch market. Embedded caps will be studied in greater detail in chapter 5.

Ad e) Quotation rate option with regard to mortgages

This is an option in which the holder has the right, but not the obligation to get a mortgage for the terms specified in the commitment. Usually, an option like this has a maturity of three months, but longer periods are also possible. Basically, the customer knows the maximum interest rate he has to pay. However, if interest rates drop during these three months the customer can lock in this lower rate. Basically, the client gets a cap on his rate. Usually, this option is free for the first three months. The quotation rate option will be studied in chapter 5 also, together with the embedded caps and floors due to its similarity with a cap.

Ad f) Choice option

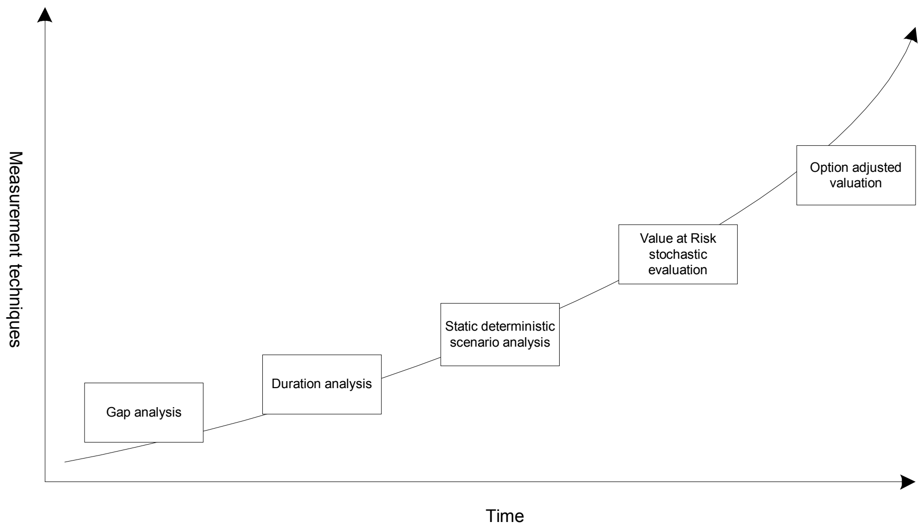
Finally, the last embedded option which one can identify is the choice option. This option is embedded in mortgages in the Netherlands. Mortgages usually have a legal maturity of 30 years, but the rate fixing period is normally shorter. As soon as the rate has to be reset, the mortgagor is free to choose a new rate fixing period of his choice. For example, assume a mortgage with a five year fixing period. After five years, the client can decide to enter into a new five year fixing period, but he can also choose another term, or even a variable rate.

2.3.3 Measurement of interest rate risk in the banking book

Introduction

To get a clear picture of the magnitude of interest rate risk in the (retail) banking book it is necessary to quantify it. During the last decades a number of techniques have been developed ranging from very simple to very complex (see Figure 2.4 below). In this section we will discuss these techniques.

Figure 2.4 Development of measurement techniques over time



Basically, four types of techniques can be identified. First, techniques either use a static or a dynamic approach. Second, techniques can be income based or value based. A static approach means that the scenarios (if any) used to model the future are known ex ante, whereas a dynamic approach uses stochastic processes to simulate the future and quantify the risk based on the outcome of that simulation. An income based approach takes the accrual net interest income as a starting point for the analysis. The impact of interest rate risk is determined based on the changes or volatility of net interest income. A value based approach on the other hand takes changes in the market value of an instrument or a portfolio as a starting point. The impact of interest rate risk is determined based on the volatility of the market value.

Although the banking book is often managed on an accrual basis, our definition of interest rate risk in the banking book allows room to include market value losses. Therefore, we will also study the value based techniques.

Combining these approaches leads to different techniques, which will be discussed in the remainder of this section. The techniques will be briefly described and the advantages and disadvantages of each technique will be stated.

Static income based approaches

Static income based approaches do not simulate future changes in the markets or the balance sheet and take accrual income as a starting point for measuring the interest rate risk exposure. The most well known technique using this approach is the *Maturity Gaps* concept. Another technique is a static version of the so-called *Earnings at Risk (EatR)* approach. These techniques will be described in the remainder of this section.

Maturity gaps

Concept

One of the simpler techniques is the so called maturity gap. A gap report consists of a number of maturity or time buckets in which both assets, liabilities and off-balance-sheet items can be slotted depending on their remaining maturity or repricing characteristics. For example, a ten year fixed bullet loan would be slotted in the ten year maturity bucket, whereas a three month variable product with a ten year maturity would be slotted in the three month maturity bucket. A third example is a two year amortising loan, in which one quarter of the principal is repaid every six months. This instrument would be slotted in the 6, 12, 18 and 24 month bucket, each bucket carrying a quarter of the total principal.

The idea behind slotting a fixed instrument at maturity while slotting variable instruments at their repricing date is that only until those dates interest rate risk is borne, because until then the rates are fixed, while after those dates the rates can be freely adjusted to equal market rates.

After slotting all assets, liabilities and off-balance-sheet items, a gap can be defined for each time bucket. The gap for a particular time bucket is calculated as total assets minus total liabilities plus the total off-balance-sheet exposure in that time bucket. This results in one gap per time bucket, which shows to what interest rate changes the bank is exposed. For example, if the bank has a positive gap in the ten year bucket and a negative gap in the overnight bucket it is exposed to an increase in interest rates.

It is even possible to estimate the possible loss from an interest rate change. For example, assume that the interest rates in the previous example rise by 100 basis points. Interest income will not change, because of the long position in the ten year time frame, but interest expenses will increase by 100 basis point times the gap in the overnight bucket. This leads to a lower net interest income.

Advantages

The maturity gap has some big advantages. First of all, the technique is very simple and easy to implement, because it only needs limited information. The only information needed is the total face amount, the maturity date in case of fixed instruments or the next repricing date in case of variable instruments, and the amortisation schedule. Secondly, because of its simplicity the technique is very intuitive to use. A further advantage is that the method can be used to quantify mismatch risk and is capable of providing a quantification of yield curve risk (see the section on Earnings at Risk below).

Disadvantages

The maturity gap technique unfortunately has some disadvantages too. First, the method is not capable of quantifying basis risk. Secondly, it cannot cope with optionality, whether explicit or embedded. A third disadvantage is that the technique is not very accurate regarding the exact repricing dates. It is assumed that all instruments in a bucket reprice at the end of the bucket period. For example, assume that a bank has, amongst others, a nine and a ten year maturity bucket. The instruments slotted in the ten year maturity bucket are assumed to reprice ten years from now. However, this bucket includes all deals which mature or reprice between nine and ten years from now. Suppose that this bucket contains only two instruments. A € 10 million bullet loan, which matures after nine years and three months and a € 1 million bullet loan which matures ten years from now. The weighted average reprice term is certainly not ten years in this example, but will be somewhere in between nine and ten years. This could lead to wrong actions, if the bank wants to hedge this risk. A solution for this problem, though, could be more time buckets.

Earnings at Risk

Concept

Earnings at Risk (EatR) is a concept that is similar to Value at Risk (see further on). EatR also uses a certain confidence interval and planning period, but differs from Value at Risk because it focuses on accrual income. Earnings at Risk can be used both as a static and as a dynamic technique. The dynamic version of EatR will be described in the next section.

The static EatR approach uses (simple) static scenarios. These could be parallel shock scenarios, non-parallel shock scenarios, and so on. However, because of the desired confidence interval, the scenario is usually derived from historic data.

Thus, the static version of EatR uses historic interest rate data to determine an interest rate shock which is expected to occur within the planning period with a certain confidence. This rate shock can then be applied to the different time buckets of the gap report. Usually, a shock is only applied to the buckets with a maturity or repricing of less than or equal to one year, because this equals the accounting time frame. It is also possible to determine individual shocks for each time bucket. In this form, the EatR approach is a sort of extension of the maturity gap concept.

Advantages

The maturity gap approach only tells to which interest rate changes the bank is exposed. Furthermore, the size of the gaps gives an idea of the magnitude of the exposure. The advantage of EatR with respect to the maturity gap approach is that it adds more clarity about the magnitude of the interest rate exposure.

If a uniform shock is determined for all time buckets the EatR approach is capable of quantifying mismatch risk. However, if different shocks are determined for each time bucket it is also capable of quantifying yield curve risk.

Disadvantages

A disadvantage of the static EatR approach is that it is based on historic data. What happened in the past does not necessarily have to happen again in the future. Another disadvantage is that the approach needs certain assumptions about the balance sheet strategy the bank takes. For example, if the planning period is one year, assumptions are needed about what the bank does with instruments that mature in, for example, three months. Another disadvantage is that the method is not capable of quantifying basis risk and it cannot cope with optionality. Finally, it is difficult to set the right planning period. For example, assume a bank has entered into a swap agreement with a five year maturity in which it pays fixed and receives three month variable. If a planning horizon of one year is chosen, the risk of the fixed leg is not visible. This could be solved by extending the planning horizon, but then further assumptions have to be made about developments in the balance sheet.

Dynamic income based approaches

Dynamic income based approaches simulate future income by use of stochastic scenario analysis. The before mentioned Earnings at Risk approach can also be used as a dynamic approach.

Earnings at Risk

Concept

The dynamic version of the Earnings at Risk (EatR) concept uses the same principles as the static version, but instead of using historic data to calculate the earnings that are at risk, now scenarios are used, that depend on stochastic processes. Usually, this means that a certain stochastic term structure model is used to simulate interest rate movements. If this is done x times, it results in x interest rate paths. For each path the net interest income can be determined, based on certain assumptions regarding client behaviour and balance sheet developments. The outcomes are then ranked and a certain percentile is taken, based on the desired confidence interval. For example, if 100 scenarios have been run and ranked, the second worst outcome equals the 99% percentile.

Advantages

An advantage of a dynamic EatR approach is that it is capable of quantifying all types of interest rate risk in the banking book. Because interest rate shifts do not have to be equal in size along the yield curve both mismatch and yield curve risk can be quantified. Basis risk can be quantified by using multiple term structure models[28]. Another way of quantifying basis risk is using one term structure model and using historic correlations between different yield curves to simulate different yield curve shifts. Finally, optionality can be quantified by using certain assumptions on client behaviour.

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[28] Usually, one term structure model is applied, but different parameter values can be used to model each yield curve separately.

Disadvantages

Although a dynamic EatR approach has certain advantages with respect to the static approaches described earlier, it has some disadvantages too. The biggest disadvantage is that the method needs numerous assumptions. First of all, the term structure model has to be chosen. The model applied can have big consequences for the outcome of the analysis (see for example Van Bussel (1996) and our own analysis in section 6.2.1 as of page 159). Second, if a term structure is chosen, the parameters have to estimated. These parameters can change over time, which causes further uncertainty. Third, to estimate the impact of embedded options further assumptions about client behaviour are needed. And finally, assumptions are needed about the development of the balance sheet. For example, what happens when an instrument matures?

Static value based approaches

Static value based approaches do not simulate future interest rates, but use pre-defined scenarios. Furthermore, they measure the impact of interest rate risk by looking at the volatility in the (market) value of an instrument. The most well known concept is the concept of duration, which will be discussed below. Some forms of the Value at Risk approach (see further below) can also be regarded as static value based approaches. However, since the basic methodology of these approaches does not differ from the dynamic version of Value at Risk, all Value at Risk techniques will be discussed in the section on Value at Risk as of page 32. Closely related to the concept of duration is the concept of basis point value or "delta" and the other "Greeks", which will also be discussed in this section.

Duration

Concept

The basic duration concept is also known as Macaulay Duration. In 1938 Macaulay developed a technique based on the present value of the cash flows of an instrument, which he called duration (Macaulay, 1938). Duration is the time weighted sum of the cash flows divided by the present value as is shown in (2.1)

$$\text{Duration} = \frac{\sum_t t \cdot CF_t \cdot df_t}{\sum_t CF_t \cdot df_t} \tag{2.1}$$

where:

t	time at which the cash flow occurs;
CF_t	cash flow at time t; and
df_t	discount factor for a cash flow at time t.

Duration in this form gives an idea when all the cash flows are received. An instrument with a long duration, for example, is more risk sensitive than an instrument with a shorter duration, because it takes longer before all cash flows have been received/paid. Normally, the duration of a bank's assets will be longer than the duration of a bank's liabilities, because the assets will normally have a longer maturity than the liabilities.

More interesting is the impact of interest changes on the market value of an instrument or portfolio. Mathematically this is expressed as

$$\frac{\Delta P}{\Delta y} \tag{2.2}$$

where:
ΔP the change in the market value of a portfolio; and
Δy the change in the yield to maturity.

With D the duration as calculated using (2.1) on page 29, y the yield to maturity and P the value of the portfolio, some simple algebra shows (see for example Bos & Bruggink, 1996, p. 69) that

$$\frac{\Delta P}{\Delta y} = -\frac{D}{1+y} P . \tag{2.3}$$

The first term on the right hand side of (2.3) is the so-called *modified duration*. This is defined as the change in market value of an instrument resulting from an instantaneous, infinitesimal parallel shock in the yield curve. Another duration measure is the so-called *effective duration*. This duration measure is normally estimated on empirical data and takes embedded options effects into account. For the Dutch market this measure is not that useful, since there is no (well-developed) secondary market for products with embedded options.

Advantages
The main advantage of the (modified) duration concept is that it results in one number which gives the risk sensitiveness of an instrument.
Another advantage is that the duration of an instrument and the duration of another instrument are additive. This means that the total duration for all assets and the total duration for all liabilities can be calculated by a simple addition. The difference between these two numbers is the duration of equity, sometimes referred to as the Equity at Risk (EQatR). If the duration of assets equals the duration of liabilities, the Equity at Risk is zero and the bank is immune to interest rate risk until the next interest rate change, because at that time the durations will change due to a change in the yield to maturity.
A third advantage is that duration is capable of quantifying optionality[29] and that no assumptions about future balance sheet developments are needed.
Duration is capable of quantifying mismatch risk, basis risk and optionality. Yield curve risk can not be dealt with right away, since the duration concept is normally only used with parallel shocks. On top of this duration has some other disadvantages.

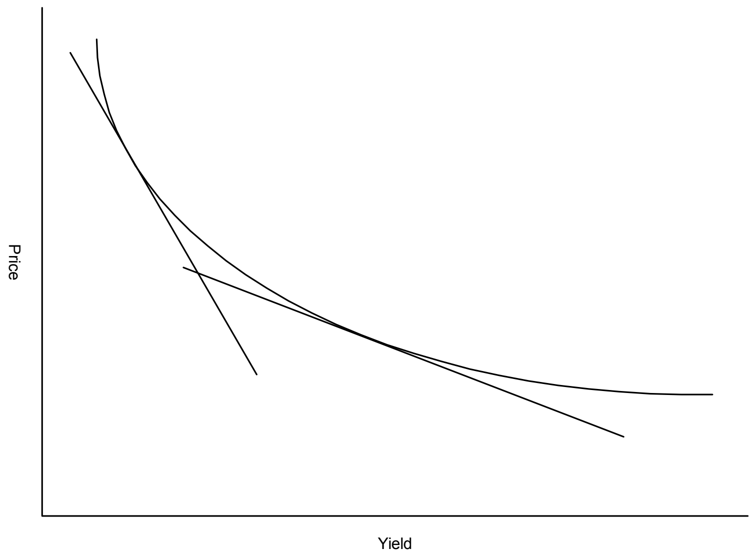
[29] Provided that the option can be valued.

Disadvantages

As stated above duration can only be used with parallel shocks. Since parallel shocks over the whole term structure are extremely rare this is a serious disadvantage. This problem can be solved though by defining multiple durations which give an instrument's sensitivity to certain term points on the yield curve. This approach is known as the key rate duration concept (for more details see Ho (1999)).

Another disadvantage is that the duration concept can only be used with very small shocks. Duration equals the tangent of the price-yield function. This function is in general not a linear function, as can be seen in Figure 2.5 below. The duration at low interest rates therefore is, in general, higher than it is at higher interest rates.

Figure 2.5 Price yield function (Source: Kahn & Lochoff, 1990, p. 75)



Therefore to use the duration concept only small interest rate shocks may be applied. If large interest rate shocks are applied, the change in the price as calculated by duration might differ substantially from the price as calculated by exact pricing formulas.

To solve this problem higher order derivatives of the price yield function can be taken. The second order derivative is called convexity and captures the curvature of the price yield function. Even higher order duration measures can also be taken. If more higher order derivatives are calculated, the outcome is referred to as the duration vector (Chambers, Carleton & McEnally, 1999). The advantage of including higher order derivatives of the price yield function is that the effect of a rate change on the price can be predicted with more accuracy. The disadvantage is that the calculations become more and more complex and require more computational power. Optionality might influence the use of higher order derivatives, because embedded options can cause 'negative convexity'. With declining rates the price will reach a maximum, because the borrowers will eventually exercise their option and refinance at a lower rate.

Basis point value & the "Greeks"

Concept

Basis Point Value (bpv) is very similar to duration. The bpv measures the change in value of a certain instrument with respect to a one basis point parallel change in the relevant yield curve. The bpv multiplied with the market value of an instrument equals duration. Instead of one bpv for the whole yield curve, it is possible to calculate the bpv per grid point of the yield curve. Basis point value is sometimes referred to as "delta". All bpvs per grid point are then referred to as the delta vector. Delta is one of the Greeks. Other Greeks are gamma, which is the change in delta relative to a one basis point parallel shift in the yield curve, and vega, which is the change in the present value of an instrument with respect to a 1% change in the relevant implied volatility. Other Greeks are rho, which is the sensitivity of the value of an option to changes in the interest rates, and theta which measures the sensitivity of an instrument's value due to the passage of time.

Advantages

The main advantage of bpv and the Greeks is that they include a lot of information in just one number. Another advantage is that it is usually relatively simple to calculate the Greeks with the help of market information.

Disadvantages

A disadvantage is that it is usually hard to manage all the Greeks. If one is delta-hedged, which means that one is insensitive to a (parallel) change in the relevant yield curve, one is not necessarily gamma-hedged and vice versa.

Dynamic value based approaches

The last group of quantification techniques are the dynamic value based approaches. These approaches use stochastic processes to calculate the future values of a portfolio or instrument. The distribution of these future values given an idea of the interest rate risk. The most well known dynamic value based approach is the value at risk (VatR) technique, which is described below.

Value at Risk

Concept

Value at Risk (VatR) is the value of potential losses that will not be exceeded in more than a given fraction of possible events (Bessis, 1998). To calculate the VatR some parameters have to be determined or chosen. Chew (1996) names the following: the holding period, the methodology, the time horizon of data and the risk factors. On top of that the confidence level has to be chosen.

The holding period refers to the period in which the position could normally be liquidated. For a trading portfolio this would be ranging from a few hours to a few days, whereas for a banking book this could range from a few days to a few weeks or even months.

The methodology refers to the method used to calculate the VatR. Van den Goorbergh and Vlaar (1999) define three methodologies: analytical methods, Monte Carlo simulation and historical simulation. If analytical methods are used, a predetermined distribution function of the expected returns is applied. Historical data is then used to determine the parameters. Usually, a normal distribution is used. Then, a certain percentile is taken based on the already chosen confidence level, for example a 99% confidence interval. Monte Carlo simulation uses the same distribution function, but instead of calculating the percentile, simulations are run. These simulations are ranked and a certain percentile is taken as VatR based on the confidence level. Finally, historical simulation uses historically observed returns, ranks these, and takes a certain percentile, again based on the confidence level.
The time horizon of data refers to the length of the history used to determine the parameters of the distribution function. This history should be long enough to include some extraordinary events, but if the history is too long the resulting distribution function might not represent the current situation accurately enough.
Finally, the risk factors have to be determined. With respect to interest rate risk these include all yield curves, all yield curve volatilities and the correlations between those in which the bank has an exposure.
Based on these numbers the bank can determine a distribution of expected returns and determine the amount which will not be exceeded during a certain period with a given confidence level. This amount is the value at risk.

Advantages

According to Bessis (1998, p. 35), the main advantage of VatR is that it is a "*value which has the very simple meaning of unexpected losses*". Other advantages are that VatR summarises in a single number all sorts of risk. Indeed, VatR gives the total interest rate risk, including mismatch, yield curve, basis risk, and through the use of option pricing formulas also the risk of (embedded) optionality[30]. Thirdly, VatR has the advantage that it is also used to quantify other risk types, notably market risks, but also credit risk, in a somewhat adjusted form. Finally, VatR only uses the current composition of the portfolio or balance sheet. So no assumptions are needed for balance sheet developments. However, there are some disadvantages as well.

Disadvantages

The biggest disadvantage of the VatR approach is that it is not the most appropriate tool for accrual books, which usually have a hold to maturity intent and unlike trading books are not normally liquidated. On top of this Chew (1996) names some other disadvantages related to the distribution function. Usually, a normal or lognormal distribution function is used. However, the distribution of the returns observed in the market is usually not normal or lognormal. This empirical distribution usually has fatter tails, which indicates that extreme returns occur more frequently than a normal distribution implies. Furthermore, the peak around the mean is usually higher than in a normal distribution. And finally, the empirical distribution is not symmetrical as is the normal distribution. Usually, it is negatively skewed.

[30] Provided that these option pricing formulas are capable of valuing embedded options.

The drawback of these deviations to the normal distribution is that the outcome of a VatR analysis does not completely reflect real life results. One can use a distribution which more accurately resembles empirical observations, but this increases the complexity of the VatR analysis.

2.4 Economic capital

2.4.1 Introduction

In this section we study the concept of capital, more specifically economic capital. In section 2.4.2 we start with finding a definition for economic capital. That section shows that economic capital is just one way of looking at an institution's equity. In the remainder of this chapter we will focus on some economic capital models which can be found in literature. Since most of these models include some basic concepts on interest rate models, we will first give some background on interest rates and interest rate models in section 2.4.3, after which section 2.4.4 will focus on economic capital models. At the end of this chapter, the first part of research question three: "what is economic capital and why is it important" will be answered. The latter part of this question will be answered in section 2.5.

2.4.2 Capital

Capital within financial institutions is not that easily defined as it is in non-financial institutions. In the latter category capital is usually considered as the amount of equity. Within banks, one can divide between at least three capital concepts (Bos, 1999a). The first concept is the concept of *accounting capital*, which is the amount of equity in the balance sheet. Accounting capital can best be compared with the amount of capital defined for non-financial institutions above. If one wants to calculate the performance of an entity by a well-known indicator as the return on capital (RoC), one would use this concept of capital.

The second concept of capital is the *regulatory capital* requirement, also known as solvency. It is the amount a bank has to keep in order to meet the capital adequacy requirements as set by the regulator. On top of the amount of equity banks are allowed, within limits, to regard other items as part of regulatory capital, for example subordinated debt. A performance indicator using solvency is the so-called return on solvency (RoS).

The RoS has to be preferred over the RoC for at least one reason. Solvency is a scarce resource. Therefore, one wants to know what entity uses this scarce resource best. This comparison can then best be made by the RoS. However, a problem with solvency is that it can only be calculated if there is a capital charge. If there is no solvency, one can not calculate the RoS and a good comparison is not possible.

To overcome this problem of management control, a third capital concept was thought of: *economic capital*. Economic capital is the amount of equity that is required to cover for unexpected losses[31] within a certain confidence level and a certain time period. One could say that it is the internal equivalent of solvency (Bos, 1999a). If one knows the amount of economic capital required for a certain activity, one can calculate a performance indicator called return on economic capital (RoEC).

[31] Expected losses should be covered by provisions.

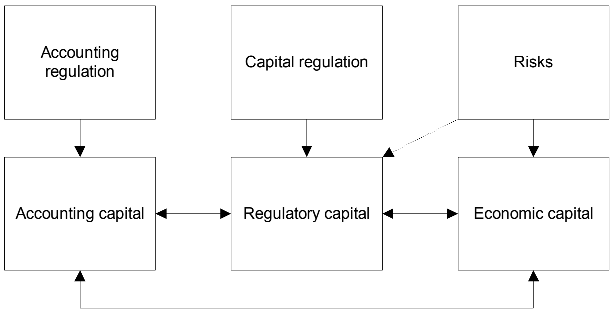
Since the amount of economic capital can be calculated for all activities within the bank or financial institution and because economic capital should incorporate all risks a good comparison of the relative performance is possible. This is called risk adjusted performance management. One can think of the already known concepts of Risk Adjusted Return on Capital (RAROC), Return on Risk Adjusted Capital (RORAC) or Risk Adjusted Return on Risk Adjusted Capital (RARORAC). From a management control perspective, if all activities were comparable (in a risk-reward context), this would allow the bank's management to allocate available equity to the most profitable activities. In Table 2.3 the three concepts of capital are summarised.

Table 2.3 Concepts of capital - summary

Concept of Capital	Definition
Accounting capital	Amount of equity in the balance sheet. Based on accounting principles
Regulatory capital	Amount of equity needed based on capital regulation. Also known as solvency
Economic capital	Amount of equity that is required to cover for unexpected losses within a certain confidence level and a certain time period

The question now is, how do the three concepts – capital, regulation and risk – relate to each other? In Figure 2.6 below this is shown. As one can see, accounting regulation leads to an amount of equity that is called accounting capital, which is the amount of equity available to the bank. Capital regulation (which is more and more based on "real" risk, therefore the dotted line) leads to regulatory capital, which is what the bank needs in other to satisfy regulators. Finally, risks lead to economic capital, which is the amount of equity that is required to cover for unexpected losses within a certain confidence level and a certain time period. These amounts of equity can then be compared to each other.

Figure 2.6 Relation between the concepts of capital



Now we have a definition of economic capital, we can focus on economic capital models in sections 2.4.3 and 2.4.4. Relevant regulation will be studied in section 2.5.

2.4.3 Some theoretical background on interest rates

Interest rates

There is no such thing as a single interest rate. First of all interest rates differ per currency, and furthermore interest rates in the market differ based on the credit risk of the underlying assets. Interest rates that can be identified amongst others are mortgage rates, deposit rates, treasury rates, LIBOR rates, zero rates, forward rates and short rates.
For interest rate models, which will be discussed in the next section, and some of the economic capital models studied in section 2.4.4 especially zero rates, forward rates and short rates are important.

Zero rates

The *n-year zero rate*, sometimes referred to as the *n-year spot rate* is the rate of interest that is earned on an investment that starts today and lasts for n years. All the interest and principal is realised at the end of n years, so there are no intermediate payments (Hull, 2000).
Unfortunately, not all rates observed in the market are zero rates, because often there are intermediate payments, for which the rate will be adjusted. Zero rates can then be calculated from known zero rates and the price of the instrument in the market, since that price will be the present value of future cash flows. This is done with a technique called bootstrapping (Hull, 2000). Equation (2.4) below shows how the price of a bond follows from zero rates R_t and its coupon c_t [32]. If the price of the bond and its coupon payments are known as well as all zero rates except one, this missing zero rate can then be calculated by using the equation. By following an iterative process all zero rates can be determined this way. The price of a bond follows from

$$P(c,T) = \sum_{t}^{T} c_t e^{-tR_t} \tag{2.4}$$

where:

$P(c,T)$	the price of a bond with coupon c and maturity T;
c_t	coupon at time t; and
R_t	zero coupon rate for maturity t years.

Forward rates

Forward rates are the interest rates implied by zero rates for a specified future time period. In other words, the one year forward rate in one year is the expected one year zero rate in one year. They follow from an arbitrage argument: investing in a two year bond today must have the same yield as investing in a one year bond today and another one year bond one year from now. If not, arbitrage would be possible.

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[32] In this equation continuous compounding is assumed. If compounding is not continuous the formula will slightly change. For more information on compounding, refer to Hull (2000).

If interest rates are continuously compounding and of equal length, the overall equivalent rate is simply the arithmetic average of the rates. In other words, the two year zero rate is the average of the one year zero rate and the one year forward rate. This is only approximately true when rates are not continuously compounded (Hull, 2000).
In general, if R_1 and R_2 are the zero rates for maturities T_1 and T_2 respectively, the forward rate R_F for the period of time between T_1 and T_2 follows from (2.5) below

$$R_F = \frac{R_2 T_2 - R_1 T_1}{T_2 - T_1} . \tag{2.5}$$

Short rates

Finally, the short rate can be identified. The short rate r at time t is the rate that applies to an infinitesimally short period of time at time t.
The interest rate models discussed below all model the short rate in one form or another. Short rates can be transformed to zero rates with help of some simple algebra[33].

Interest rate models

Interest rate models are used to model the developments of the yield curve in the future. These models are sometimes referred to as term structure models. Basically, two forms of interest rate models can be identified. These are equilibrium models and no-arbitrage models. The main difference between the two is that an equilibrium model does not necessarily fit today's term structure, whereas no-arbitrage models provide a perfect fit. For pricing this is an advantage, however, the models a more complex. In simple words the difference between equilibrium models and no-arbitrage models is that in the former today's term structure is an output, whereas in the latter this is an input (Hull, 2000).
Furthermore, interest rate models can be one-factor or multi-factor models. In one-factor models, the interest rate dynamics are dependent on only one factor, whereas in a multi-factor model, interest rate dynamics are dependent on more than one factor. This gives these models the advantage that they are better capable of showing a richer spectrum of term structure dynamics. A drawback is that multi-factor models are usually more complex to estimate.
To give an idea of how interest rate model look like, we will describe two one-factor equilibrium models as well as two no-arbitrage models in this section. This description is based on Hull (2000, p. 565-577).
In the description of the economic capital models below, we will see that Emmen (2001) and Boughanmi (2001) use a model that looks like a multi-factor model. We will describe Boughanmi's interest rate model while discussing Emmen's economic capital model.

[33] See Hull (2000), p. 565.

Equilibrium models

In one-factor equilibrium models there is only one source of uncertainty. All models have the same notation, which is shown in (2.6)

$$dr = m(r)dt + s(r)dz \qquad (2.6)$$

where:

dr	the instantaneous change in the interest rate;
$m(r)$	the instantaneous drift;
dt	an infinitesimally short change in time;
$s(r)$	the instantaneous standard deviation; and
$dz = \varepsilon\sqrt{dt}$	a Wiener process, with $\varepsilon \sim N(0,1)$ is a standardized normal distribution.

In this section two well-known one-factor models will shortly be described, which are the Vasicek and Cox, Ingersoll & Ross models.

The Vasicek model

Vasicek's model (1977) incorporates mean reversion. As is shown in (2.7) the short rate is pulled back to a level θ with speed κ, which are constants as is the volatility measure σ. Unfortunately, the model allows for negative interest rates.

$$dr = \kappa(\theta - r)dt + \sigma dz \qquad (2.7)$$

The Cox, Ingersoll & Ross model

The Cox, Ingersoll & Ross model (1985) is an extension of the Vasicek model where the rates are always non-negative[34]. Their mean reversion term is the same as Vasicek's, but the standard deviation is proportional to $\sqrt{r}$. This means that as the short-term interest rate increases, its standard deviation increases too. The model is shown in (2.8).

$$dr = \kappa(\theta - r)dt + \sigma\sqrt{r}dz \qquad (2.8)$$

No-arbitrage models

As shown in (2.6) the drift in a one-factor equilibrium model is not a function of time. In general, however, in a no-arbitrage model the drift is dependent on time, which allows a perfect fit to the initial term structure. In this section, the no-arbitrage models of Ho & Lee and the Hull & White model will be briefly described. Again, the descriptions are taken from Hull (2000).

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[34] Although they can reach zero. Depending on the parameter values the behaviour of the model at 0 needs to be specified. See James & Webber (2000).

The Ho & Lee model

The Ho & Lee model (1986) is shown in (2.9). In this model σ is the instantaneous standard deviation, which is assumed constant. The drift term $\theta(t)$ is a function of time. It can be calculated from forward rates, time and the instantaneous standard deviation.

$$dr = \theta(t)\,dt + \sigma dz \tag{2.9}$$

An advantage of the Ho & Lee model is that it is analytically tractable and provides a perfect fit to the initial term structure. A disadvantage, however, is that the model does not incorporate mean reversion.

The Hull & White model

The Hull & White model (1990) is an extension of the Vasicek model that fits the initial term structure. The model is shown in (2.10), with κ and σ constants.

$$dr = \kappa\left(\frac{\theta(t)}{\kappa} - r\right)dt + \sigma dz \tag{2.10}$$

The model can be seen as a form of the Ho & Lee model with a mean reversion at rate κ, or, alternatively, as the Vasicek model with a time dependent mean reversion level. At time t the short rate reverts to $\theta(t)/\kappa$ at rate κ.

Again, the drift term $\theta(t)$ is analytically tractable, which is one of the advantages of the model. Another advantage is that the model includes mean reversion.

2.4.4 Existing economic capital models

Bessis/Matten (1998/1996)

Bessis (1998) and Matten (1996) state that either an earnings approach or a value approach can be taken to calculate the economic capital requirement. In fact, the income approach equals the earnings at risk technique, whereas the value approach equals the duration (Bessis) and value at risk (Matten) techniques. All these techniques were already mentioned in section 2.3.3. Below these models are shortly described.

Earnings volatility model

If the income approach is to be used, first the volatility of interest rates and a period have to be determined. According to Bessis a period of one year should suffice, since banking book products[35] are considered medium term. However, since exposures can be hedged or reversed at any time, shorter time spans should also be considered.

[35] Bessis calls them ALM positions. It is assumed that these are banking book positions, since interest rate risk as defined by Bessis is not a market risk, and therefore does not focus on trading books.

Once the volatility for a certain period has been determined, the next step is to chose a certain confidence level based on a desired target rating. If a normal distribution of interest rates is assumed, a multiplication factor follows from this confidence level.
The next step to take is to multiply the gap (per bucket) with the volatility (per bucket) and the multiplication factor. The resulting outcome is the maximum downside deviation of income. This amount less the expected income is the amount of economic capital.
Matten takes a somewhat different approach. He does not use the gap and interest rate volatility, but focuses on the volatility of earnings. This volatility times a certain multiplication factor gives the amount of economic capital.

Value approach

The value approach as proposed by Bessis is largely equal to the income approach mentioned above. The only difference is that the amount of economic capital is based on the volatility of the net present value of the banking book. The volatility of the net present value is based on the modified duration of the banking book and the volatility of interest rates as shown in (2.11)

$$\sigma(\text{NPV}) = \frac{D_{\text{NPV}}}{1+r}\sigma(r) \tag{2.11}$$

where:

$\sigma(\text{NPV})$	the volatility of the net present value;
D_{NPV}	the duration of the net present value;
r	the interest rate; and
$\sigma(r)$	the interest rate volatility.

Again Matten takes a somewhat different approach. He uses the value at risk technique. However, the holding period should be lengthened to for example one year, and the confidence level should be adjusted to resemble the default frequency of the desired target rating. For example, the default frequency of an AAA-bank is 0.01%. This translates in a confidence level for economic capital calculations of 99.99%.

Comments

The main advantage of Bessis' approaches is their relative simplicity. However, the problem with these approaches is that they implicitly assume a stable balance sheet for the period over which economic capital is calculated.
Furthermore, embedded options are not taken into account. Options can not be slotted into a gap report as already mentioned in section 2.3.3 (see page 27). Because Bessis' income approach is based on gaps, embedded option effects can not be taken into account.
The latter is not true for Matten's model. However, because the model is based on the ex-post total results, one can not differentiate between the causes of the risk. From a management control perspective the model therefore has little informational value.
Embedded options effects are also not taken into account in the right way for Bessis' value approach, although for another reason. Options can cause negative convexity as was also already mentioned in section 2.3.3 (see page 31). Usually for small interest rate changes this is

no problem, and duration can be used without any problems. However, economic capital is calculated for extreme events, which are in fact large interest rate changes. At that time, negative convexity becomes an issue and duration should not be used any longer to estimate value changes. Thus an economic capital amount based on duration is doubtful.
Matten's value at risk approach is more useful, although this model again implicitly assumes a stable balance sheet during the holding period of one year. For the retail banking book this is a doubtful assumption due to the embedded options.

Oliver, Wyman & Company (2001)

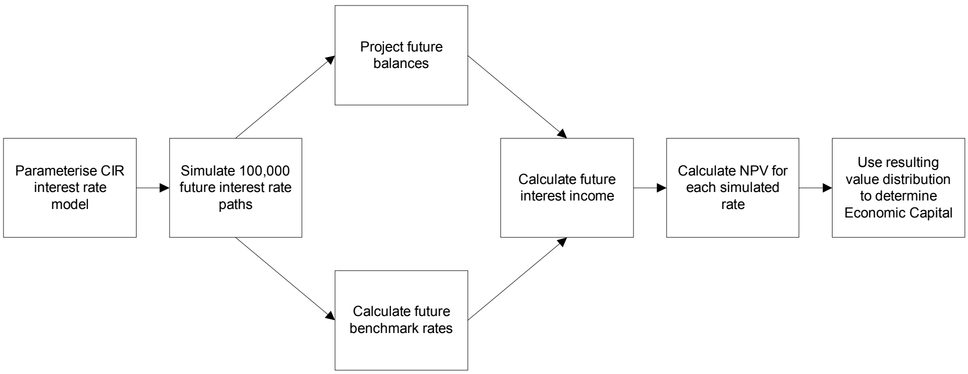
Definition

In this section the approach to calculate the amount of economic capital for interest rate risk in the banking book taken by Oliver, Wyman & Company (OWC) will be described.
OWC defines interest rate risk as the volatility of a book's *Net Asset Value* or the *Present Value of Equity*. The net asset value is the difference between the net present value of assets and the net present value of liabilities. Thus, one can state that OWC uses a value approach.
According to OWC interest rate risk is caused by a mismatch in the repricing characteristics of assets and liabilities. This part is called a "structural" risk. Another cause of interest rate risk are the risks due to embedded optionality (OWC, 2001).

Interest rate risk capital

As already mentioned, OWC uses a value based approach in measuring interest rate risk. This approach can be summarized according to Figure 2.7 (OWC, 2001).

Figure 2.7 OWC economic capital approach (Source: Oliver, Wyman & Company)



To model interest rates the well known model of Cox, Ingersoll & Ross (CIR), which is a one-factor model will be used[36]. Since the economic capital horizon is one year, during the first twelve months a stochastic approach will be used. After this period, interest rates will revert to their long time average.

[36] For more details regarding this model, please refer to Cox, Ingersoll & Ross (1985), Hull (2000) or see page 38.

OWC recognises the potential serious inconsistency between their approach and the current treatment of the retail banking book within banks, which is the fact that a value based approach is used in measuring the risk, whilst returns are being measured using accruals accounting. OWC therefore recommends to develop mark-to-market measures of the returns in these books (OWC, 2001).

To calculate the amount in interest rate risk capital, the steps mentioned in Figure 2.7 above have to be followed. First, the CIR model has to be parameterised and interest rate simulations will be done. These simulations will have a horizon of ten years. Only the first twelve months will be modelled using the stochastic component of the CIR model. For the resulting months the stochastic component is removed and only the mean reverting term is in place.

The modelled interest rates will be used to calculate future benchmark rates and to model the future balance sheet. The repricing characteristics of the current balance sheet depend on the book that is under focus. For the retail banking book, it is assumed that the balance sheet is "going concern". This means that once existing balances roll off, they will be replenished. For the other banking books this approach is not used. Since (some of) these books are intended to take a strategic position, the balances will not automatically be replenished irrespective of the interest rate environment. Instead, they simply roll off (OWC, 2001). For both books, the assumption is made that repricing occurs gradually over the year. Therefore, $1/12^{\text{th}}$ of the balance sheet will reprice every month.

OWC take into account some embedded option effects, which are described below.

Behavioural assumptions

OWC states that "*ideally, it would be possible to link the responsiveness of each individual product group to interest rate changes. However, in practice this will not be feasible, due to data availability limits and insufficient computational power*". Therefore, they focused only on the major product groups in the retail banking book balance sheet, which are the savings accounts, term deposits and mortgages (OWC, 2001).

The model which OWC proposes is built on three different effects which may arise from interest rate changes (OWC, 2001):

- *level effects*, which are effects caused by the absolute level of interest rates;
- *switching effects*, which are effects caused by the spreads between the rates on various products; and
- *expectations effects*, which are the effects of clients' expectations on the direction of interest rate changes.

Apart from these behavioural effects a certain growth rate is assumed which can not be explained by interest rate changes. This leads to the model as shown in (2.12) below, which incorporates all three effects. The model was estimated using the ordinary least squares method.

$$\ln\left(B_t\right) - \ln\left(B_{t-1}\right) = c + \beta_1 r + \beta_2\left(r - r^*\right) + \beta_3\left(r - \overline{r}\right) \tag{2.12}$$

where:

B_t	the balance sheet on time t;
c	the constant growth rate;
r	the current interest rate;
r^*	the interest rate on a substitute product;
$\overline{r}$	the average interest rate over the past twelve months; and
β_i	the regression coefficients.

Optionality

OWC identifies two types of optionality, which are the prepayment option and the so-called pipeline option[37]. The latter is considered the six month period in which the mortgage rate is determined. This is simply modelled by assuming that new mortgages in any month will be priced at the lowest rate of the preceding six months (OWC, 2001)[38].

Another embedded option that is mentioned by OWC is the prepayment option. However, no solution for this embedded option is given, but the risk is assumed to be mitigated by the following two factors (OWC, 2001):

- since rates are currently relatively low, a general upward movement of interest rates is expected[39]. The prepayment option is not likely to be exercised in a rising rate environment;
- the prepayment option is not a free option. Therefore, it could be expensive to prepay.

All this results in future balance sheet projections. From these balance sheet projections, future interest incomes and Net Present Values (NPVs) can be calculated. Since this process will be repeated 100,000 times, it will result in a value distribution. The target rating again defines the confidence interval, which is then used to determine the amount of economic capital needed.

Management intervention

Finally, there is the concept of management intervention. Management intervention is the process that risks are mitigated, because management will intervene if losses were to become to big. Thus, the actual loss will be less than the maximum calculated loss, depending on the point of time the management intervenes.

The actual amount of economic capital reduction and thus management intervention depends on two factors. The first is the so-called *intervention trigger*. This parameter represents the likelihood of intervention, i.e. at what percentage loss will management intervene. The second factor is the ease and cost of intervention. Intervention will be done by hedge contracts. Depending on the size and structure of the book, this might be more of less difficult and costly. For more information on management intervention, please refer to OWC (2001).

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[37] We refer to this option as the quotation rate option.

[38] To our knowledge most quotation rate options in The Netherlands have a three months maturity.

[39] Due to the mean reversion in the CIR model.

Comments

At first glance the OWC approach looks useful. However, the model has some disadvantages. The first concerns the interest rate model. Since the Cox, Ingersoll & Ross interest rate model is a one factor model, only one interest rate is simulated. The other rates in the term structure are assumed to be perfectly correlated to this single rate. This results in parallel shocks in the yield curve only, which is not realistic.

Another point is the modelling horizon of ten years, of which twelve months are stochastically simulated. No end term is included after ten years. However, the discount factor for a cash flow occurring in ten years is still around 50%[40]. This is a substantial amount and can not be neglected (Emmen, 2001).

A third issue is that the OWC approach only focuses on mismatch risk, which they call structural risk and optionality. However, losses can also be caused by basis risk as already described in section 2.3.2. OWC does not take this risk into account.

Finally, although OWC models pipeline risk, the effects of other embedded options are not included. Therefore one can question the resulting economic capital number. A positive aspect of the model is the management intervention factor. In practice, it is unlikely that a bank's management will not intervene in a position on which losses are constantly growing. At some point the position will be unwound. On the other hand, it will be difficult to model this intervention factor.

Emmen (2001) & Boughanmi (2001)

Introduction

Emmen (2001) and Boughanmi (2001) are both internal Rabobank documents. Where Emmen provides the economic capital framework, Boughanmi details how to model interest rates as well as how to calculate economic capital using the interest rate model. Below, we will first describe the economic capital framework as laid out by Emmen (2001). After that we will describe Boughanmi's interest rate model.

Economic capital framework

Emmen's economic capital model tries to find the "*maximum amount of value that can be lost in a year due to unexpected rate movements*" (Emmen, 2001). To find this amount a three step process has to be followed:

1. find the possible interest rate changes within a year and the effect on the pricing for certain products;
2. find the relationship between market rates, product rates and the effects of those on the various product choices by customers; and
3. simulate a number of paths and determine the amount of economic value based on the resulting distribution.

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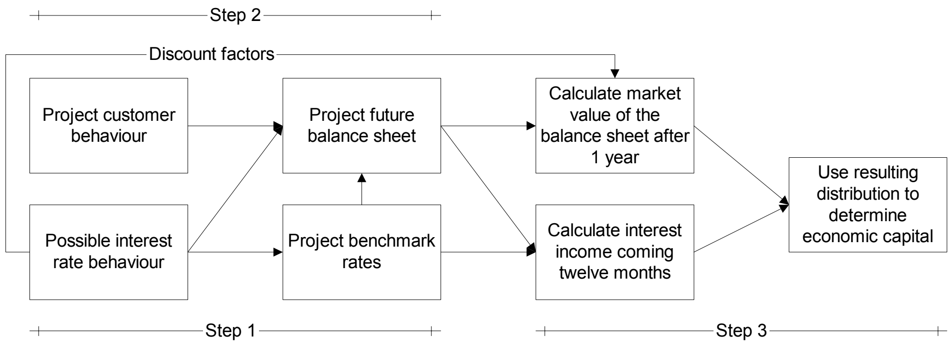
40 Depending on the current interest rates in the market.

Emmen states that economic capital is the difference between today's market value and the worst case[41] market value after one year. The market value after one year is the present value of the position at that time plus the interest income in the coming year. Graphically, his model can be presented as shown in Figure 2.8.

Figure 2.8 Emmen's economic capital approach



Interest rate model (Boughanmi, 2001)

Boughanmi refers to his interest rate model as a four-factor model. Four points on the yield curve are modelled. Since these rate are not assumed to be perfectly correlated a wide range of yield curve shape are possible. Thus, not only parallel shifts are possible, but also tilts and flexes, which are slope and curvature effects respectively (Boughanmi, 2001).
Of course, it will still be necessary to interpolate between the grid points and to use a certain correlation factor for other yield curves.
A disadvantage is that instead of parameterising only one model, now actually four models have to be parameterised. This will add some complexity. However, due to the improved variety of yield curve shapes and the dependence of interest rate risk measurement on the shape of the curve, a four factor model is preferable (Boughanmi, 2001). The interest rate model is shown in (2.13)

$$r_{i,t+1} - \mu_i = \gamma_i \left(r_{i,t} - \mu_i \right) + \varepsilon_{i,t+1} \tag{2.13}$$

where:

$r_{i,t}$	the modelled zero coupon rate for maturity vertex i at time t;
μ_i	the mean reversion rate for maturity vertex i;
γ_i	the speed with which $r_{i,t}$ is pulled towards the mean reversion rate μ_i;
$\varepsilon_{i,t}$	normally distributed random variables, $\varepsilon_{i,t} \sim N(0, \mathbf{\Sigma})$; and
$\mathbf{\Sigma}$	the variance-covariance matrix.

[41] Depending on the confidence interval.

A simple four step approach is then taken to estimate μ_i, γ_i and $\mathbf{\Sigma}$ (Boughanmi, 2001). First, the long time average rate for vertex μ_i is calculated as given by (2.14)

$$\hat{\mu}_i = \frac{1}{T}\sum_t^T r_{i,t} \tag{2.14}$$

where:

$\hat{\mu}_i$ the estimated mean reversion for maturity vertex i;
T the number of periods over which observations are available; and
$r_{i,t}$ the observed rate at time t for maturity vertex i.

Step two is to centre the observations by the expected values, $r_{i,t} - \hat{\mu}_i$, after which the gammas can be estimated by the ordinary least square (OLS) regression method per yield curve vertex as is shown in (2.15)

$$\hat{\gamma}_i = \frac{\sum_t^{T-1}\left(r_{i,t+1} - \hat{\mu}_i\right)\left(r_{i,t} - \hat{\mu}_i\right)}{\sum_t^{T-1}\left(r_{i,t} - \hat{\mu}_i\right)^2} \tag{2.15}$$

where:

$\hat{\gamma}_i$ the estimated mean reversion speed for maturity vertex i.

Finally, the covariance matrix has to be estimated by applying (2.16), where $\hat{\sigma}_{i,j}$ is the (co-)variance between maturity vertexes i and j and $\hat{\varepsilon}_{i,t} = \left(r_{i,t} - \hat{\mu}_i\right) - \hat{\gamma}_i\left(r_{i,t} - \hat{\mu}_i\right)$ are the OLS residuals:

$$\hat{\sigma}_{i,j} = \frac{1}{T-1}\sum_t^{T-1}\hat{\varepsilon}_{i,t}\hat{\varepsilon}_{j,t} \;. \tag{2.16}$$

Boughanmi states that the parameters could be better estimated using the seemingly unrelated regression (SUR) method. This way the parameters are not estimated separately, but jointly, which should result in better parameter estimates. For further details, refer to (Boughanmi, 2001).

Economic capital calculation

When applying Emmen's framework using Boughanmi's interest rate model multiple times, it results in multiple values, which are normally distributed with mean μ and standard deviation σ[42]. The amount of economic capital is then determined by (2.17)

$$\text{EC} = \left|\kappa\sigma\right| - \mu \tag{2.17}$$

[42] Provided that deterministic or normally distributed balance sheet projections are used.

where:

EC economic capital;

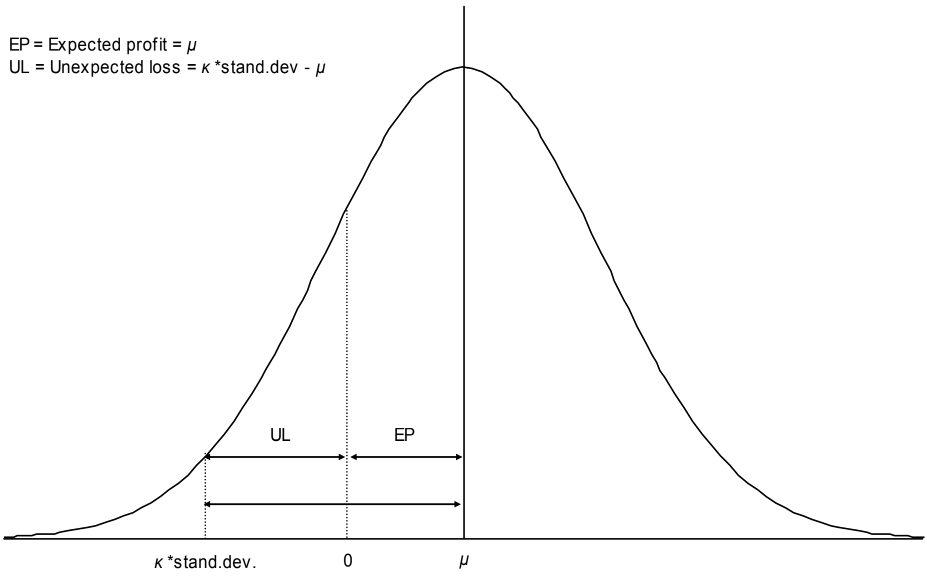
κ multiplication factor which determines the desired confidence interval. For example, if one wants a one sided 97.5% confidence interval, κ equals ± 1.96 ;

σ the standard deviation of the value distribution; and

μ the mean of the value distribution, in other words the expected value of the portfolio.

The expression in (2.17) above can be understood by looking at Figure 2.9 below and remembering that economic capital should only cover for unexpected losses.

Figure 2.9 Calculating economic capital



As one can see from Figure 2.9 above the expected return of this portfolio is above zero. If economic capital was to be calculated as $|\kappa\sigma|$, the amount of economic capital will be overestimated since the expected profit is included in that number. Therefore, this number has to be subtracted.

Of course, theoretically, it is also possible that the expected result is below zero. In that case economic capital is calculated as $|\kappa\sigma|$. However, when a bank applies decent interest rate risk management, expected future losses will not occur, since the position will be either closed or hedged in this instance.

Comments

Although the approach taken by Emmen and Boughanmi is by far the most detailed approach when it comes to interest rate simulation, it lacks detail on how to model embedded options. This makes the resulting economic capital number doubtful. Furthermore, the framework does not take basis risk into account, nor do the other models described before.

Concluding remarks on economic capital models

Summarising, one can state that the approach taken by Emmen (2001) & Boughanmi (2001) looks most promising. A second conclusion is that none of the models incorporates basis risk explicitly. This can be done by simultaneously modelling more yield curves. A disadvantage is that extra complexity will be added to the model if this is done. Finally, after studying the above mentioned economic capital models, the general structure of economic capital models as shown in Figure 2.10 below can be defined.

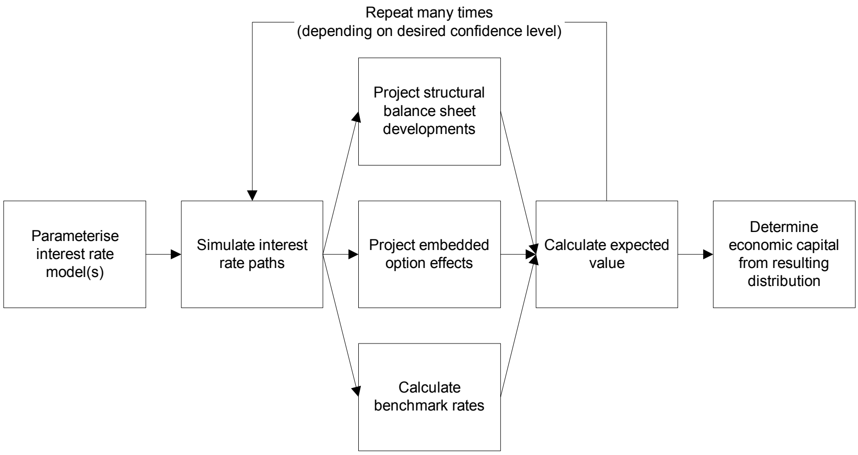
First, one has to start by parameterising an interest rate model for each yield curve in which the bank has an exposure. Secondly, an interest rate path has to be simulated for all interest rate models. The third step can be split in three sub-steps. The first is to project structural balance sheet developments from the simulated interest rate paths. Structural balance sheet developments are those balance sheet developments not caused by embedded optionality, growth for example. The second step is to project the effects of embedded optionality based on the simulated rates, and finally one has to calculate benchmark rates (discount factors) from the simulated rate paths.

Step four in the whole process is to calculate the expected value of the balance sheet resulting from the simulated interest rate paths.

In order to find the resulting number of economic capital, steps two to four have to be repeated many times. The exact number of paths that have to be simulated depends on the desired confidence level and thus on the target rating.

Finally, this results in a value distribution, from which the amount of economic capital can be determined.

Figure 2.10 General economic capital calculation framework



2.5 Regulation

2.5.1 Introduction

In this section we will describe existing capital regulation. Furthermore, we will elaborate somewhat on upcoming capital and accounting regulation. At the end of this section we will have found an answer to the second part of research question three, i.e. why economic capital is important. We will start with capital adequacy regulation in section 2.5.2. In section 2.5.3 we will describe some upcoming accounting regulation that may impact the way banks have to report their income and capital.

2.5.2 Capital adequacy regulation

Introduction

Until the 1980's banks were not forced to keep a specific amount of equity. Exchange rates were fixed and banking was not as international as today. Sometimes this time in banking is referred to as 3-6-3-banking. In the morning the banker takes a loan at 3%, he gives a loan at 6% and at 3 pm he is on the golf course (Matten, 1996).

But that all changed in the early 1970's. Back then, the Bretton Woods pact, established in 1944, was abandoned. The Bretton Woods pact regulated exchange rates. Because of that there was no volatility in exchange rates and international banking was less risky than today. However, due to the war in Vietnam and the enormous costs this led to, the United States were not able to hold the Bretton Woods pact together. Because of this, exchange rates became volatile and this ended the period of 3-6-3-banking.

As a result supervisors of the G-10 countries and Luxembourg formed the Basel Committee on Banking Supervision and decided to meet on a regularly basis to discuss supervisory issues. One of them was a sort of "early warning system"[43]. During the first years most effort was put into closing the gaps in international supervisory coverage in pursuit of two basic principles: that no foreign banking establishment should escape supervision; and that supervision should be adequate[44].

In the early 1980's supervisors in the different countries had implemented capital adequacy guidelines. As a result of the differing rules international competitive inequality arose. Because of that "*there was a strong recognition within the Committee of the overriding need for a multinational accord to strengthen the stability of the international banking system and to remove a source of competitive inequality*"[45]. After publishing a consultative paper in December 1987 the Committee released a capital adequacy measurement system in July 1988, which came effective as of 1 January 1992[46].

This system is known as the 1988 Capital Accord or Basel I and gave capital requirements for credit risk. The methodology used to quantify this type of risk is based on risk weightings.

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[43] Basel Committee (1997a), p. 10.

[44] Basel Committee (1997a), p. 11.

[45] Basel Committee (1997a), p. 12.

[46] Basel Committee (1988).

This means that a bank has to weight its assets and off-balance-sheet items. The weightings differ depending on the counterparty of the asset and sometimes the maturity of the claim. For off-balance-sheet items the weightings are similar, but they have to be converted to '*credit equivalents*' first. On the other side of the balance sheet equity is divided in two categories, known as Tier 1 and Tier 2 capital. Tier 1 capital contains items like share-capital, while Tier 2 contains items like revaluation reserves and general provisions. The Capital Accord requires that a bank's capital base contains at least 50% Tier 1 capital. In total the capital base has to be at least 8% of the risk-weighted assets and off-balance-sheet items.

The 1988 Accord has been amended a few times since it became effective. The most important amendment is the addition of rules to incorporate market risk in 1996[47]. The 1996 amendment defined a few different types of market risk and allowed banks, at discretion of their national authority, to employ a third tier of capital, Tier 3, for the sole purpose of meeting the capital requirements for market risk[48]. But the most important innovation issue of this amendment was that banks were allowed, subject to some conditions, to use their own models to calculate the capital requirement for market risk. The 1996 amendment became effective as of January 1, 1998.

The latest big development was the release of a series of consultative papers, starting in June 1999[49], which will lead to a new capital accord, known as Basel II, which will be effective as of 1 January 2007. The biggest change is that the accord leaves more room for internal models and that more risk types are included. This new Capital Accord is based on three pillars. The first one is about minimum capital requirements for credit risk, market risk and operational risk. The second Pillar is about the supervisory review process, the third is about the use of market discipline and deals with reporting issues. For interest rate risk in the retail bankbook no minimum capital requirements are given, which means it falls completely under Pillars II and III.

In the meantime the European Union also released capital adequacy guidelines. In 1989 the European Union released two documents. The first one is known as the Own Funds Directive (OFD) (EEC, 1989a). It defines what can be taken into capital and what cannot. The second document is known as the Solvency Ratio Directive (SRD) (EEC[50], 1989b), which obliged banks to hold capital for credit risk. In 1993, the Commission released another paper, which is known as the Capital Adequacy Directive (CAD I) (EEC, 1993). This paper obliged banks to hold capital for market risks too. But only a standardised approach was given. In 1998, Capital Adequacy Directive II (CAD II) (EC[51], 1998) was issued, which allowed banks to use their own models for calculating the capital charge for market risk. Finally, at the end of 1999, the European Commission released a consultative paper (EC, 1999), which closely follows the Basel proposals.

In the remainder of this section we will study some regulation specifically relating to interest rate risk.

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47 Basel Committee (1996).

48 A few conditions have to be met. See for further details: Basel (1996), p. 7.

49 Basel Committee (1999).

50 EEC stands for the European Economic Community, which is called the European Union (EU) nowadays.

51 EC stands for European Commission. This name superseded the name EEC.

Regulation relating to interest rate risk

Introduction

In the late seventies and early eighties, interest rates in the United States rose rapidly. As a result numerous Savings and Loan banks (S&Ls) became insolvent. Their regulator at that time, the Federal Home Loan Bank (FHLB) therefore issued guidelines. Between 1984 and 1989 thrifts[52] had to report interest rate risk information in the form of a maturity gap report to the FHLB on a confidential basis. In 1989, the FHLB system's Office of Regulatory Activities issued Thrift Bulletin 13 (TB 13)[53]. This was the first regulation that required thrifts to have a proper system of interest rate risk management. However, neither an explicit risk measurement system nor a capital charge for interest rate risk was provided. TB 13 was worked upon by the Office of Thrift Supervision (OTS), the successor of the FHLB. However, a capital charge was still not required nor applied. This changed in 1991 with the Federal Deposit Insurance Corporation Improvement Act (FDICIA)[54]. All banking regulators, including the OTS, the Federal Reserve Bank and the Office of the Comptroller of the Currency (OCC), had to incorporate explicit interest rate risk regulation and had to develop capital charges for it[55]. Because of this, the OTS issued the Net Portfolio Value (NPV) model in 1994 (OTS, 1994). Thrifts had to complete forms showing their exposures. Then, the OTS with help of the NPV model calculates the exposure to interest rate risk.
In 1993 the first attempt to develop international guidelines for interest rate risk and capital charges for it was undertaken. In that year the Basel Committee on Banking Supervision issued a consultative paper to include interest rate risk into their regulatory framework (Basel, 1993). The proposal was rejected by the banking industry as being to simple and was never implemented. However, it was an important first step to include interest rate risk in the regulatory framework. Interest rate risk in the trading books was included in the Basel framework by the 1996 amendment to the 1988 Basel Accord, which were briefly described and referred to above. Interest rate risk in the banking book was not discussed until the 1999 Basel II consultative paper and its follow-ups. As discussed before, that paper distinguished three so-called pillars.
In the meantime, the Basel Committee issued a document containing principles for the management of interest rate risk (Basel, 1997c). This document was updated with the second consultative paper regarding Basel II in January 2001 (Basel, 2001).
Almost at the same time as the Basel Committee, the European Union also issued a consultative paper (EC, 1999). This paper also included a section on interest rate risk in the banking book.

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52 A thrift is a savings and loan bank.

53 Federal Home Loan Bank System's Office of Regulatory Activities, *Thrift Bulletin 13, Responsibilities of the board of directors and management with regard to interest rate risk*, January 1989.

54 One Hundred Second Congress of the United States of America, *Federal Deposit Insurance Corporation Improvement Act*, P.L. 102-242, 105 STAT. 2236, Washington, January 1991.

55 For a more elaborate discussion on the American banking crisis and FDICIA, see Benston, G.J. and G.G. Kaufman, *FDCIA after five years: a review and evaluation*, Federal Reserve of Chicago working paper, Chicago, June 1997.

In this section the regulation noted above will be described and discussed in somewhat greater detail. We first concentrate on the American regulation, starting with Thrift Bulletin 13 followed by the OTS Net Portfolio Value model. Then we will turn our focus to international regulation with the 1993 Basel proposal, followed by the 1999 consultative paper and its follow-ups. This short review of regulation regarding interest rate risk in the banking book ends with the Basel principles for the management of interest rate risk.

Thrift Bulletin 13

Thrift Bulletin 13 (TB 13) was first issued in 1989. It has been revised a few times since. TB 13 focuses on the management of interest rate risk. This means not necessarily eliminating all exposure to changes in interest rate risk, but about controlling that exposure. In order to be able to manage interest rate risk in TB 13 a number of responsibilities for the board and senior management were defined. Some of these responsibilities resemble the 1997 principles of the Basel Committee (see as of page 60). Furthermore, TB 13 required larger institutions to calculate their interest rate exposure. To do this, the bank should at least calculate the effect of a parallel shock of 100, 200, 300 and 400 basis points up and down. For each shock the bank's management should set limits for both Net Interest Income (NII) and the Market Value of Portfolio Equity (MVPE) that represents the maximum allowed change in those numbers. Usually, calculating the NII and MVPE require some assumptions, for example about the prepayment behaviour of customers. These assumptions should be well documented and clearly understood, as well as revised regularly.
TB 13 has been amended a few times. The most important amendment was TB 13a (OTS, 1998). This amendment is an extended version of TB 13. Instead of calculating the MVPE, TB 13a requires the calculation of the Net Portfolio Value (NPV), which can be done by applying the OTS Net Portfolio Value model (see below) or a own model.
The risk sensitiveness of an institution is then determined using two dimensions. First, the Interest Rate Sensitivity measure, which is the difference between the post- and pre-shock NPV ratio[56]. The higher the Interest Rate Sensitivity measure the higher the risk for the institution. The second dimension the OTS uses to assess the interest rate risk exposure of a thrift is the post-shock NPV ratio. The higher the post-shock NPV ratio the lower the risk is. These two dimensions are included in a table to determine the level of interest rate risk (see Table 2.4).

Table 2.4 Summary of the level of interest rate risk (Source: OTS, TB 13a, 1998)

Post-shock NPV ratio	Interest Rate Sensitivity measure			
	0 – 100 bp.[57]	100 – 200 bp.	200 – 400 bp.	Over 400 bp.
Over 10%	Minimal risk	Minimal risk	Minimal risk	Moderate risk
6% – 10%	Minimal risk	Minimal risk	Moderate risk	Significant risk
4% - 6%	Minimal risk	Moderate risk	Significant risk	High risk
Below 4%	Moderate risk	Significant risk	High risk	High risk

[56] See the section on the OTS Net portfolio Value model in this chapter on how to calculate the NPV ratio.
[57] bp. = basis points.

The level of interest rate risk combined with an assessment of the quality of risk management gives the so-called S rating. In Table 2.5 the S ratings are summarised.

Table 2.5 S rating (Source: OTS, TB 13a, 1998)

Quality of risk management	Level of Interest Rate Risk			
	Minimal risk	Moderate risk	Significant risk	High risk
Well controlled	1	2	3	4 or 5
Adequately controlled	2	2	3	4 or 5
Needs improvement	3	3	3	4 or 5
Unacceptable	4	4	4	4 or 5

As can be seen in the table above a high risk institution always receives a four or five rating. A five rating is only applied if the risk poses an immediate threat to the solvency of the institution.

The S rating is part of the so-called CAMELS rating system. In this system banks receive a rating, called the composite rating, based upon the rating on the individual components of the CAMELS system, which are Capital adequacy, Asset quality, Management, Earnings, Liquidity and Sensitivity to market risk. The higher the rating the higher the risk. If necessary bank management has to take actions to improve the rating.

The OTS Net Portfolio Value model (1994)

The Office of Thrift Supervision's Net Portfolio Value model was issued in 1994 to measure the interest rate risk exposure of thrift institutions. The Office of Thrift Supervision (OTS) recognises a few types of interest rate risk, which are risks due to "*differences in maturity, repricing and coupon characteristics of assets and liabilities; and the existence of options*"[58]. This includes all risk types defined in section 2.3.2.

In its document the OTS states that interest rate risk can be measured both as the risk to net interest income or as the risk to economic value. The latter is also referred to as the price sensitivity of a financial instrument, or the changes in the value of the instrument due to changes in interest rates. The advantage of the price sensitivity approach is that it uses all future cash flows of an instrument, whereas the risk to net interest income approach only uses the information relating to the coming year. Therefore, the OTS uses the price sensitivity approach in their Net Portfolio Value (NPV) model. To measure the risk, the NPV is calculated in nine scenarios, which are a base case scenario, using today's interest rates, and eight parallel shock scenarios, which shock the base case interest rates 100, 200, 300 and 400 basis points up and down[59].

The Net Portfolio Value is calculated as shown below in (2.18)

$$NPV = PV_A - PV_L - PV_O \tag{2.18}$$

[58] Office of Thrift Supervision, *The OTS net portfolio value model*, Washington, 1994, p. 1-1.

[59] Actually, if interest rates are below 4% the 400 basis points down shock is replaced by a downward shock equal to half of the value of the three-month bill rate (OTS, 1994, p.1-2).

where:

NPV	net portfolio value;
PV_A / PV_L	present value of expected net cash flows from existing assets/liabilities; and
PV_O	present value of expected net cash inflows from existing off-balance-sheet contracts.

The greater the change in NPV for a given change in interest rates, the greater the exposure of the institution.
To calculate the present value of assets, liabilities and off-balance-sheet items, three methods are used. Simple products, that is, instruments without embedded options are valued using a static discounted cash flow analysis. The present value is then calculated as shown below

$$\mathrm{PV} = \sum_{t}^{T} \frac{CF_t}{\prod_{i=1}^{t}\left(1 + f_i + s\right)} \tag{2.19}$$

where:

PV	present value;
T	maturity;
CF_t	cash flow at time t;
f_i	implied forward rate between time i and $i+1$; and
s	spread.

The cash flows are sometimes known in advance, in other cases they are not known for sure, because of prepayments or unexpected withdrawals. In that case, the OTS NPV model makes certain assumptions about future cash flows. These assumptions will not be discussed here. The spread in (2.19) above is calculated iteratively. It is the number that causes a newly issued instrument to be valued at par. The spread is assumed to be constant in the shock scenarios. A spread is usually applied to correct for credit risk. If no credit risk is present, no spread needs to be applied. This is for example the case for AAA rated government paper. In that case one can use spot rates or zero coupon rates.
If a shock scenario is applied, first the "new" spot rates and implied forward rates are determined, after which an adjusted PV is calculated.
When an instrument contains embedded options, like the prepayment option in a mortgage, a somewhat more sophisticated approach is used. In this case a Monte Carlo model is applied which simulates 200 paths of short-term rates based on the long-term volatility of these short-term rates. Based on the empirically derived behaviour of long-term (five year) interest rates, 200 paths of long-term rates are simulated as well. These long-term rates are then used to model prepayment behaviour. This prepayment behaviour plus the simulated short-term rates are used to determine the expected cash flows and to calculate a present value out of them. An average price is then calculated based on the outcome of all 200 simulates paths. To value an instrument at par an option adjusted spread (OAS) is determined. The OAS is that amount that causes the average price to be equal to par. Finally, the economic values in the alternate rate scenarios can be determined. It is assumed that the OAS does not change in the alternative scenarios. The above is summarised in Figure 2.11 on page 55.

Finally, the third method used to determine the economic value of instruments is applied to interest rate derivatives, such as cap and floor agreements. The value of these instrument is calculated by using the 1976 Black model for interest rate derivatives, which is given in expressions (2.20) to (2.22)

$$C = e^{-rT}\left[FN\left(D_f\right) - XN\left(D_f - s\sqrt{T}\right)\right] \tag{2.20}$$

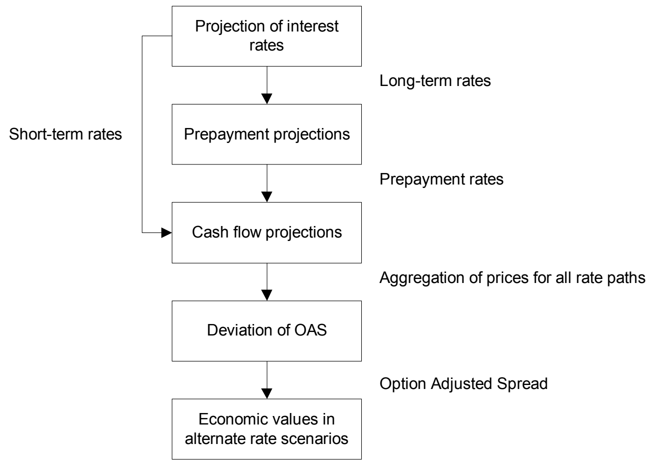
$$P = e^{-rT}\left[XN\left(-D_f + s\sqrt{T}\right) - FN\left(-D_f\right)\right] \tag{2.21}$$

$$D_f = \left[\ln\left(\frac{F}{X}\right) + \left(\frac{s^2T}{2}\right)\right] \Big/ s\sqrt{T} \tag{2.22}$$

where:

C	price of a call option;
P	price of a put option;
F	forward price;
X	strike price of the option;
T	time to option expiration;
r	risk free interest rate;
$N(\cdot)$	cumulative normal distribution; and
s	volatility of forward price.

Figure 2.11 Illustration of the option-based approach (Source: OTS NPV model)



As soon as the present values of assets, liabilities and off-balance-sheet instruments have been calculated a number of risk measures can be determined. First of all the so-called NPV ratio, which is calculated as shown in (2.23) below

$$\text{NPV}_{ratio} = \frac{\text{NPV}_i}{\text{PV}_{\text{A},i}} \tag{2.23}$$

where:

NPV_i	net portfolio value in scenario i ; and
$\text{PV}_{\text{A},i}$	present value of assets in scenario i .

The pre-shock NPV ratio is the NPV ratio if the base case scenario used. The *exposure measure*, also known as the post-shock NPV ratio is the NPV ratio resulting from an adverse 200 basis points shock. The *sensitivity measure*, already referred to in the section on Thrift Bulletin 13 on page 52, is the difference between the above mentioned measures. The last measure which is based on the NPV is the *measured IRR*[60]. This measured IRR forms the basis for a possible capital charge and is calculated as follows

$$\text{Measured IRR} = \frac{\text{NPV}_{base} - \text{NPV}_{\pm 200}}{\text{PV}_{\text{A},base}} \tag{2.24}$$

where:

NPV_{base}	net portfolio value in the base case scenario;
$\text{NPV}_{\pm 200}$	net portfolio value in case of an adverse 200 basis points shock; and
$\text{PV}_{\text{A},base}$	present value of assets in the base case.

If this measured IRR is bigger than 2% a capital charge is applied which is calculated using (2.25). If a capital component is applied the institution is allowed to use the lowest IRR capital component of the three preceding quarters[61].

$$\text{IRR Capital Component} = \left(\frac{\text{Measured IRR} - 0.02}{2} \right) \cdot \text{PV}_{\text{A},base} \tag{2.25}$$

All measures stated above are calculated based on the data provided to the OTS by the thrift institution. The OTS creates look-up tables based on data found in the market and the valuation methods mentioned earlier. The data provided by the thrift is then compared to the price information in the look-up tables, which gives the exposure of the thrift.

The 1993 Basel consultative paper (Basel, 1993)

In 1993 the Basel Committee issued a consultative paper to update its 1988 Capital Accord. This paper, "*Measurement of banks' exposure to interest rate risk*" was never implemented due to comments from the industry. Some of the comments argued that the proposal was too difficult to implement. Another that interest rate risk in the banking book is a heterogeneous risk. That is, the source and level of the risk differs significantly per country. Introducing a common fixed capital regulation for this type of risk would deteriorate the principle of a level

60 IRR stands for interest rate risk.

61 OTS (1994), p. 2.A-4

playing field of the 1988 Capital Accord. Although one can defend these propositions, one can as easy argue against them, since the same holds for, for example, credit risk.

However, the ideas laid out in that paper formed the basis for later ideas of the Committee. Therefore, the document will be briefly described in this section.

In the paper a distinction is made between economic value approaches and so-called current earnings approaches. Like the OTS the Committee prefers an economic value approach, but it does not reject current earnings approaches. The approach proposed by the Committee resembles a gap analysis approach described in section 2.3.3. All assets, liabilities and off-balance-sheet items should be slotted in one of a number of maturity bands, depending on their maturity (fixed rate instruments) or their next rate reset date (variable rate instruments). The resulting exposures in each time band would then be multiplied by a duration measure for that period and an estimated interest rate change. The resulting numbers for each time band would be summarised, thus resulting in a total exposure[62]. This exposure should then receive a capital charge, but the paper does not give a methodology or a number for this charge. Furthermore, the Committee is of the opinion that some interest rate mismatch is part of the normal banking business, such that only banks with excessive mismatches should be given a capital charge. This is known as the so-called "outlier" approach.

An alternative approach, also mentioned in the paper, does not start from an economic value basis but from a current earnings basis. Again the instruments are slotted in numerous time bands. But instead of multiplying the resulting exposures with a duration measure, they are multiplied by the length of time the gap would be in effect[63]. After that the expected interest rate shock is applied. This is only done for the time buckets within the planning period, which is usually one year.

Although the approach above seems very simple, which is an advantage, some problems with typical banking book instruments are identified. First, some instruments have an uncertain reset date. One could think of demand deposits, or some types of mortgages with embedded options. Second, other instruments have an uncertain maturity. That is, their contractual maturity differs from their actual (or expected) maturity. One could think again of mortgages, which can be prepaid, or instruments like savings accounts. The problem then is, how to slot these instruments into an appropriate time band. Furthermore, options can not be slotted into a gap report. The solution the Committee provides is one of two. The first method is the most prudent one. All instruments of this type should be placed in the first or second time band. However, because it is possible to statistically determine what the expected reprice or maturity date is, the second option uses these dates and slots the instruments accordingly into the appropriate time bands. Although this might give a clearer view on the risks taken, it might prove wrong in extreme conditions (for example a bank run).

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62 In the paper, the Committee asks the industry's opinion about offsetting between time bands. A positive exposure in one time band could then offset a negative exposure in another time band. However, this would imply that interest rate changes in both time bands would always be equal. This is highly unlikely. On the other hand, interest rate changes between time bands often are correlated, so the issue was left open.

63 For example, under the assumption that all instruments reprice/mature at the middle of the time band, the gap in the 0-1 months time band would be in effect for 0.5 months, because after that time horizon rates will be adjusted to equal market rates.

Basel II

Although a capital charge for market risks, amongst which interest rate risk in the trading book, was set with the 1996 amendment to the Capital Accord, interest rate risk in the banking book was not mentioned again until the 1999 proposals to a new capital adequacy framework. The Committee wanted to include interest rate risk in the banking book in Pillar I, building on the 1993 proposals. So, only banks with an excessive exposure to interest rate risk in the banking book should get a capital charge, since some interest rate risk exposure is the basis of the banking business (outlier approach). But whether or not a bank is an outlier should also depend on some qualitative criteria such as the adequacy of a bank's risk management system. The Committee refers to the 1997 principles (see next section). Whether a bank complies with these principles sufficiently enough is up to the national supervisor. In other words, this is part of Pillar II.

In the 1999 proposal the Committee did not propose a standard approach for measuring the exposure to interest rate risk in the banking book. Instead, the Committee argued that, although there are differences between interest rate risk in the banking and trading book, the current approach of interest rate risk in the trading book – the standardised approach or the use of internal models - can be extended to measure the interest rate risk in the banking book (Basel, 1999).

In 2000 the Committee issued a follow-up paper (Basel, 2000). In this paper the Committee provides more detailed information on how it wants to measure the exposure to interest rate risk, and how to calculate a capital charge. First of all, the Committee gives the objectives in which the supervisory treatment of interest rate risk in the banking book should be framed. These objectives are[64]:

- the burden of managing interest rate risk should remain clearly with bank's management;
- the supervisory treatment should provide incentives to internationally active banks - since the Committee focuses primarily on these banks - to invest in risk management processes that are appropriate for the scale and nature of their business and to improve these processes in the future;
- the supervisory treatment adopted should lead to a reduction in the risk faced by outlier banks or to a specific capital charge to support that risk;
- the supervisory treatment adopted should be commensurate in terms of burden with the risk under consideration; and
- the supervisory treatment adopted should first of all be directed at internationally active banks, although its underlying principles should be suitable to other banks too.

The Committee identifies a few problems typical to the banking book. These are that instruments in the banking book often do not have an observable change in market value and furthermore that their response to changes in the market rates are often dependent on country specific demographic, behavioural or competitive factors, which makes it difficult to apply a "one size fits all" approach. In order to measure interest rate risk at all, three issues are important[65]. First, is the applied measurement process. Numerous techniques are available

[64] Basel Committee (2000), p. 2

[65] Basel Committee (2000), p. 3-5

and used (see section 2.3.3), which makes a qualitative evaluation a necessary part of supervisory review. Second, as already mentioned before, two concepts of loss can be applied. These are a decline in interest income and a decline in the economic value of the banking book. Both concepts are used. The Committee prefers the latter one, because it also accounts for the impact of future rate changes. A second advantage is that this approach is linked to the approach for interest rate risk in the trading book. However, income based methods are not rejected. Third, in order to measure the impact of interest rate changes scenarios can be defined. These range from simple parallel interest rate shocks to complex changes of the term structure, including inverse yield curves or changes in the relationship between interest rates (basis risk). In order to include all effects, multiple scenarios are necessary.

Bearing these factors in mind, the Committee proposes for interest rate risk in the banking book a similar approach as for interest rate risk in the trading book. That is, both a standardised and an internal models approach. Both would be applied only to an outlier bank. Outliers can be defined as banks that suffer "*a potential loss of more that "x"% of its capital following a "y" basis point shock to interest rates*"[66]. However, it is also possible to grant national supervisors full discretion to define outliers[67].

A standardised approach would use a duration approach, very similar to the approach used for interest rate risk in the trading book. Although the consistency with the treatment of interest rate risk in the trading book is a big advantage a number of issues need to be resolved before the approach can be used. One could think of the treatment of options; the treatment of typical banking book products, which do no have a contractual rate reset date or for which the contractual maturity differs from the actual or expected maturity; and the treatment of products without an observable market value.

A second approach the Committee is considering is an internal models based approach. The advantage of this approach is that banks can use the systems they should already have, based on the 1997 principles (see below), and secondly, that the assumptions and parameters used could reflect the bank's particular business and balance sheet. However, there are a few disadvantages of such an approach too[68]. One could think of the fact that an internal models approach makes it very hard to make a fully consistent comparison of risks across institutions. This can be improved by prescribing the interest rate scenario and/or the assumptions that have to be used, instead of allowing the bank full discretion in this[69].

Second, it could increase the burden on supervisors since they have to evaluate the model. And third, bank's management could tilt the assumptions used towards those that minimise the capital charge rather than objectively measure risk. However, this can be prevented by sufficient supervisory review.

Before a bank could use its internal model supervisors should be satisfied that the model is compliant with the 1997 principles. Furthermore the model should be suitable to the bank's exposure, meaning that it is capable of measuring all material exposures and types of interest rate risk. Third, the bank should have appropriate controls to ensure the integrity and the

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[66] Basel Committee (2000), p. 6

[67] Basel Committee (2000), p. 21

[68] Basel Committee (2000), p. 19

[69] Basel Committee (2000), p. 21

quality of the data. Moreover, the bank should have appropriate controls to ensure the validity of the assumptions it uses. Finally, the model must be used in day to day management of interest rate risk in the banking book.

The 1999 proposal and its 2000 follow-up received lots of comment. The Netherlands Bankers' Association (NVB), for example, is not in favour of a duration based approach, because this assumes that the banking book is managed on a mark-to-market basis. This is often not the case, since banks mostly use accrual accounting for their banking book. An income based approach that measures the sensitivity of net interest income to changes in interest rates is therefore preferred. This sensitivity could be called Earnings at Risk (EatR) for example. The EatR number could also be used to determine the outlier banks. An outlier bank would then be a bank with an "*EatR above "x"% of net interest income*" [70]. The NVB proposes the following four steps to determine whether a bank is an outlier[71]:

1. determine a standard maximum deviation from the interest yield over a certain time horizon, for example twelve months, based on a certain interest rate shock of a number of deviations for each currency. This leads to a maximum amount for each bank;
2. compare the actual deviation of each bank with the maximum;
3. the difference constitutes the ground for a possible regulatory capital charge in Pillar I;
4. if a bank is found sensitive to fluctuations in the interest rate, the national supervisor can perform additional assessments of the sensitivity of a bank's capital to interest rate shocks under Pillar II.

The maximum derived under 1 should be an absolute number instead of a relative one, based on the average of the sensitivity of all banks, otherwise the bulk becomes the standard.

In 2001 the Basel Committee issued its second consultative document regarding the new Capital Adequacy framework (Basel, 2001a), which was followed by a third consultative paper in 2003 (Basel, 2003). In these follow-ups interest rate risk in the banking book was moved from Pillar I to Pillar II. This implies that no explicit capital charge will be applied due to Basel II, but that the review of a bank's exposure to interest rate risk in the banking book is left to the national supervisor. As of the 2001 follow-up, however, some new principles for the sound management of interest rate risk were added. The next section will discuss these.

The 1997 Principles & the 2001 follow-up

In 1997 the Basel Committee on Banking Supervision issued the "*Principles for the Management of Interest Rate Risk*" (Basel, 1997c). The document included eleven principles a bank and its supervisor should have in place to measure, monitor and control interest rate risk. In 2001 the Committee issued a follow-up to its 1997 document (Basel, 2001b). In this section the 1997 document will be described. After that the proposed changes in the 2001 follow-up will be discussed.

The principles should be applied both on the measurement, monitoring and controlling of interest rate risk in the banking and the trading book. All members of the Basel Committee

[70] Nederlandse Vereniging van Banken (2000b), p. 5

[71] Nederlandse Vereniging van Banken (2000a), p. 38

agreed the principles set out in the paper should be used in evaluating the adequacy and effectiveness of a bank's interest rate risk management[72].
The paper starts with identifying the sources of interest rate risk. The four sources of interest rate risk, already defined in section 2.3.2 - mismatch risk, yield curve risk, basis risk and optionality - are identified. Furthermore, the Committee distinguishes two broad approaches of measuring interest rate risk. Measurement techniques can have an earnings perspective or an economic value perspective. The advantage of the latter is that it "*provides a more comprehensive view of the potential long-term effects of changes in interest rates*", because it "*considers the potential impact of interest rate changes on the present value of all future cash flows*"[73].

The Committee thinks that sound interest rate risk management involves the application of four basic elements[74], which are stated below:

a) appropriate board and senior management oversight;
b) adequate risk management policies and procedures;
c) appropriate risk measurement, monitoring and control functions; and
d) comprehensive internal controls and independent audits.

Ad a) Appropriate board and senior management oversight

Appropriate board oversight includes the approval of strategies and policies with respect to interest rate risk and ensures that the senior management takes the steps necessary to monitor and control the risk properly. Also they should be informed regularly on the interest rate risk exposure (principle 1).
Senior management is responsible for incorporating policies and procedures, for a limit and control structure and for the assignment of adequate staff to actually measure, monitor and control the interest rate risk exposure (principle 2).
Finally, principle 3 states that the board and/or senior management should clearly assign individuals responsible for managing interest rate risk. These individuals should be independent from position-taking functions within the bank and should report directly to senior management and/or the board.

Ad b) Adequate risk management policies and procedures

A bank should have policies and procedures with respect to interest rate risk management. The policies and procedures should be consistent with the nature and the complexity of a bank's activities. If new products are developed or if activities are expanded, the bank should ensure that these are subject to appropriate procedures and controls, before being introduced or undertaken (principles 4 and 5).

Ad c) Appropriate risk measurement, monitoring and control functions

With respect to the measurement of interest rate risk, banks should have a system that captures all material sources of interest rate risk and can assess the effect of interest rate

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[72] Basel Committee (1997), p. 2

[73] Basel Committee (1997), p. 8

[74] Basel Committee (1997), p. 10

changes in ways that are consistent with the scope of the activities of the bank. The assumptions underlying the system should be clearly understood by the risk managers and bank management. These assumptions should also be well documented (principle 6). One could think of assumptions with respect to (changes in) the prepayment behaviour of mortgagors as a result of interest changes.

Furthermore, banks should have appropriate limits on exposures and should conduct stress tests on a regular basis (principles 7 and 8).

Finally, banks should have adequate information systems for reporting interest rate exposures. These reports must be provided to senior bank management on a timely basis (principle 9).

Ad d) Comprehensive internal controls and independent audits

Principle 10 states that the bank should have an adequate system of internal controls. This includes regular independent reviews and evaluations of the effectiveness of the system, and if necessary , ensuring that appropriate revisions or enhancements to internal controls or systems are made.

Finally, the document ends with principle 11 which states that bank supervisors should obtain sufficient and timely information with which they can evaluate the bank's exposure to interest rate risk. This information should take account of the range of maturities and currencies of the bank's portfolio, including off-balance-sheet items.

In 2001 a new document was released that updated the 1997 paper. Basically, all principles from the 1997 paper remained, and four more principles we added[75]. Principle 12 explicitly states that banks must hold capital commensurate with the level of interest rate risk they undertake. Furthermore, principle 13 obliges banks to release to the public information on the level of interest rate risk and their policies for its management. Finally, principles 14 and 15 give guidelines for the supervisory treatment of interest rate risk in the banking book specifically. First of all, supervisory authorities must assess whether the internal measurement systems of banks adequately capture the interest rate risk in their banking book. If a bank's internal measurement system does not adequately capture interest rate risk, banks must bring the system to the required standard. To facilitate supervisory monitoring of interest rate risk exposures across institutions, banks must provide the results of their internal measurement systems, expressed in terms of the threat to economic value, using a standardised interest rate shock. Second, if supervisors determine that a bank is not holding capital commensurate with the level of interest rate risk in the banking book, they should consider remedial action, requiring the bank either to reduce its risk, to hold a specific additional amount of capital, or a combination of both.

Summarising, what the 2001 follow-up adds is an explicit demand to hold a commensurate amount of capital and that supervisor can require a bank to reduce its risk or hold more capital if it finds the current amount of capital not commensurate with the level of interest rate risk.

[75] Basel Committee, *Principles for the management and supervision of interest rate risk*, consultative document, January 2001.

2.5.3 Accounting regulation

Introduction

Basically, there are two ways to present assets and liabilities in a balance sheet:

- mark-to-market accounting; and
- accrual accounting.

In short, mark-to-market accounting uses the market value of assets, liabilities and off-balance-sheet items to present the value and profit or loss in the balance sheet. Accrual accounting on the other hand uses the (nominal) principal and accrual income to present the value and the profit and loss in the balance sheet.

Both accrual and mark-to-market accounting have advantages and disadvantages. In fact, one can state that the advantages and disadvantages of accrual accounting are opposite to the advantages and disadvantages of mark-to-market accounting. An advantage of accrual accounting is that the balance sheet and profit & loss statement are relatively stable, because instruments are carried at historic costs. A disadvantage is that the balance sheet does not show the actual value of the instruments, whilst this is the biggest advantage of mark-to-market accounting. A disadvantage of mark-to-market, however, is that is causes more volatility in the balance sheet and the profit & loss statement, due to the fact that the value of the instruments changes with the market.

Recently the term "*fair value accounting*" has come up. Fair value was first defined in IAS 32 (IASB, 1996). It is defined as:

'…the amount for which an asset could be exchanged, or a liability settled, between knowledgeable, willing parties in an arm's length transaction.'

If we take a closer look at this definition, especially the second part attracts attention. The parties in a deal have to be knowledgeable and willing and the transaction has to be at arm's length. This excludes forced sales and also transactions in which the parties are not independent, or at least don't regard each other as independent.

In IAS 39 (IASB, 1998) the market value is quoted to be the best indicator for fair value provided that the market is highly liquid and active. For these types of markets, one could say that, with a lot of buyers and sellers, parties could be knowledgeable and willing. One could also state that most transactions are between independent parties, so at arm's length. Therefore market value could be a good indicator for fair value. But for less liquid markets there often is no market value. In these cases the value of an instrument is usually based on a model. This is called mark-to-model.

Fair value accounting is based on mark-to-market and mark-to-model accounting. To get the fair value of a financial instrument it is sometimes necessary to adjust the market value of that instrument. This is known as '*valuation adjustment*'[76].

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[76] The term 'valuation adjustment' is taken from Bos (1999b).

Fair value is an important concept. With IAS 39 financial institutions have to use fair value to account for in their trading portfolios, which is defined broadly in IAS 39. In this section we will study IAS 39 more closely as this may impact the way banks have to report their positions in the banking book.

IAS 32 & 39: Financial Instruments

Whereas IAS 32 only gives regulation about the presentation and disclosure of financial instruments, IAS 39 supplements this with regulation about recognition and measurement. Or in other words, when a financial instrument needs to be taken into the balance sheet and on which basis it should be valued. In this section we describe the regulation of IAS 32 & 39.

In IAS 32 no regulation was given about the methodology used to measure financial instruments. Fair value was suggested. In IAS 39 fair value becomes far more important. In fact, on the asset side of the balance sheet most items have to be valued using fair value. IAS 39 names the following instruments[77]:

a) nearly all derivative assets and liabilities (which are often unrecognised);
b) all financial assets held for trade;
c) all financial assets that are not held for trade, but are nonetheless available for sale;
d) derivatives that are embedded[78] in non-derivative instruments (which are often not recognised);
e) non-derivative instruments containing embedded derivative instruments that cannot reliably separated from the non-derivative instrument;
f) non-derivative assets and liabilities that have fair value exposures being hedged by derivative instruments;
g) fixed maturity investments that the enterprise does not designate as 'held to maturity'; and
h) purchased loans and receivables that the enterprise does not designate as 'held to maturity'.

Only three classes of financial assets do not have to be valued at fair value. These are loans and receivables originated by the enterprise; fixed maturity instruments, which the enterprise intends and is able to hold to maturity; and unquoted equity instruments for which no reliable fair value can be derived. Financial liabilities also do not have to be measured at fair value, unless they are part of the trading book.

In the above some important things can be noted. First of all the fact that IAS 39 requires instruments not recognised today, almost all off-balance-sheet items, to be recognised. Secondly, almost all assets need to be measured at fair value, whereas this is not required for financial liabilities. Finally, in some cases the intention of the enterprise determines whether or not the instrument is carried at fair value.

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[77] See IAS 39, paragraph 13 of the introduction.

[78] IAS 39 uses the term "imbedded".

Definitions

Based on the definition IAS 32 uses[79], a *financial instrument* is any contract that gives rise to both a financial asset of one enterprise and a financial liability or equity instrument of another enterprise. A *financial asset* is any asset that is (a) cash, or (b) a contractual right to receive cash or another financial asset from another enterprise, or (c) a contractual right to exchange financial instruments with another enterprise under conditions that are potentially favourable, or (d) an equity instrument of another enterprise. A *financial liability* is any liability that is a contractual obligation (a) to deliver cash or another financial asset to another enterprise, or (b) to exchange financial instruments with another enterprise under conditions that are potentially unfavourable. Finally, an *equity instrument* is any contract that evidences a residual interest in the assets of an enterprise after deducting all of its liabilities.

In IAS 39 the same definitions are used as in IAS 32. But the Standard uses some additional definitions[80]. First of all a definition of a derivative is given. Under IAS 39 a *derivative* is a financial instrument (a) whose value changes in response to the change in a specified interest rate, security price, commodity price, foreign exchange rate, index of prices or rates, a credit rating or credit index, or similar variable, and (b) that requires no initial net investment or little net investment relative to other types of contracts that have a similar response to changes in market conditions, and (c) that is settled at a future date.

As mentioned before, IAS 39 differentiates between different types of financial assets. The measurement and disclosure varies between the categories. Four groups of assets are defined. The first category contains assets *held for trading*[81]. An asset held for trading is one that is acquired principally for the purpose of generating a profit from short-term fluctuations in price. If the asset is part of a portfolio for which there is evidence that it is used for short-term profit-taking, it should be classified as held for trading, regardless of the reason why is was acquired. Derivative financial assets (and liabilities) are always deemed held for trading, except when they are designated for hedging purposes.

The second category is *hold-to-maturity investments*. These are financial assets with fixed or determinable payments and fixed maturity that the enterprise has the positive intent and ability to hold to maturity, other than loans and receivables originated by the enterprise.

The third category is made up by *loans and receivables originated by the enterprise*. These are financial assets that are created by the enterprise by providing money, goods, or services directly to a debtor, other than those that are originated with the intent to be sold immediately, or in the shorter term, because these should be classified as held for trading.

Finally, the fourth category is *available-for-sale financial assets*. These are all assets that do not fall in one of the other three categories.

Instruments with embedded derivatives form a difficult category of instruments. Derivatives should normally be measured at fair value under IAS 39. But, it is possible that the instrument containing the embedded derivative is a hold to maturity instrument, which is not carried at fair value. Therefore IAS 39 requires the embedded derivative and the instrument

[79] See IAS 32, paragraph 5.

[80] See IAS 39, paragraph 10.

[81] Financial liabilities can also be classified as held for trading. The definition is the same. There should be the intent to make profits from short-term fluctuations of market prices.

containing the derivative to be separated. In fact, this should be done if the following conditions are met[82]:

a) the economic characteristics and risks of the embedded derivative are not closely related to the economic characteristics and risk of the host contract;
b) a separate instrument with the same terms as the embedded derivative would meet the definition of a derivative; and
c) the hybrid (combined) instrument is not measured at fair value with changes in fair value reporting in net profit or loss.

If an enterprise is required by IAS 39 to separate an embedded instrument from its host contract, but is unable to separately measure the embedded derivative, it should treat the combined contract as held for trading.

Fair value measurement considerations

In paragraph 95 IAS 39 states that the fair value of a financial instrument is reliably measurable if (a) the variability in the range of reasonable fair value estimates is not significant for that instrument or (b) if the probabilities of the various estimates within the range can be reasonably assessed and used in estimating fair value.
Situations in which fair value is reliably measurable include (a) a financial instrument for which there is a published price quotation in an active public securities market for that instrument, (b) a debt instrument that has been rated by an independent rating agency and whose cash flows can be reasonably estimated, and (c) a financial instrument for which there is an appropriate valuation model and for which the data inputs to that model can be measured reliably because the data come from active markets[83].
If it is not possible to estimate the fair value of an instrument reliably other techniques can be used, like referring to the market value of an instrument that is substantially the same, discounted cash flow analysis or option pricing models. If a market does not exist for an instrument, but markets exist for its components, a fair value can be estimated by adding the fair values of its components.

Comment on IAS 32 & 39

A closer look at the accounting regulation learns that (fair) value accounting will gain importance in the (near) future. In the United States, the Federal Accounting Standard Board (FASB) already implemented FAS 133, which is heavily focussed on fair value. And IAS 39 will become effective as of 1 January 2005.
This will have its impact on risk management too. Currently, the retail banking book is usually accounted for on an accrual basis, or in other words, based on historic costs. As a result, most banks primarily use income-like measures of interest rate risk, such as gap analysis, and earnings-at-risk. Value based risk measures, like duration and value-at-risk are used as well, but usually not considered that important. With IAS 39 this might change with (fair) value becoming more and more important and sometimes even required.

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[82] See IAS 39, paragraph 23.

[83] See IAS 39, paragraph 96.

Some typical instruments on the asset side of the retail banking book are mortgages and other loans. These are originated loans and therefore will be measured at historic costs. On the liability side, only instruments explicitly held for trading should be measured at fair value, all others at historic costs, or better at amortised costs. That means that typical retail banking book instruments on the liability side on the balance sheet such as savings accounts or demand deposits will be valued on a amortised cost basis. However, a bank will usually hedge interest rate risks in the banking book with derivatives, for example swaps. These have to be valued at fair value. As a result, the profit & loss statement of the banking book might become more volatile as it is today.

Although there are some problems with fair value, which is sometimes hard to determine, it is a better concept than historic or amortised costs. The reason is that the development of the (fair) value of the banking book can be regarded as an early warning system[84]. We already saw in section 2.4 that most existing economic capital models apply a value approach[85].

For a further overview of the advantages and disadvantages of fair value as the main accounting standard, refer to Bos (1999b, chapter 6).

2.5.4 Concluding remarks on capital adequacy and accounting regulation

In this section we studied capital and accounting regulation. The reason for this was to find an answer to the question why economic capital is important.

Starting with capital adequacy regulation, it was shown that the first big step in global capital adequacy regulation was the 1988 Basel Accord (Basel, 1988). In 1996, the Accord had a major amendment. This 1996 Amendment introduced market risk into the capital adequacy regulation. However, it was not the fact that banks had to hold equity for their market risks that was the biggest change from this accord, but the fact that banks were allowed to calculate the capital charge based on their own internal models (Basel, 1996). In fact, this can be considered as a first step of making the capital adequacy regulation more risk-based, and thus the resulting regulatory capital more closely equal to economic capital.

The biggest change, though, came in 1999, when a new capital adequacy framework was introduced, known as Basel II. A more risk-based approach was proposed in this new framework. Furthermore, more risks were to be included: operational risk *and* interest rate risk in the banking book (Basel, 1999)[86].

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[84] An example of this is the Savings & Loans crisis in the 1980's in the USA. During that period short-term interest rates rose rapidly. The Savings & Loans banks all had long term assets and short-term liabilities, which rates had been fixed in the past. On an accrual basis the banks looked profitable, because of the locked-in margin. However, as soon as the liabilities started to reprice against the then high market rates, profits dropped rapidly, and a lot of these banks bankrupted. On a value basis profits dropped earlier, because positions are discounted against market rates. The result was that the value of a bank's capital was long below zero, before the banks actually bankrupted. Therefore, it may be concluded that a value approach can act as an early warning system, whereas an earnings approach does not. This explains why more recent regulation and economic capital models all use a value approach.

[85] Although only a few models take some embedded options into account.

[86] We saw that in later versions of Basel II interest rate risk in the banking book was removed from Pillar I, as a result of which it will not receive an explicit capital charge.

Regulation on interest rate risk in the banking book was published as early as the late 1980's. In 1989, the Federal Home Loan Bank (FHLB), the supervisor of thrifts in the United States, published Thrift Bulletin 13 (TB 13). TB 13 required thrifts to have a sufficient risk measurement and management system in place. Furthermore, some principles about the risk management process were given, which thrifts had to comply with. Finally, thrifts had to calculate the so-called Market Value of Portfolio Equity (MVPE), which is the difference between the present value of assets and the present value of liabilities and the net interest income by using a total of nine scenarios and set limits on those.
In a later amendment, the MVPE was renamed the Net portfolio Value (NPV). Some numbers are calculated based on this NPV and the outcome is weighted based on some rating system in order to get an idea of the interest rate risk of the thrift.
In 1991, the American Federal Deposit Insurance Committee Improvement Act (FDICIA) was issued which obliged American regulators to include capital adequacy rules into their regulation. The successor of the FHLB at that time, the Office of Thrift Supervision (OTS) therefore issued their Net Portfolio Value model, with principles on how to measure the present value of financial instruments (OTS, 1994).
In the mean time the Basel Committee on Banking Supervision in 1993 issued a proposal to include interest rate risk and market risk in the 1988 Accord. It was proposed to use an "outlier" approach for interest rate risk, that is only banks with an "abnormally" high risk position should get a capital charge. The reason for this is that some interest rate risk is part of the banking business, since banking is traditionally about transforming short-term liabilities into long-term assets, which causes some mismatch. Furthermore, if a capital charge was to be calculated a value approach was to be preferred, although an earning approach was not rejected (Basel, 1993). However, this 1993 proposal was not implemented into the capital adequacy regulation until 1999 with the Basel II proposals.
In 1997 the Basel Committee issued a document that had some principles about proper and sound interest rate risk management. Banks had to make sure that their risk management organisation and risk management systems complied with these principles (Basel, 1997).
In later versions of the Basel II proposals interest rate risk in the banking book was removed from Pillar I. We also learned that the 1997 principles were updated with some additional principles about the level of capital for interest rate risk in the banking book.

Studying the international accounting regulation, it can be concluded that International Accounting Standard 39 (IAS 39) will have a big impact on current accounting practices within banks. The first big change is that under IAS 39 all financial instruments, including derivatives, should be recognised in the balance sheet. As a result off-balance sheet items will not exist anymore (IASB, 1998).
Second, financial instruments should initially be measured at cost, but subsequently financial assets should be measured at fair value, except for three categories:

a) loans and receivables originated by the enterprise and not held for trading;
b) other fixed maturity investments, that the enterprise intends and is able to hold to maturity; and
c) financial assets whose fair value cannot be reliably measured.

Fair value was already defined in IAS 32 (IASB, 1996) as "*the amount for which an asset could be exchanged, or liability settled, between knowledgeable, willing parties in an arm's length transaction*".

On the other hand, financial liabilities should always be measured at original amount less principal repayments and amortisation. Only derivatives and liabilities held for trading should be measured at fair value.

Summarising, IAS 39 will have a big impact on banks as well as on risk management. Currently, the retail banking book is usually accounted for on an accruals basis, or in other words, based on historic costs. As a result, most banks primarily use income-like measures of interest rate risk, such as gap analysis, and earnings-at-risk. Value based risk measures, like duration and value-at-risk are used as well, but usually not considered that important. With IAS 39 this might change with (fair) value becoming more and more important and sometimes even required.
Based on the above, we see a tendency in both capital as well as accounting regulation to focus more and more on market value approaches and "real" risks. All this calls for a risk management and economic capital framework that is capable of giving correct risk and economic capital figures. In fact what we see is that the capital concepts we defined earlier (see section 2.4.2) are becoming more alike. As a result, economic capital is becoming more important.

2.6 Conclusions

In this chapter we gave some theoretical background on (interest rate) risk, economic capital and regulation, thus answering research questions one to three. We started with a study of risks inherent to banking. Three main risk categories were identified: credit risk, market risks and other risks (see Figure 2.2 on page 17). Other risks include interest rate risk in the banking book, liquidity risk, operational risks and external risks, amongst which is business risk. This answered research question one.
We then focused on interest rate risk in the banking book. First of all we gave a definition of interest rate risk in the retail banking book, which read:

Negative effects in accrual income of and/or negative value changes in on- and off-balance-sheet positions in the retail banking book due to unexpected changes of interest rates.

We concluded that it is not necessary to bear an actual loss to speak of interest rate risk in the retail banking book. A decline in earnings or value due to interest rate changes is also interest rate risk. Furthermore, the change in interest rates had to be unexpected, since one can anticipate on expected rate changes.
The banking book was defined as the portfolio on which the bank tries to profit from the margin between what is earned on assets and paid on liabilities. It was stated that the banking book can be split in a wholesale and a retail part. Since most embedded options can be found in typical retail instruments, this thesis focuses on the retail banking book.
Studying interest rate risk in the banking book in greater detail revealed that it can be caused by a difference in the repricing characteristics of assets and liabilities (repricing or mismatch risk and yield curve risk). Another cause can be basis risk. Finally, embedded optionality in banking book products like mortgages, savings accounts and demand deposits can also cause interest rate risk. A total of six embedded options were identified, which are:

a) withdrawal option;
b) prepayment option;
c) interest rate consider period option;
d) embedded caps and/or floors;
e) optional commitments with regard to mortgages; and
f) choice option.

We found that a number of measurement techniques have been developed in the past to quantify the amount of interest rate risk (in the banking book). Techniques like gap analysis, earnings at risk, duration analysis, and value at risk were studied in some detail in section 2.3.3. All these techniques take either a value or an income approach. This means that the magnitude of interest rate risk is related to the chances of losses in either the value of a portfolio or the loss of (accrual) income in that portfolio. Furthermore, techniques could be used statically or dynamically. Static approaches use predetermined scenarios (if any), whereas dynamic approaches use some form of simulation. All techniques have their pros and cons. This study answered research question two.

Our next step was to find an answer to research question three. We split that question in two. First we studied the concept of economic capital and economic capital models, then we focused on why economic capital is so important.

It was shown that within the banking industry three concepts of capital can be identified, which are accounting capital, regulatory capital or solvency and economic capital. Economic capital is the amount of equity that is required to cover for unexpected losses within a certain confidence level and a certain time period. From a management control perspective, economic capital is a useful concept, because it allows for good risk-reward trade-offs.

Regarding economic capital models, at first, it seems strange that there is no decent earnings based economic capital model available, although current accounting practice is usually income based (accrual). This can be explained from the fact that the concept of economic capital is relatively new, and only until recently has got more attention.

Because new regulation is becoming more value based and focussing on bank's internal capital adequacy models – economic capital models – these models are likely to be value based too. An advantage of a value approach is that changes in market interest rate have a more direct influence on the exposure of a bank and therefore can act as an early warning system (also see footnote 84 on page 67). As a result, we developed a general economic capital framework as laid out in Figure 2.10 on page 48.

We then had to find an answer for the second part of research question three, i.e. why economic capital is so important. We studied capital and accounting regulation to find an answer.

Starting with capital adequacy regulation, it was shown that this regulation becomes more risk-based and that more risk types are included. As a result regulatory capital more closely resembles economic capital.

Studying the international accounting regulation, it can be concluded that International Accounting Standard 39 (IAS 39) will have a big impact on current accounting practices within banks. The first big change is that under IAS 39 all financial instruments, including derivatives, should be recognised in the balance sheet. As a result off-balance sheet items will not exist anymore. Furthermore, all assets must be valued a fair value, except for three categories:

a) loans and receivables originated by the enterprise and not held for trading;
b) other fixed maturity investments, that the enterprise intends and is able to hold to maturity; and
c) financial assets whose fair value cannot be reliably measured.

On the other hand, financial liabilities should always be measured at original amount less principal repayments and amortisation. Only derivatives and liabilities held for trading should be measured at fair value.

Summarising, IAS 39 will have a big impact on banks as well as on risk management. Currently, the retail banking book is usually accounted for on an accruals basis, or in other words, based on historic costs. As a result, most banks primarily use income-like measures of interest rate risk, such as gap analysis, and earnings-at-risk. Value based risk measures, like duration and value-at-risk are used as well, but usually not considered that important. With IAS 39 this might change with (fair) value becoming more and more important and sometimes even required.

Based on the above, we see a tendency in both capital as well as accounting regulation to focus more and more on market value approaches and "real" risks. All this calls for a risk management and economic capital framework that is capable of giving correct risk and economic capital figures. In fact what we see is that the capital concepts we defined earlier (see section 2.4.2) are becoming more alike. As a result, economic capital is becoming more important.

3

Effects of the withdrawal option

3.1 Introduction

In this chapter we will study the effects of the withdrawal option more closely. The withdrawal option was defined in section 2.3.2 as an embedded option which gives the holder the right, but not the obligation, to withdraw credits on his account at any time for free. As such, the withdrawal option is a common option in Dutch demand deposits and savings accounts.

In the Netherlands saving is popular. Total savings expressed as a percentage of Gross National Product (GNP) is the biggest in the European Union: between 23 and 26 percent (see for example Mulders & Van de Ven (1997) and Enting (1995)).

Whether or not individuals save depends on their liquidity-preference (Keynes, 1936). According to Keynes, an individual basically makes two decisions. The first is how much of his income he will consume and how much he will reserve in *some form* for later consumption. The second decision is in *what form* he will store this reserved part. Keynes distinguishes between three divisions of liquidity-preference, which he calls (1) the transactions-motive or income- or business-motive; (2) the pre-cautionary-motive and (3) the speculative-motive. The first motive can be explained: individuals store money in cash to bridge the interval between the receipt of income and its imbursements. The second motive can also be explained: individuals want security about the future cash equivalent of their resources today to provide cash for sudden expenditures. The third motive is that individuals wanting to make a profit do so by investing their money. It is not the immediate availability of money without the risk of loosing some that is important here but the return. The amounts of money stored by the first two motives are not expected to be very sensitive to interest rate changes, whereas the money used for the speculative-motive is.

When this is applied with respect to the withdrawal option, we can identify the same three classes. First of all, "saving" by individuals to pay bills is done on demand deposits. Interest on these accounts is low or zero. The amounts on these accounts are expected to be relatively interest rate insensitive – people have to pay for their bills anyway. However, with the introduction in the Netherlands of telebanking and internet banking, this might have changed. Because it has become easier to transfer amounts between a demand deposit and a savings account and vice versa, often within a day, people might have become more interest rate sensitive and thus try to minimize the amounts on their demand deposit. Due to a lack of data the impact of this effect is not modelled.

A second class of savings are the "normal" savings. People save on their savings accounts for later big consumptions, for example buying a car. Savings in this category are expected to be moderately interest rate sensitive.
The above two categories of savings are typically done on products, which include the withdrawal option. The third category, speculative savings, is somewhat different. It is not the type of product that is important here but the return. In this category, people are expected to switch relatively quicker between products. Investments in stocks or stock options, for example, are located in this category. But also investments in term deposits or ordinary savings accounts, depending on the expected return.
In basic terms, what we see is that in order to get a good picture of savings behaviour we need to study the "behaviour" of demand deposits, savings accounts and term deposits over time in relation to the interest rate.
We do this by performing time series analysis on demand deposits, savings accounts and term deposits. Although the latter product does not have the embedded option, it is considered an important alternative product which is still relatively safe for savers and therefore a product where savers can put their money once it is withdrawn from a savings account.

The question is thus how this embedded option affects the risk profile of these products and therefore the economic capital charge. Economic capital was defined as the amount of capital required for unexpected losses. In section 2.4.4 we showed that economic capital is determined by the distribution of possible future values. Therefore, we are interested in determining the value (distribution) of demand deposits, savings accounts and term deposits.
If we take a closer look at demand deposits and savings accounts, we see two features that increase complexity. The first is that there is often no contractual maturity; the second that the rate paid on these products is adjustable and indexed to some internal pricing curve.
We will start with studying existing literature on the valuation of indeterminate maturity contracts (section 3.3). Because these models require modelling the developments in demand deposits, savings accounts and term deposits volume, existing demand models will be studied in section 3.4. Because we find these models not appropriate for our dataset we will present a new analysis regarding demand models in section 3.6. Before we start our own analysis, however, some background on model development and time series analysis will be given in section 3.5. In that section we will also explain which software we used. The valuation models from section 3.3 also require models for the interest rate. We will estimate models for the savings rate, the term deposits rate and the market rate in section 3.7. After that section we have answered research question four with regard to the withdrawal option. The actual valuation will be postponed to chapter 6. Finally, section 3.8 concludes. We start however with a list of symbols in section 3.2.

3.2 List of symbols

This chapter uses mathematical expressions. Instead of explaining what the symbols in each expressions mean we try to use a uniform notation, which is given below. Unless stated otherwise, all expressions use this notation.

B_t	balance[87] at time t
TV_t	volume of total volume[88] at time t
DD_t	volume of demand deposits at time t
SA_t	volume of savings accounts at time t
TD_t	volume of term deposits at time t
r_t^j	equals r_t^{SA} or r_t^{TD} depending on whether the model is estimated for savings accounts or term deposits respectively
r_t^{SA}	savings rate at time t
r_t^{TD}	term deposits rate at time t
r_t^i	market rate at time t for a instrument with a maturity of i months
$\tilde{r}_t^i$	i month moving average of r_t^i
r_t	market rate in Jarrow – Van Deventer framework, reference rate in Selvaggio's demand model
δ_i	dummy variable, which has the value one if the observation is in the i^{th} month/quarter and zero otherwise
AEX_t	value of the Dutch stock market index at time t
GNP_t	value of the Dutch Gross National Product (GNP) at time t
R_t	return on the Dutch stock market at time t
P_t	price of a risk-free bond paying one at time t
τ	planning horizon
$\tilde{E}_t(\cdot)$	expectations operator at time t
V_0^B	time zero net present value of B_0 volume
β_i, α_i	parameters
ε_t	error term, $\varepsilon_t \sim N(0,\sigma^2)$
$N(\mu,\sigma^2)$	normal distribution, with mean μ and standard deviation σ

[87] Used in valuation models. Can be either demand deposits volume, savings account volume, term deposits volume, or the sum of these volumes.

[88] The sum of demand deposits, savings accounts as well as term deposits.

3.3 Valuation techniques

3.3.1 Introduction

Some valuation models for non-maturing contracts can be found in literature. A relatively simple method includes the technique proposed by Wilson (1994) called the replicating portfolio. We also study the models proposed by Hutchison & Pennacchi (1996) and the Jarrow-Van Deventer model (Jarrow & Van Deventer, 1998, Goosse, et al, 1999, Janosi, et al, 1999 and O'Brien, 2000) in more detail. These approaches are mathematically sophisticated. Finally, there are the models of Selvaggio (1996) and De Jong & Wielhouwer (2001). The latter is more or less an extension of Selvaggio's model. Selvaggio uses an Net Present Value approach for valuing savings accounts, as do De Jong & Wielhouwer. Moreover, Selvaggio uses an option-adjusted spread (OAS) approach, where the OAS is derived from premiums paid on the secondary market. Since there is no secondary market for savings account in the Netherlands, we will not focus on these approaches.

3.3.2 Wilson (1994)

One of the approaches which can be found in literature is Wilson's replicating portfolio technique (Wilson, 1994). An optimal replicating portfolio is a mix of market instruments that exactly match "*the repricing behaviour of the target account*" as well as "*fully replicate the account's prepayment or withdrawal risks*" (Wilson, 1994). In order to set up a replicating portfolio, Wilson divided deposit demand into two parts. The first part is referred to as the core deposits, which will "always" be available to the bank[89]. The second part is some stochastic component[90], which Wilson suggests to be invested in the shortest possible maturity. This division of deposits in two parts is also reflected in Wilson's demand model (see equation (3.4) on page 78). Depending on the rate a bank wants to offer its clients, the replicating portfolio is relatively easily constructed (Wilson, 1994, p. 17). The advantage of using market instruments to create a replicating portfolio is that it is relatively easy to determine the value of this replicating portfolio. Since the replicating portfolio is assumed to have the same characteristics as the original portfolio is demand deposits or savings accounts, the latter portfolio should have the same value.

3.3.3 Hutchison & Pennacchi (1996)

Hutchison & Pennacchi value bank deposits by using an equilibrium approach. If one defines $f(t)$ as the instantaneous cash flow (profit) the bank makes by issuing deposits in amount of $D(t)$ and investing the proceeds in short (instantaneous) maturity bonds paying rate of return $r(t)$ this leads to

$$f\left[r(t),x(t)\right]=\left[r(t)-r_d^*(t)-c(t)\right]D(t) \tag{3.1}$$

[89] Compare with Keynes' income-motive and precautionary-motive.

[90] Compare with Keynes' speculative-motive.

where:

$f\left[r(t),x(t)\right]$	instantaneous cash flow (profit) from issuing deposits as a function of the market rate $r(t)$ and other variables $x(t)$;
$r_d^*(t)$	optimal deposits rate at time t (see Hutchison & Pennacchi (1996) for further details);
$c(t)$	cost of issuing deposits at time t; and
$D(t)$	total volume of deposits at time t (see equation (3.7) on page 79).

Further Hutchison & Pennacchi define $P(t,T)$ as the price at time t of a default-free bond paying one at time T. This implies that the present value of the stream of cash flows of the deposits, F, for all future dates is

$$F = \int_t^{\infty} P(t,s)\,\tilde{E}_t\left\{f\left[r_{s-t}(s),x(s)\right]\right\}ds\,. \tag{3.2}$$

To estimate this value F a term structure model needs to be applied. Hutchison & Pennacchi use the Vasicek model (see section 2.4.3 on page 38). Furthermore, several mathematical transformations are required in order to estimate the parameters. For this, we refer to Hutchison & Pennacchi (1996). As soon as F is estimated, the value of the deposits is calculated by subtracting the face value of the deposits from F.

3.3.4 Jarrow & Van Deventer (1998)

Another mathematically sophisticated approach is the Jarrow-Van Deventer model. They use an arbitrage-free approach and this leads to other valuation equations. In fact, what they do is calculating the present value of a cash flow scheme under risk-neutral conditions. Table 3.1 shows the Jarrow-Van Deventer cash flow scheme.

Table 3.1 Cash flow scheme Jarrow-Van Deventer model (Source: Jarrow & Van Deventer, 1998)

Time 0	1	2	…	$\tau-1$	τ
$+B_0$	$-B_0r_0^j$	$-B_1r_1^j$	…	$-B_{\tau-2}r_{\tau-2}^j$	$-B_\tau r_\tau^j$
	$-B_0$	$-B_1$	…	$-B_{\tau-2}$	$-B_{\tau-1}$
	$+B_1$	$+B_2$	…	$+B_{\tau-1}$	

Table 3.1 reads as follows: total balance at time zero equals B_0. At the end of period $t+1$ it is assumed that the client withdraws an amount of B_t and immediately deposits an amount of B_{t+1}. Furthermore, interest in amount of $B_t r_t^j$ has to be paid. This continues until the end of the planning horizon at time τ at which point it is assumed that clients withdraw all their funds.

This is mathematically stated in (3.3). The first part of the right hand side of the expression shows the cash flow due to volume changes, until time $\tau - 1$. The final withdrawal at time τ, which equals $B_{\tau-1}$, is shown in the second term on the right hand side of the expression. Finally, the bank has to pay interest, which is the third part of the expression.

$$\begin{aligned} V_0^B &= B_0 + \tilde{E}_0\left(\sum_{t=1}^{\tau-1}\frac{B_t - B_{t-1}}{P_t}\right) - \tilde{E}_0\left(\frac{B_{\tau-1}}{P_\tau}\right) - \tilde{E}_0\left(\sum_{t=1}^{\tau}\frac{r_{t-1}^j B_{t-1}}{P_t}\right) \\ &= \tilde{E}_0\left(\sum_{t=1}^{\tau}\frac{B_{t-1}\left(r_{t-1} - r_{t-1}^j\right)}{P_t}\right) \end{aligned} \tag{3.3}$$

The Jarrow-Van Deventer model has been used in several studies like O'Brien (2000), Goosse, et al. (1999) and Janosi, et al. (1999). These studies will not be restated here. The interest reader is referred to the respective articles.

3.4 Demand models

As can be seen from section 3.3 all valuation techniques require some sort of demand model. In this section we study the demand models used in the valuation approaches described in the previous section. We add the demand models developed by two Dutch banks.

The first demand model is the one Wilson (1994) used for his replicating portfolio technique. In order to be able to model volume changes, Wilson used a demand function as shown in (3.4) below

$$B_t = \beta_0 e^{\beta_1 t} + \sum_i \sum_j \alpha_{ij} Diff_{t-i,j} + \sum_i \sum_T \phi_{iT} R_{t-i,T} + \varepsilon_t \tag{3.4}$$

where:

$Diff_{t-i,j}$	i months lagged differential between the customer rate and opportunity rate j at time t;
$R_{t-i,T}$	i months lagged absolute opportunity rate level for maturity T at time t;
ε_t	purely random volume changes at time t; and
α_{ij}, ϕ_{iT}	parameters.

The first part of the right hand side models the deterministic trend growth. One can regard this as the growth of the core volume. The second and third parts give the sensitivity of the customer to spreads and absolute levels of interest rates. Finally, there is an error term.

Another demand model is given by Selvaggio (1996) who used it in his valuation approach. A similar model is later used by Goosse et al. (1999), who applied Selvaggio's model to the Belgian savings accounts market. The models are used to simulate balance sheet developments for non-interest bearing demand deposit accounts and Belgian savings accounts respectively and are shown in (3.5) and (3.6).

$$\ln B_t = \beta_0 \ln B_{t-1} + \beta_1 \ln r_t^i + \beta_2 t + \sum_{j=3}^{14} \beta_j \delta_{j-2} + \varepsilon_t \tag{3.5}$$

From (3.5) it can be seen that this period's balance is dependent on last period's balance plus the level of interest rate in the market. Furthermore there is a linear time trend plus dummy variables capturing seasonality. The main difference with Goosse's model is in this seasonality. Goosse et al. only identify extra volume in December:

$$\ln B_t = \beta_0 + \beta_1 \ln B_{t-1} + \beta_2 \ln r_t + \beta_3 t + \beta_4 \delta_{12} + \varepsilon_t . \tag{3.6}$$

Both Selvaggio and Goosse, et al. fit this model to market data using regression analysis and find an extremely good fit with the data.
Hutchison and Pennacchi (1996) also specify a demand model, which they use in their valuation model (see section 3.3.3). Their demand model has the following form

$$D(r, r_d, x) = \left[\beta_1 r(t) + \beta_2 r_d^*(t) + \eta(t)\right] e^{\mu t} + \varepsilon_t , \tag{3.7}$$

where:

$D(r, r_d, x)$	volume as a function of r, r_d and x;
$r(t)$	return on a competitive, short (instantaneous) maturity default-free bond at time t;
$r_d^*(t)$	optimal deposit rate set by a bank at time t;
x	vector of other variables affecting demand, that are assumed to be independent of $r(t)$;
$\eta(t)$	variable that shifts the demand for deposits without affecting the elasticity of deposits with respect to r_d; and
μ	trend growth rate.

Hutchison and Pennacchi assume that the deposit rate is reset periodically to maximise the return on demand deposits. For more details we refer to Hutchison & Pennacchi (1996).
A fifth demand model is a model specified by Wielhouwer and Van der Ende (1997). They model this period's savings accounts volume as a function of previous period's volume and the difference between the savings rate and a short-term and long-term rate in the market (see (3.8))

$$B_t = \beta_0 + \beta_1 B_{t-1} + \beta_2 \left(k_{t-1} - r_{t-1}^{SA}\right) + \beta_3 \left(s_{t-1} - r_{t-1}^{SA}\right) + \varepsilon_t \tag{3.8}$$

where:

k_t	long-term rate at time t; and
s_t	short-term rate at time t.

Next, a demand model developed by a Dutch savings bank can be mentioned (Schreurs, 1997). The model has been estimated using quarterly data of this bank. Expression (3.9) below shows the model. Apart from this so-called statistic model, this bank also uses a so-called economic model, which has two additional variables, which are not statistically significant, but which intuitively explain saving behaviour (Schreurs, 1997). This model is shown in (3.10) below.

$$\Delta B_t = \beta_0 + \beta_1\delta_1 + \beta_2\delta_4 + \beta_3\left(\overline{r} - \overline{s}\right) + \beta_4\left(\overline{r} - \overline{k}\right) + \varepsilon_t \tag{3.9}$$

$$\Delta B_t = \beta_0 + \beta_1\delta_1 + \beta_2\delta_4 + \beta_3\left(\overline{r} - \overline{s}\right) + \beta_4\left(\overline{r} - \overline{k}\right) + \beta_5\left(\overline{r} - \overline{r}_c\right) + \beta_6\Delta R_t + \varepsilon_t \tag{3.10}$$

The meaning of the variables is:

$\overline{r}$ average savings accounts rate;
$\overline{s}$ average short-term rate;
$\overline{k}$ average long-term rate; and
$\overline{r}_c$ average rate of main competitor.

Finally, Jarrow & Van Deventer (1998) also give a demand model, which is used in their valuation model (see section 3.3.4). The model is straightforward and is as shown in (3.11)

$$\log B_t = \log B_{t-1} + \beta_0 + \beta_1 t + \beta_2 r_t + \beta_3\left(r_t - r_{t-1}\right) + \varepsilon_t\,. \tag{3.11}$$

As can be seen, this period's demand is dependent on the last period's demand, some macroeconomic factors, embedded in a linear time trend t, the market rate at time t and the difference between this period's market rate and previous period's market rate.

Summarising, it can be seen that several demand models are available from literature. Some of these have been estimated using Dutch data (Wielhouwer & Van der Ende, 1997 and Schreurs, 1997). However, we will not use these models, due to the properties of our data, which show unit root in some of the time series.
If a time series contains a unit root time series theory tells that the above models should not be used. We will therefore estimate our own demand models in section 3.6. First, we give some background on several important concepts in time series analysis.

3.5 Some background

3.5.1 Introduction

In this section, we give some background on a few important concepts. Since the models we develop are all time series models, we describe the basics of time series analysis and some important concepts in that field in section 3.5.2. We end this section with some considerations on which software to use (section 3.5.3).

3.5.2 Time series analysis

Introduction

A time series is a sequence of numerical data in which each item is associated with a particular instant in time (Maddala, 2001). In this section we describe a few important concepts with regard to time series analysis. First we briefly describe the two estimation methods used in this thesis, viz. Ordinary Least Squares (OLS) and Maximum Likelihood (ML).

Time series are often modelled as so-called ARIMA models. These models are sometimes referred to as Box-Jenkins approaches, since Box & Jenkins were among the first to extensively describe the statistics of these models (Box & Jenkins, 1976).
Stationarity is an important concept in time series modelling. We will therefore shortly describe the concept of stationarity in this section as well. Finally, we address the important issues of residual analysis, model selection and forecasting.
We will keep the description in this section short, since there are many good textbooks on these subjects, for example the before-mentioned book of Box & Jenkins for example (Box & Jenkins, 1976). More recent text books include Clements & Hendry (1998), Franses (1998), Kennedy (1998), James & Webber (2000) and Maddala (2001).

Estimation methods

Ordinary Least Squares (OLS)[91]

Assume the model

$$y_t = \beta_0 + \sum_{i=1}^{n} \beta_i x_{it} + u_t \tag{3.12}$$

with y_t the observed values of the stochastic variable Y_t and $x_{1t},\ldots,x_{nt}$ as observed values of a matrix of explanatory variables $\mathbf{X}$ and u_t the error term. With $\hat{\beta}_i$ the estimator of β_i, the sample counterpart of u_t would be the residual

$$\hat{u}_t = y_t - \hat{\beta}_0 - \sum_{i=1}^{n} \hat{\beta}_i x_{it} \ . \tag{3.13}$$

The goal of OLS is to find those values of $\hat{\beta}_i$ that minimise the sum of squared $\hat{u}_t$, or

$$Q = \sum \left(y_t - \hat{\beta}_0 - \sum_{i=1}^{n} \hat{\beta}_i x_{it} \right)^2 \ . \tag{3.14}$$

From (3.14) so-called "normal equations" can be derived by taking partial derivatives of Q with respect to $\hat{\beta}_i$ for $i = 1,\ldots,n$. Solving these normal equations gives the values of the $\hat{\beta}_i$. For the above to be true it is required that the error term u_t is (1) normally distributed with (2) a mean of zero and (3) a variance of σ^2 for all t. Furthermore, (4) the u_t are independent of each other and (5) independent of the x_{it} for all t. If assumption (4) is violated this is called serial correlation in the residuals (see below). If assumption (5) is violated, this is called heteroskedasticity. We will not discuss this concept, but refer to the before mentioned textbooks.

[91] Based on Maddala (2001).

The above is just a simple description of Ordinary Least Squares. The procedure is complicated if the relation between Y_t and $\mathbf{X}$ is not linear or if the assumptions are violated. Again, we refer to the before-mentioned textbooks for a more in-depth discussion of these issues.

Maximum Likelihood (ML)[92]

Maximum likelihood methods find parameter values for which the actual outcome has the maximum probability. Suppose we have a time series r_{t_i}, $i = 1,\ldots,n$, with transition densities $p\left(t_{i+1}, r_{t_{i+1}}; t_i, r_{t_i} \left|\theta\right.\right)$. The joint density of these observations is

$$p\left(r_{t_1},\ldots,r_{t_n} \left|\theta\right.\right) = p_0\left(r_{t_1} \left|\theta\right.\right)\prod_{i=1}^{n-1} p\left(t_{i+1}, r_{t_{i+1}}; t_i, r_{t_i} \left|\theta\right.\right), \tag{3.15}$$

where p_0 is the prior density for r_{t_1}. The likelihood function is

$$L(\theta) = \prod_{i=1}^{n-1} p\left(t_{i+1}, r_{t_{i+1}}; t_i, r_{t_i} \left|\theta\right.\right). \tag{3.16}$$

An estimate for θ, the parameters in the model, is found by maximising the likelihood function. Since maximising $L(\theta)$ yields the same estimate for θ as maximising $\ln L(\theta)$, one can choose the log-likelihood function if that is more convenient. The problem in an ML procedure is to find the density function. We refer to James & Webber (2000) for a more elaborate description of maximum likelihood methods and some examples.

ARIMA models

Time series are often estimated using so-called ARIMA models. In this section we will shortly describe moving average (MA) processes, autoregressive (AR) processes and combinations of these processes, so-called ARMA or ARIMA processes. For a more elaborate discussion on these models see for example Box & Jenkins (1976) and Maddala (2001).
Some of the models we estimate in sections 3.6 and 3.7 use these processes. In this section we define X_t as a stochastic variable, ε_t as a purely random process with mean zero and variance σ^2 and α_i, β_i as parameters in the models.

Moving average processes

If the stochastic process of X_t is defined by

$$X_t = \beta_0\varepsilon_t + \beta_1\varepsilon_{t-1} + \ldots + \beta_{t-m}\varepsilon_{t-m} \tag{3.17}$$

it is called a moving average process of order m and denoted by $\text{MA}(m)$.

[92] Based on James & Webber (2000)

Autoregressive processes

If the stochastic process of X_t is defined by

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \ldots + \alpha_r X_{t-r} + \varepsilon_t \tag{3.18}$$

it is called an autoregressive process of order r and denoted by $\mathrm{AR}(r)$.

ARMA & ARIMA processes

If we combine AR and MA models, the resulting model is referred to as a ARMA model. For example,

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \ldots + \alpha_p X_{t-p} + \varepsilon_t + \beta_1 \varepsilon_{t-1} + \ldots + \beta_{t-q} \varepsilon_{t-q} \tag{3.19}$$

is an $\mathrm{ARMA}(p,q)$ process.

If a time series is non-stationary (see below), a procedure that is often used to convert the series to a stationary series is successive differencing (Maddala, 2001). Define the difference operator Δ so that $\Delta X_t = X_t - X_{t-1}$, $\Delta^2 X_t = (X_t - X_{t-1}) - (X_{t-1} - X_{t-2})$ and so on. If $\Delta^d X_t$ is a stationary series, which can be represented by an $\mathrm{ARMA}(p,q)$ model, we say that X_t is represented by an autoregressive integrated moving average (ARIMA) model of order (p,d,q).

Stationarity

Theoretically, a time series is a collection of random variables X_t. An important concept in estimating time series models is whether the time series is stationary. A time series is said to be stationary when the distribution of X_t is independent of time. In a non-stationary series, this is not the case. Consider the two models

$$y_t = y_{t-1} + \varepsilon_t \tag{3.20}$$

and

$$y_t = \alpha y_t + \varepsilon_t \qquad |\alpha| < 1 \tag{3.21}$$

where ε_t is a zero-mean stationary process. In the first case a shock influences all future observations, whereas in the second model, this shocks fades away over time. The first model therefore is non-stationary, whereas the second model is stationary. This is important because it influences model identification. For example, if we use ordinary least squares to estimate a time series, and the time series is not stationary, we violate assumptions (2) and/or (3) (see page 81), which means we can not use plain OLS.

As can be seen from the models above, a series is non-stationary when $|\alpha| = 1$. The series is then said to have a unit root. One can test for the presence of a unit root using so-called unit root tests.

The unit root test used in Eviews 3.1 (see section 3.5.3) is the Augmented Dickey-Fuller test. More about the Dickey-Fuller test can be found in Dickey & Fuller (1979), MacKinnon (1991), Maddala (2001) and the Eviews 3.1 help-file for example.

To be short, the Dickey-Fuller (DF) test considers the $\mathrm{AR}(1)$ model $y_t = \mu + \rho y_{t-1} + \varepsilon_t$, where μ and ρ are parameters and ε_t a zero-mean stationary process. It tests the null-hypothesis $H_0 : \rho = 1$ versus the alternative hypothesis $H_1 : \rho < 1$. This is done by subtracting y_{t-1} from both the left and right hand side of the model above, yielding $\Delta y_t = \mu + \gamma y_t + \varepsilon_t$ where $\gamma = \rho - 1$ and testing $H_0 : \gamma = 0$ versus $H_1 : \gamma < 0$.

This only tests for a unit root if the series is a $\mathrm{AR}(1)$ process. If the series is correlated at higher order lags, the assumption of white noise errors is violated. In that case the Augmented Dickey-Fuller test (ADF) is to be used, which controls for these higher order lags by estimating the model $\Delta y_t = \mu + \gamma y_{t-1} + \alpha_1 \Delta y_{t-1} + \alpha_2 \Delta y_{t-2} + \ldots + \alpha_p \Delta y_{t-p} + \varepsilon_t$ and testing the same hypotheses. This can be done either with the constant μ included, or with a constant and trend term[93] included or with neither terms included. The general principle is to choose a specification that is a plausible description of the data under both the null and alternative hypotheses. If the series seems to contain a trend (whether deterministic or stochastic), one should include both a constant and trend in the test regression. If the series does not exhibit any trend and has a nonzero mean, one should only include a constant in the regression, while if the series seems to be fluctuating around a zero mean, one should include neither a constant nor a trend in the test regression.

A second issue is whether to use a DF or ADF test, or in other words, assume an $\mathrm{AR}(1)$ process or a process with higher order lags. An approach is to start with a general model and progressing to a more specific one (Maddala, 2001). That is, start with a high lag length p and progressively going down. Another approach is to choose the lag length which minimises some information criterion like Akaike's (see page 86). The choice of the appropriate lag length is important, because if some serial correlation in the residuals remain (that is, the lag length is too short) the assumption of white noise residuals does not hold and the model is not correct, whereas a overparameterized model (that is a lag length that is too long) looses power, meaning that it can fail to detect a unit root, where there is one. See for example Ng & Perron, (1995).

If the ADF test statistic is bigger than a critical value for a certain significance level, the null hypothesis of a unit root can not be rejected. In that case one has to conclude that the series contains a unit root. A solution is to difference the series. We will frequently do this.

Residual analysis

Once a model is estimated, one has to check the residuals to see whether they show a clear pattern. If this is the case, the model might be misspecified. Two common problems with residuals are heteroskedasticity and autocorrelation. Residuals are heteroskedastic when they correlate with the observations. For example, when residuals become larger or smaller over

[93] This is done by including the variable t in the model.

time. We will not discuss techniques to detect heteroskedasticity or correct for it, but refer to the textbooks mentioned in the introduction.
Autocorrelation, which is also referred to as serial correlation means that the residuals correlate with each other instead of being independent. There are several tests to detect serial correlation. We will discuss the Durbin-Watson test and the Breusch-Godfrey Lagrange multiplier test. If autocorrelation is present, one can solve this for example by adding more variables to the models, since the autocorrelation might be caused by a misspecified model. Another solution is to add a moving average term.

Durbin-Watson test

The Durbin-Watson test quickly gives an indication of the presence of serial correlation. The test statistic is provided by Eviews 3.1 for every regression. The Durbin-Watson statistic, denoted by d is defined as

$$d = \frac{\sum_{t=2}^{n} \left(\hat{u}_t - \hat{u}_{t-1} \right)^2}{\sum_{t=1}^{n} \hat{u}_t^2} \tag{3.22}$$

where $\hat{u}_t$ is the estimated residual for time t. If the correlation between u_t and u_{t-1}, $\hat{\rho}$, equals one, we have $d = 0$. On the other hand, if $\hat{\rho} = -1$, then $d = 4$. If there is no correlation, that is $\hat{\rho} = 0$, then $d = 2$ (Maddala, 2001). So values of the Durbin-Watson statistic far from two can indicate serial correlation in the residuals. A drawback of this statistic is that it can only detects first order autocorrelation.

Breusch-Godfrey Lagrange multiplier test[94]

The Breusch-Godfrey Lagrange multiplier test does not have this drawback. It can be used to test for higher order serial correlation. Consider the model

$$y_t = \sum_{i=1}^{k} \beta_i x_{it} + u_t \qquad t = 1, \ldots, n \tag{3.23}$$

and

$$u_t = \sum_{j=1}^{p} \rho_j u_{t-j} + \varepsilon_t \tag{3.24}$$

where ε_t are independent normally distributed variables with mean zero and variance σ^2. Basically, what we are interested in is testing the hypothesis $H_0 : \rho_1 = \rho_2 = \ldots = \rho_p = 0$. The Breusch-Godfrey Lagrange multiplier test is as follows. First, estimate (3.23) using OLS to find least squares residuals $\hat{u}_t$. Then, estimate the regression equation (3.25) below and test whether the coefficients of $\hat{u}_{t-j}$ are all zero.

[94] Based on the Eviews 3.1 help system (Quantitative Micro Software).

$$\hat{u}_t = \sum_{i=1}^{k} \beta_i x_{it} + \sum_{j=1}^{p} \rho_j \hat{u}_{t-j} + \eta_t \tag{3.25}$$

Model selection

When it comes to model selection, one usually tries to find a model that uses as few variables as necessary. In the analysis below on the modelling of demand, we will develop models by making them increasingly complex. In the modelling of the savings and term deposits rate, we develop a couple of models based on some propositions and choose the model which performs best. For this, we set two conditions. The first is that all variables are significant. If that turns out to be inconclusive, we add a second condition, which is the score of the model on the Akaike Information Criterion (AIC).
The AIC can be applied to any model that can be estimated by the method of maximum likelihood, discussed above (Maddala, 2001). The aim is to find the model which minimizes

$$\frac{-2\log L}{n} + \frac{2k}{n} \tag{3.26}$$

where k is the number of variables in the model, n the number of observations and L the log likelihood (see above).

Forecasting

In the end we are interested in forecasting with our models. Regarding forecasting, we can refer to Box & Jenkins (1976) or more recent publications such as Franses (1998) and Clements & Hendry (1998).
Basically, we can distinguish between static and dynamic forecasting. Assume we have the model $X_{t+1} = \alpha X_t + \varepsilon_{t+1}$. Static forecasting uses the observed value in forecasting. That is, X_{t+1} is forecasted using the observed X_t. One period later, X_{t+2} is forecasted based on the observed X_{t+1}. Franses (1998) refers to static forecasting as one-step ahead forecasting.
Dynamic forecasting uses the forecasted X_t to forecast X_{t+1}. This means that at time $t=1$ both approaches give the same forecasted value. But after time $t=1$ the forecasted values will differ. Franses (1998) refers to dynamic forecasting as *h*-step ahead forecasting with h the length of the forecasted period. A drawback of dynamic forecasting is that forecasting errors can build up. We will use static forecasting for in-sample testing of the model, whereas we will use dynamic forecasting to perform out-of-sample testing.

3.5.3 Software

Our ultimate goal in this chapter is the valuation of savings accounts. We will do that by Monte Carlo simulation. For this we need simulation software, capable of doing Monte Carlo analysis. We then basically have two options, that is using a standard package or programming the software ourselves. Since standard software packages are available, we did not bother to program the software ourselves, but decided to use a standard software package. A second choice involves the choice of the package to use. There are several options. We chose to use Crystal Ball 2000 Standard Edition for Windows. The most

important reasons were its ease of use and the fact that we already had worked with this package before.
We needed a second software package for developing our demand and interest rate models. For this we needed a time series package. We had Eviews 3.1 to our disposal and found this package very easy to use. We therefore chose to use this package.

3.6 Modelling saving behaviour

3.6.1 Introduction

Based on Keynes' liquidity-preference theory, which was briefly described in section 3.1 on page 73 we will model "saving" behaviour by looking at the developments over time in demand deposits, regular savings accounts and term deposits. We limit our data to the retail sector[95], since we are only interested in the retail banking book. We will start our analysis with a study of the determinants of saving behaviour (section 3.6.2). After that we will briefly describe the data (section 3.6.3). Especially the demand deposits require some attention. Next, we will develop a model for total volume, which is the sum of demand deposits, savings accounts and term deposits (section 3.6.4). The final model explains the developments in total volume quite well but is expected to behave poorly in forecasting. We will therefore develop models for demand deposits, savings accounts and term deposits separately in sections 3.6.5 to 3.6.7. Finally, section 3.6.8 concludes.

3.6.2 Determinants of saving behaviour

In recent years, every now and then articles in newspapers mention the saving behaviour of households. For example, in early 1992, the increased volume of amounts in term deposits was highlighted, with the possible explanation that households were becoming more interest rate sensitive, since at that time, interest rate on term deposits were higher than interest rates on normal savings accounts[96].
Furthermore, in 1992 the Dutch Central Bureau of Statistics (CBS) conducted a study to the savings behaviour of Dutch households between 1980 and 1990. It was found that on average 6.5% of the household's net income was saved. However, large differences could be found within the population. These differences were caused by differences in household income, the presence of children, age and social background[97].
In 1993, another study was conducted trying to find evidence whether new types of savings products giving a higher interest rate had changed saving behaviour. However, it was found that 70% of the savers did not change to other products for a higher interest rate. However, those who did change were largely wealthy clients between the age of 45 and 65 in possession of a house[98].
Hochgürtel et al. (1995) studied the determinants of household portfolio allocation in the Netherlands using 1988 data. They assume that household wealth is either saved, invested in

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95 Small and medium sized enterprises and private clients.

96 Utrechts Nieuwsblad, "*Toename concurrentie tussen banken met spaarrente-tarieven*", June 1, 1992

97 Staatscourant, "*Huishoudens sparen jaarlijks 6,5 procent*", December 21, 1992

98 Volkskrant, "*Oudere spaarder stapt snel over voor meer rente*", April 19, 1993

stocks or bonds or consumed. The amount of wealth invested or saved is called financial wealth. In their study they found financial wealth is largely affected by family income, the marginal tax rate, age and family composition[99]. Furthermore, a regional indicator was found to be significant.

After finding the determinants of family financial wealth, Hochgürtel et al. studied the effects of financial wealth on the allocation of wealth between savings accounts and investments in stocks or bonds. It was found that the level of wealth was an important determinant; the higher the level of wealth the higher the amount allocated to investments in stocks and bonds. The same holds for the educational level. Finally, the marginal tax rate was found to be a significant determinant of wealth allocation[100].

In 1995 the CBS published data on the saving behaviour of households over the first half year of 1995. It was shown that total savings had grown enormously as compared with the first six months of 1994. However, total savings turnover decreased by 24%, due to less payments and withdrawals. Causes are not known, but it is expected that the changes are due to a shift from savings products to more tax-friendly products. Another cause that is given is the low rate of interest[101, 102].

The increase in savings in the first half year of 1995 was also subject of an article in Trouw[103]. In that article the reasons for this increase are questioned. No clear cause can be given. The Dutch organisation Nibud thinks that the increase is caused by uncertainty over the role of the government. It is argued that there are numerous fields in which the government first took care for the people, but is planning to quit this. To be sure, people start to save. However, a representative of Rabobank, the bank with the highest market share in savings accounts, argues that the increase is due to investors, disappointed by the bad returns on the stock exchange. They therefore start saving again. Another cause is given by the CBS. This bureau argues that the increase is due to some tax measures making saving via the employer more attractive. However, the banks argue that these types of savings cannibalises other savings products and therefore can not explain the increase.

In the first quarter of 1996, the amounts stored in Rabobank savings accounts increased by NLG 3.6 billion. The bank said this increase was caused by investors locking in the increased value of stocks and returning to savings accounts[104].

To that same conclusion comes the NRC in August 1996, when analysing the increase in savings amounts over the first half year of 1996[105]. However, other causes are also mentioned. First of all, savings amounts increased due to the increase in total income.

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[99] Married and unmarried couples and parents with children hold significantly more (financial) wealth than single individuals (Hochgürtel, et. al, 1995).

[100] The data in the research was from 1988. The tax regime in the Netherlands at that time taxed interest income above a certain threshold, whilst returns on stocks and bonds, except dividends and interest payments, were not taxed. As of January 1, 2001 this has changed. Interest received on savings accounts as well as returns on stocks and bonds are now taxed using an assumed return of 4%.

[101] Volkskrant, "*Consument laat spaarrekening vallen*", August 17, 1995

[102] Het Financieel Dagblad, "*Spaarzin van particulieren neemt fors toe*", August 17, 1995

[103] Trouw, "*Nederlandse spaarlust is groot, maar waarom?*", August 21, 1995

[104] NRC Handelsblad, "*Klanten Rabobank verzilveren koerswinst en gaan sparen*", June 7, 1996

[105] NRC Handelsblad, "*Spaarzin van consument met raadselen omgeven*", August 16, 1996

Although the increases in salary were not that big, unemployment decreased causing an increase in total national income. Another cause which is thought of are the mortgages rates, which were low at that time. This stimulated people to cash the increased value of their house and take a new mortgage at a lower rate, thus hardly increasing monthly payments. The new mortgage is assumed to be temporarily stored on a savings account, thereby increasing savings volume.

Mulder and Van de Ven (1997) conducted a study to find the determinants of saving behaviour. They distinguish between two types of savings. The first category is formed by so-called contractual savings, for example savings in a saving mortgage contract. The second category is formed by the free savings, amongst which is saving with a bank. Mulder and Van de Ven focus on this latter category. They found three determinants, which are income developments, return on savings, and demographic factors. Regarding income, they show that the contractual savings are based on the expected development of future income whilst free savings are more sensitive to cyclical economic developments.

Regarding the return on savings accounts, it is shown that total free savings are sensitive to the financial climate. High returns on the stock market means low free savings and vice versa.

Demographic factors also determine saving behaviour. Mulder and Van de Ven find that the age of the saver is important. It is stated, that, in general, older people save more than younger people. A reason for this could be that older people are physically limited in their consumption and thus are more or less “forced” to save.

Another issue that is mentioned is the difference in tax treatment between savings products and investments in, for example stocks, which make savings accounts less attractive tax-wise. However, tax-laws have been changed in the Netherlands as of January 1, 2001 taking away this inequality (see also footnote 100 on page 88).

The effect of equal tax regulation for investments and savings is shown in a CBS paper[106]. During the first eight months of 2001 total savings were 13 times larger than during the first eight months of 2000. Regarding the CBS, this is largely due to the changed tax regulation and the decreased stock prices.

Summarising the above, the following determinants of saving behaviour can be identified:

- household income;
- the level of interest rates on savings accounts;
- return on the stock market;
- the marginal tax rate; and
- several demographic factors such as:
  - age;
  - social background;
  - family composition; and
  - region.

Unfortunately we don’t have data on all of the above mentioned factors. Therefore we use the gross national product (GNP) as a proxy of household income. The demographic factors as well as other economic factors will be modelled in a trend term if required.

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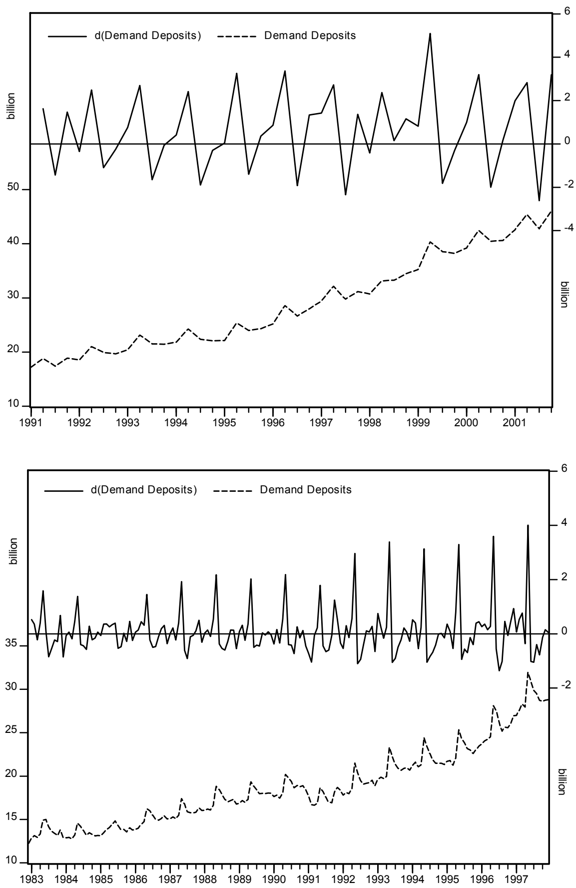
[106] CBS, “*Sparen is weer in*”, NewsSelect CBS, October 1, 2001

3.6.3 The data

Demand deposits

It was particularly hard to find data on demand deposits in the Netherlands. The Dutch Central Bureau of Statistics (CBS) does not collect that data. The Dutch Central Bank (DNB) does. Unfortunately, recent data are only available on a quarterly basis. That is, we have data on a series ranging from the first quarter of 1991 to the fourth quarter of 2001 (see upper pane of Figure 3.1 below). We will use this series in our model of total volume behaviour.
DNB does have recent monthly data, but that data are on an aggregated level and include non-retail sectors and can therefore not be used. The only monthly data on retail demand deposits are somewhat dated, ranging from December 1982 to December 1997 (see lower pane of Figure 3.1 below). However, due to the lack of more recent data, we decided to use this series to estimate a separate demand deposits model.

Figure 3.1 Demand deposits over time – quarterly (upper pane) and monthly (lower pane) observations (source: DNB)

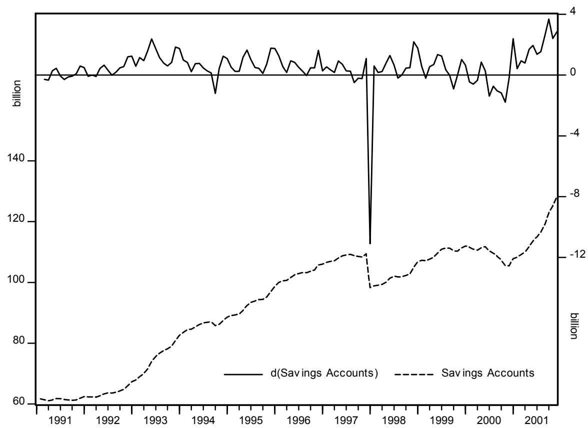


From the figures we see a slowly upward sloping series with some seasonality in it. More specifically, we see that monthly changes are around zero every month, except for most observation in May, which show large upward peaks, and most observations in July, August and December, which show relatively small decreases of demand deposits volume. This can be explained by the fact that most Dutch people receive a holiday allowance in May, whereas most people will go on vacation during July or August, thereby spending money. The December decline can be explained by expenses due to "Sinterklaas"[107] and Christmas.
The volumes in both panes are not completely comparative, because DNB uses a somewhat different definition for demand deposits nowadays then back in 1997. The main difference is that the monthly series only contains demand deposits of Dutch banks held by Dutch citizens, whereas today demand deposits of Dutch banks held in total euroland are counted for. Nevertheless, the majority of these demand deposits are still held by Dutch citizens, so the difference is fairly small.

Savings accounts

Data on savings accounts were much easier to find. We found monthly data on savings accounts ranging from January 1991 to December 2001 on the website of the Dutch Central Bureau of Statistics (CBS) (see Figure 3.2 below). We see an upward sloping series again, which grew fast in the early nineties and again in 2001. We also see a strange shift in January 1998. This is due to a change in the regulatory regime at that date. Regarding the month-to-month changes some seasonality can be observed. We see that in general upward peaks can be noticed in December and (to a smaller extent) in January, which are due to interest rate payments. Other positive peaks can be observed often in May and June, which might be explained by extra savings due to the holiday allowance received in May.

Figure 3.2 Savings accounts over time (source: CBS)

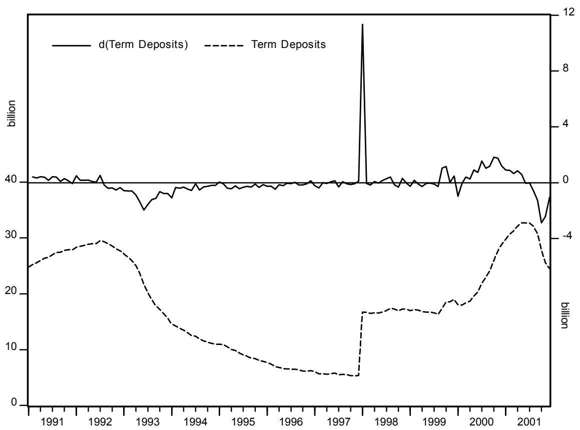


[107] Sinterklaas is a Dutch holiday when parents give presents to their children.

Term deposits

Data on term deposits were also found on the CBS website. Again the data are ranging from January 1991 to December 2001 (see Figure 3.3 below). We see that term deposits volume was declining as of 1993 until about 1998, from which it stayed relatively stable until the first half of 1999, ignoring the observation for January 1998. After that we see a sharp rise and equally sharp decrease of term deposits volume. The large upward peak in January 1998, which is almost opposite to the peak we saw for the savings accounts, is due to a change in the regulatory regime at that date. With regard to the month-to-month changes we do not see anything that can point to seasonality.

Figure 3.3 Term deposits over time (source: CBS)

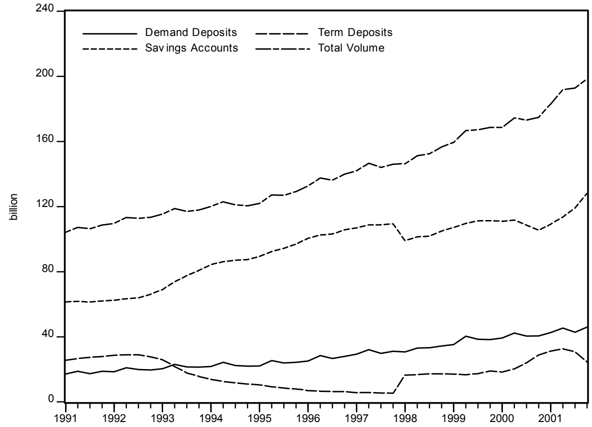


Total volume

If we take the previous series together and sum them, we find total volume (see Figure 3.4 below). This is a quarterly series. There are two major reasons for that. The first is that we only have recent data on demand deposits on a quarterly basis, as mentioned before. The second reason is that the series on GNP, one of the explanatory variables for total volume, is only available on a quarterly basis as well (see section 3.6.4).

From the figure we see that the biggest part of total volume is made of savings accounts, whereas demand deposits and term deposits form a much smaller part.

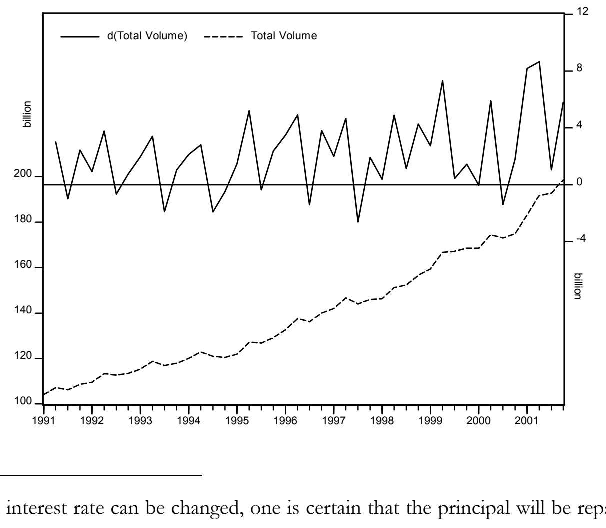
Figure 3.4 Total volume and its components over time



3.6.4 Modelling total volume

Below the development of total volume over time is given again together with the changes in total volume over time (see Figure 3.5 below). These changes show some seasonal pattern. A big peak can be observed in the first quarter of 2001, which might be caused by a change in the tax regime in January 2001, which taxes an assumed return on investments. In times of low or even negative returns on the stock markets this makes the "certain" returns[108] on savings accounts or term deposits even more attractive. Another interesting observation is that in general the change in volume is positive, indicating structural growth in total volume.

Figure 3.5 Total volume and changes in total volume over time



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[108] Although the paid interest rate can be changed, one is certain that the principal will be repaid, assuming that the bank will not default. And even if that happens, the Dutch Central Bank (DNB) guarantees the pay back of the principal to some maximum amount.

We start our analysis by checking whether the series is stationary. A closer look at the autocorrelation of total volume learns that there is a large correlation between TV_t and TV_{t-1}, or in other words, this month's volume versus last month's volume (see Table 3.2). Therefore, we suspect that there might be a unit root in our data. As a result, we start by doing a unit root test.

Table 3.2 Autocorrelation for total volume

Sample: 1991:1 2001:4
Included observations: 44

Autocorrelation	**Partial Correlation**	**Lag**
0.914	0.914	1
0.838	0.013	2
0.755	-0.078	3
0.688	0.042	4

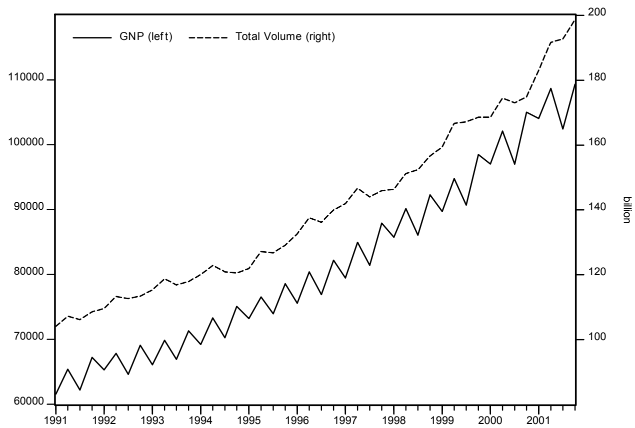
Regarding the lag length, we chose to start with a longer lag length and progressively going down. Since the series shown in Figure 3.5 above shows a trend, a constant and trend term are included in the test equation. We start with a lag length of four quarters. In this case none of the variables in the test equation, except for the four quarters lagged change in total volume, is significant. We therefore also tested models with lag lengths of three, two and one quarter(s), with and without trend term and constant. We do not show the results of all these tests, but in every case the results strongly indicate the presence of a unit root.
Based on these results, we suspect the models presented in section 3.4, which also include a lagged volume variable to have a unit root too. Because of this, these models are not stationary and therefore do not comply with the assumptions used in least squares. As a result, we will develop our own models.

An option when a unit root is present is to look at first differences. We then have to think of variables that influence the development of ΔTV_t. Based on the literature study in section 3.6.2, factors that may have an impact are:

- developments in the gross national product (GNP), since this indicates the total amount available for either consumption, investments, or savings. It is therefore a proxy of household income;
- developments in the stock exchange, in this case the Dutch stock exchange, since high returns on the stock market let people tend to invest their money in stocks instead of in savings accounts;
- seasonality effects, as can clearly be seen from Figure 3.5 above; and
- demographic and other economic factors.

Regarding GNP quarterly figures are available, which show a clear seasonal pattern (see Figure 3.6 below). In that figure, also the development in total volume is given. As one can see there is some similarity. Because we are estimating a model of ΔTV_t, we use ΔGNP_t in our model.

Figure 3.6 Quarterly GNP (Source: CBS) & Total volume



Regarding the stock exchange variable the developments in the Dutch stock index AEX are taken. The assumption is that people tend to look at the changes in the AEX over some period of time i. If the stock index has increased people will withdraw funds from their savings account and invest it in stocks and vice versa. This is operationalised as in (3.27).

$$x_t = AEX_{t-i} - AEX_t \tag{3.27}$$

Seasonality effects will be dealt with by dummy variables. We will not include a time trend, since ΔTV_t doesn't show a trend (see Figure 3.5 on page 93). The model that will be estimated then becomes

$$\Delta TV_t = \sum_{i=1}^{4} \beta_i \delta_i + \beta_5 \Delta GNP_t + \beta_6 x_t + \varepsilon_t \,. \tag{3.28}$$

We started with a lag term of six months (or two quarters) in (3.27) above. In this model, the GNP variable as well as the dummy variables for the third quarter and fourth quarter are not significant. We decided to remove the dummy variables for the third and fourth quarter and re-estimated the model. Now all remaining variables are significant, so the model becomes

$$\Delta TV_t = \beta_1 \delta_1 + \beta_2 \delta_2 + \beta_3 \Delta GNP_t + \beta_4 x_t + \varepsilon_t \,. \tag{3.29}$$

The results are shown in Table 3.3 below. As one can see, the results look good, although the Durbin-Watson statistic is low. We therefore do the Breusch-Godfrey Lagrange multiplier test, which shows serial correlation of the first order in the residuals. We solve this by adding the one-quarter lagged change in total volume to the model, which then becomes

$$\Delta TV_t = \beta_1 \delta_1 + \beta_2 \delta_2 + \beta_3 \Delta GNP_t + \beta_4 x_t + \beta_5 \Delta TV_{t-1} + \varepsilon_t \tag{3.30}$$

Table 3.4 below shows the results and Figure 3.7 on page 97 shows the residuals. Residuals are calculated as the difference between the actual observation at time t and the estimated value at that time.

Table 3.3 Total volume model 2 as shown in equation (3.29) on page 95

Dependent Variable: ΔTV_t

Method: Least Squares

Sample(adjusted): 1991:3 2001:4

Included observations: 42 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔGNP_t	0.000382	0.000061	6.241544	0.0000
x_t	0.019960	0.004282	4.661136	0.0000
δ_1	3.913891	0.508804	7.692340	0.0000
δ_2	3.969684	0.527498	7.525497	0.0000
R-squared	0.744414	Akaike info criterion		3.658184
Adjusted R-squared	0.724236	Durbin-Watson stat		1.104923
S.E. of regression	1.440452	F-statistic		36.89256
		Prob(F-statistic)		0.000000

Table 3.4 Total volume model 3 as shown in equation (3.30) on page 95

Dependent Variable: ΔTV_t

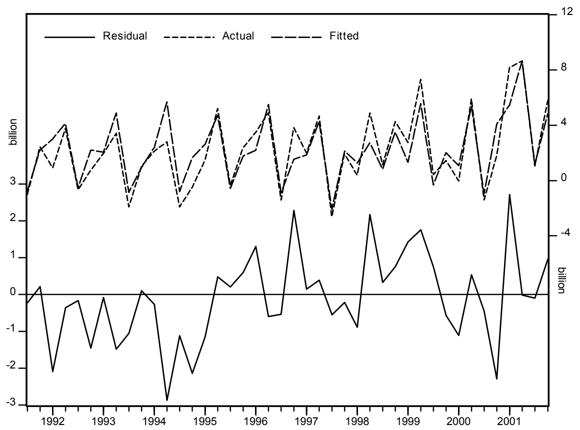
Method: Least Squares

Sample(adjusted): 1991:3 2001:4

Included observations: 42 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔGNP_t	0.000497	0.000066	7.595858	0.0000
x_t	0.018559	0.003860	4.808508	0.0000
δ_1	3.617484	0.464865	7.781787	0.0000
δ_2	2.843930	0.587605	4.839869	0.0000
ΔTV_{t-1}	0.255709	0.079373	3.221613	0.0027
R-squared	0.800402	Akaike info criterion		3.458546
Adjusted R-squared	0.778824	Durbin-Watson stat		1.715336
S.E. of regression	1.290027	F-statistic		37.09321
		Prob(F-statistic)		0.000000

Figure 3.7 Residuals for total volume model 3



Although the residual plot seems to show some serial correlation in the residuals, the Durbin-Watson statistic improved. Another Breusch-Godfrey Lagrange multiplier test does not show any serial correlation. We therefore decide this to be the final model. The explanatory power is quite well with an adjusted R^2 of around 78%.

We regard it as a drawback, however, that the model is dependent on GNP and the AEX. When forecasting, models for these variables have to be developed as well. The forecast model itself would then be based on many models, which might cause serious model risk.

Another approach would therefore be to estimate separate models for demand deposits volume, savings accounts volume and term deposits volume respectively.

3.6.5 Demand deposits

We start our analysis of the individual series with the demand deposits, DD_t. For this we will use the monthly series ranging from 1982:12 to 1997:12, which was already discussed in section 3.6.3. Table 3.5 gives the autocorrelation of this series for a lag period up to four months. We see that there is a large correlation between DD_t and DD_{t-1}. This might indicate a unit root, so we start with a unit root test.

Table 3.5 Autocorrelation for demand deposits

Sample: 1982:12 1997:12

Included observations: 181

Autocorrelation	Partial Correlation	Lag
0.962	0.962	1
0.925	-0.003	2
0.897	0.099	3
0.872	0.028	4

Because the series in Figure 3.1 on page 90 shows a trend, we include a trend term and constant. The results give no evidence of serial correlation in the residuals, so we do not take lag terms into the unit root test. The results are shown in Table 3.6 below and present weak evidence of a unit root. More precise, at a 5% confidence level we would reject the presence of a unit root, whereas at a 1% confidence level, we would not reject this hypothesis.

Table 3.6 Unit root test demand deposits volume.

ADF Test Statistic	-3.703434	1% Critical Value*		-4.0117
		5% Critical Value		-3.4356
		10% Critical Value		-3.1416
*MacKinnon critical values for rejection of hypothesis of a unit root.				

Augmented Dickey-Fuller Test Equation
Dependent Variable: ΔDD_t

Method: Least Squares

Sample(adjusted): 1983:01 1997:12

Included observations: 180 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DD_t	-0.151604	0.040936	-3.703434	0.0003
Constant	1.773060	0.486090	3.647599	0.0003
Trend	0.012849	0.003509	3.661853	0.0003
R-squared	0.073296	Akaike info criterion		2.501529
Adjusted R-squared	0.062825	Durbin-Watson stat		1.882635
S.E. of regression	0.838252	F-statistic		6.999761
		Prob(F-statistic)		0.001187

Since the unit root test only presents weak evidence of a unit root in the series, we will not difference the series and estimate a model for DD_t rather than ΔDD_t. Based on the description of the series in section 3.6.3, we will estimate a model, which includes a constant, a trend term and some seasonality factors. This way, the model becomes

$$DD_t = \beta_0 + \beta_1 DD_{t-1} + \beta_2 t + \beta_3 \delta_5 + \beta_4 \delta_7 + \beta_5 \delta_8 + \beta_6 \delta_{12} + \varepsilon_t . \tag{3.31}$$

Estimating this model, the dummy for December turns out to be insignificant. We therefore, remove it from the model, which then becomes

$$DD_t = \beta_0 + \beta_1 DD_{t-1} + \beta_2 t + \beta_3 \delta_5 + \beta_4 \delta_7 + \beta_5 \delta_8 + \varepsilon_t \tag{3.32}$$

and estimate the model again. The results are shown in the table below and indicate that the model is highly significant. Furthermore, all variables have the expected signs. The residuals, shown in Figure 3.8 below do not show any particular pattern, so we leave this model as it is.

Table 3.7 Results demand deposits model as shown in equation (3.32) on page 98

Dependent Variable: DD_t

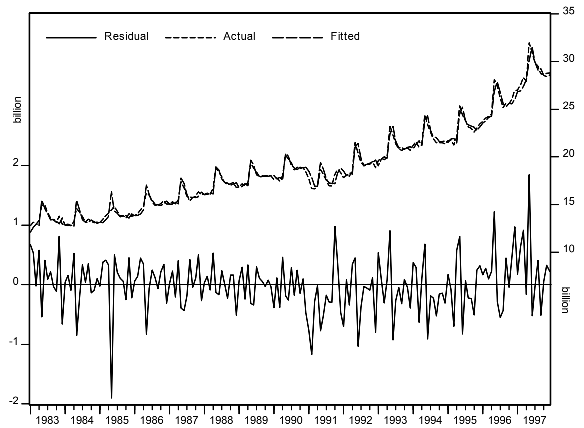
Method: Least Squares

Sample(adjusted): 1983:01 1997:12

Included observations: 180 after adjusting endpoints

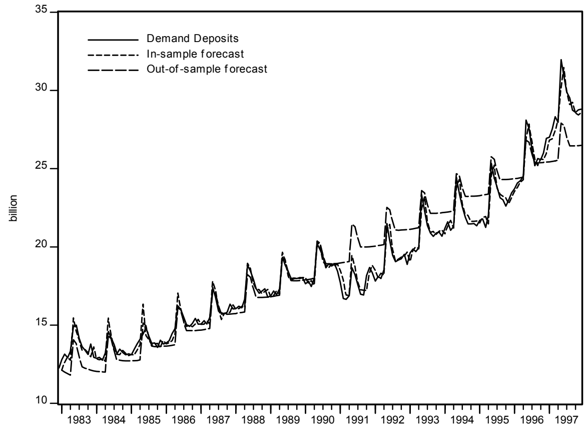
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.892919	0.277033	3.223154	0.0015
DD_{t-1}	0.915108	0.023617	38.74725	0.0000
Trend	0.007617	0.002014	3.782717	0.0002
δ_5	2.329548	0.126439	18.42433	0.0000
δ_7	-0.607540	0.130779	-4.645557	0.0000
δ_8	-0.496377	0.127198	-3.902405	0.0001
R-squared	0.989666	Akaike info criterion		1.335687
Adjusted R-squared	0.989369	Durbin-Watson stat		2.176439
S.E. of regression	0.464182	F-statistic		3332.822
		Prob(F-statistic)		0.000000

Figure 3.8 Residuals for the demand deposits model shown in equation (3.32)



Finally, we perform both an in-sample and out-of-sample forecast. The first is done by using a static forecast, whereas the latter is done by applying a dynamic forecast. The results are shown in Figure 3.9 below. We see that the in-sample forecast is quite good, whereas the out-of-sample forecast misses the somewhat larger decrease in early 1991. In general, however, we feel confident with this forecasting performance.

Figure 3.9 Forecast of demand deposits



3.6.6 Savings accounts

In this section we will estimate a model for savings accounts volume. As explained in section 3.6.3, the observation of January 1998 shows a strange shift due to a regulatory change in regime (see Figure 3.2 on page 91). We will therefore leave this observation out of the analysis.

We start with looking at the autocorrelation table (see Table 3.8), which shows a large correlation between SA_t and SA_{t-1}. Because of this we do a unit root test.

Table 3.8 Autocorrelation for savings accounts volume

Sample: 1991:1 2001:12		
Included observations: 132		
Autocorrelation	**Partial Correlation**	**Lag**
0.973	0.973	1
0.946	-0.008	2
0.919	-0.014	3
0.894	0.011	4

Since the series of savings accounts shows a clear upward trend, we include a constant and trend term in the unit root test and start with a three months lag term. Only the one month lagged variable is significant. We therefore do the unit root test again, now with shorter lag terms and excluding the constant and trend term. Finally, the model with a one month lag term and no trend term and constant added is the only model in which all variables are significant. The results of this model are shown in Table 3.9 below and strongly indicate the presence of a unit root.

Table 3.9 Unit root test savings accounts volume

ADF Test Statistic	3.140382	1% Critical Value*	-2.5815
		5% Critical Value	-1.9424
		10% Critical Value	-1.6170

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: ΔSA_t
Method: Least Squares
Sample(adjusted): 1991:03 2001:12
Included observations: 130 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SA_t	0.004050	0.001290	3.140382	0.0021
ΔSA_{t-1}	0.237334	0.087284	2.719090	0.0075

R-squared	0.049223	Akaike info criterion	3.383588
Adjusted R-squared	0.041795	Durbin-Watson stat	2.058287
S.E. of regression	1.303722	F-statistic	6.626699
		Prob(F-statistic)	0.011184

Because of this, we decide to difference the series and estimate a model of ΔSA_t. We start with the model shown in (3.33), for which the results are shown in Table 3.10.

$$\Delta SA_t = \beta_0 + \beta_1 \Delta SA_{t-1} + \varepsilon_t \tag{3.33}$$

Table 3.10 Savings accounts volume model 1 as shown in equation (3.33)

Dependent Variable: ΔSA_t
Method: Least Squares
Sample(adjusted): 1991:03 2001:12
Included observations: 128
Excluded observations: 2 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.212862	0.069744	3.052066	0.0028
ΔSA_{t-1}	0.674695	0.069090	9.765448	0.0000

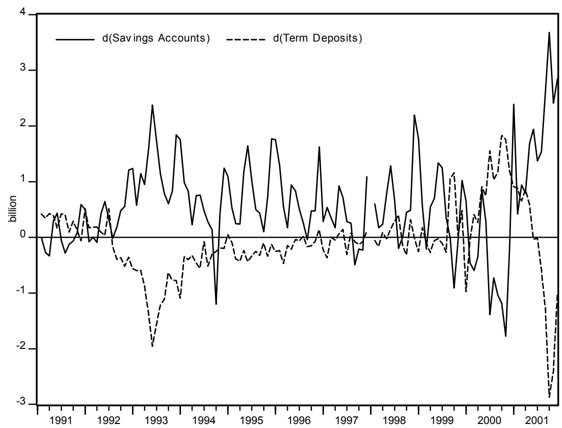
R-squared	0.430802	Akaike info criterion	1.988714
Adjusted R-squared	0.426284	Durbin-Watson stat	1.800211
S.E. of regression	0.648994	F-statistic	95.36398
		Prob(F-statistic)	0.000000

The question is what causes the remaining changes? First, we take a closer look at the relation between ΔSA_t and ΔTD_t. Figure 3.10 below shows the changes of term deposits volume and savings accounts volume over time. As can be seen, the changes are more or less opposite. This is also expressed in the large negative correlation between the two series, which is about -0.64. Therefore, we take ΔTD_{t-1} [109] into the model, which then becomes

$$\Delta SA_t = \beta_0 + \beta_1 \Delta SA_{t-1} + \beta_2 \Delta TD_{t-1} + \varepsilon_t \,. \tag{3.34}$$

Table 3.11 on page 103 shows the results. The residuals of this model are shown in Figure 3.11, also on page 103. An analysis of these residuals shows that there is a clear seasonal pattern. In most years around December and January and around May and June peaks can be observed. These peaks can be explained from interest payments which normally take place at the end of December or the beginning of January and the payment of holiday allowances. The latter normally occurs in May, but people may not save this until June. To correct for this seasonal pattern in the residuals, we add dummy variables for each of the previously mentioned months. These dummies have the value one if the observation is in that month and zero otherwise. The model is therefore altered and shown in (3.35) below.

Figure 3.10 Changes in term deposits and savings accounts volume over time



[109] We take ΔTD_{t-1} rather than ΔTD_t because of simulation issues. At time t we do not know ΔTD_t yet, but we do know ΔTD_{t-1}. Due to the rather large correlation between ΔTD_t and ΔTD_{t-1} (see next section), we do not expect this to influence our results significantly.

Table 3.11 Savings accounts volume model 2 as shown in equation (3.34) above

Dependent Variable: ΔSA_t

Method: Least Squares

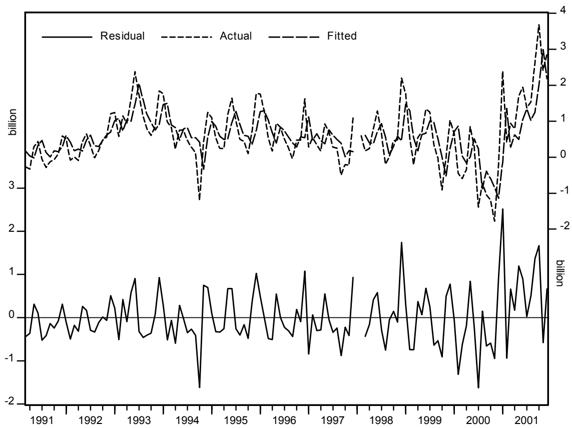
Sample(adjusted): 1991:03 2001:12

Included observations: 128

Excluded observations: 2 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.264283	0.072297	3.655506	0.0004
ΔSA_{t-1}	0.549520	0.087659	6.268853	0.0000
ΔTD_{t-1}	-0.244414	0.108041	-2.262231	0.0254
R-squared	0.453189	Akaike info criterion		1.964213
Adjusted R-squared	0.444440	Durbin-Watson stat		1.734528
S.E. of regression	0.638642	F-statistic		51.79909
		Prob(F-statistic)		0.000000

Figure 3.11 Residuals for savings accounts model 2 as shown in equation (3.34)



$$\Delta SA_t = \beta_0 + \beta_1 \Delta SA_{t-1} + \beta_2 \Delta TD_{t-1} + \beta_3 \delta_1 + \beta_4 \delta_5 + \beta_5 \delta_6 + \beta_6 \delta_{12} + \varepsilon_t \qquad (3.35)$$

The results show that all dummy variables are significant. However, the constant, β_0, which was taken into the model is no longer significant. This can be explained by the fact that the constant more or less took over the role of the dummy variables in the earlier estimated model. It is therefore removed from the model shown in (3.35) above and this model is re-estimated (see Table 3.12 below). As one can see all variables are now significant.

Figure 3.12 below shows the plot of the actual, fitted, and residual values. This plot looks good, as do the statistics in Table 3.12, although the Durbin-Watson statistic does seem to be a little low. Unfortunately, because we omitted the observation for January 1998, we can not do the Breusch-Godfrey Lagrange multiplier test. Nevertheless, we decide to use the model as shown in (3.35) above, but without β_0. Equation (3.36) on page 105 shows the resulting model.

Table 3.12 Savings account model 3b. Model 3b is shown in equation (3.36) on page 105

Dependent Variable: ΔSA_t

Method: Least Squares

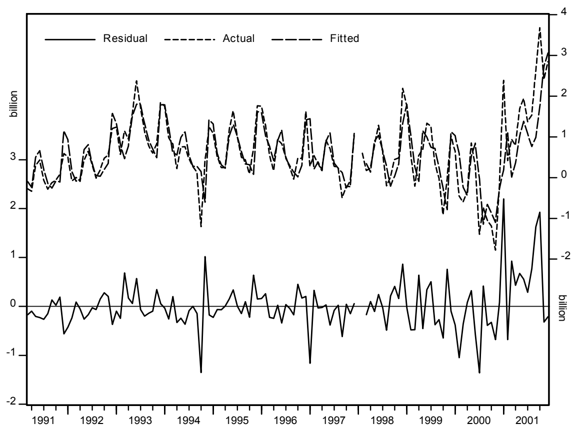
Sample(adjusted): 1991:03 2001:12

Included observations: 128

Excluded observations: 2 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔSA_{t-1}	0.552041	0.065209	8.465728	0.0000
ΔTD_{t-1}	-0.243851	0.087322	-2.792542	0.0061
δ_1	0.583127	0.189628	3.075113	0.0026
δ_5	0.784838	0.154570	5.077547	0.0000
δ_6	0.597455	0.164614	3.629428	0.0004
δ_{12}	1.138570	0.154999	7.345646	0.0000
R-squared	0.658859	Akaike info criterion		1.539280
Adjusted R-squared	0.644878	Durbin-Watson stat		1.865814
S.E. of regression	0.510600	F-statistic		47.12473
		Prob(F-statistic)		0.000000

Figure 3.12 Residuals for savings account model 3b

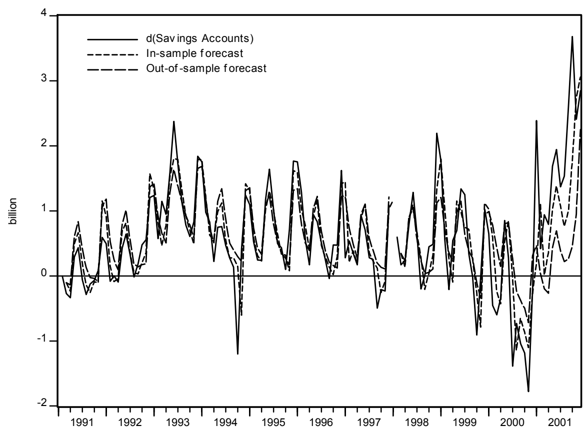


A last type of variable that might add something to the model is some form of interest rate. However, no clear relation can be found with either the short-term rate[110], the long-term rate or the savings rate. When these variables are included in the model, they are either not significant, or the sign is wrong. If we include the deposits rate in the model, it turns out to be significant, but at the cost of term deposits volume, which becomes insignificant. So, basically these variables measure the same effect. We also tested the difference between the term deposits rate and the savings rate. If we use the two-month lagged difference the variable turns out to be significant, but again at the cost of term deposits volume. Therefore, we decide to use the model as is, which was

$$\Delta SA_t = \beta_1 \Delta SA_{t-1} + \beta_2 \Delta TD_{t-1} + \beta_3 \delta_1 + \beta_4 \delta_5 + \beta_5 \delta_6 + \beta_6 \delta_{12} + \varepsilon_t \,. \tag{3.36}$$

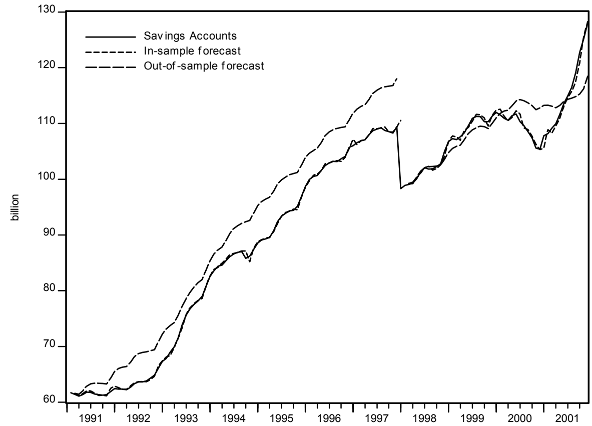
Finally, the forecasting performance is tested. As for the demand deposits we use static forecasting to perform an in-sample test and use dynamic forecasting for out-of-sample testing. The results are shown in Figure 3.13 below and Figure 3.14 on page 106. What can be seen is that "normal" changes are forecasted quite well. The large upward peak in January 2001 is missed. However, this extreme peak can be explained from the new tax regime as of that date, which makes saving more attractive in a bad stock market climate. Still, the forecast of savings volume is quite good.

Figure 3.13 Forecast of the change in savings volume over time



[110] In this case we used three-month EURIBOR for the short-term rate. The reason is that the savings rate is more or less dependent on this rate, as will be become clear from section 3.7.3.

Figure 3.14 Forecast of savings volume



3.6.7 Term deposits

Finally, we will estimate a model for term deposits volume. The development over time of term deposits volume shows a different pattern than the development of demand deposits and savings accounts. Whereas these show a trend, term deposits show a more cyclical pattern. We therefore estimate another type of model for term deposits.

As with demand deposits and savings accounts we start with a look at the autocorrelation table (see Table 3.13). Again, the correlation between TD_t and TD_{t-1} is quite large. We therefore do a unit root test.

Table 3.13 Autocorrelation for term deposits volume

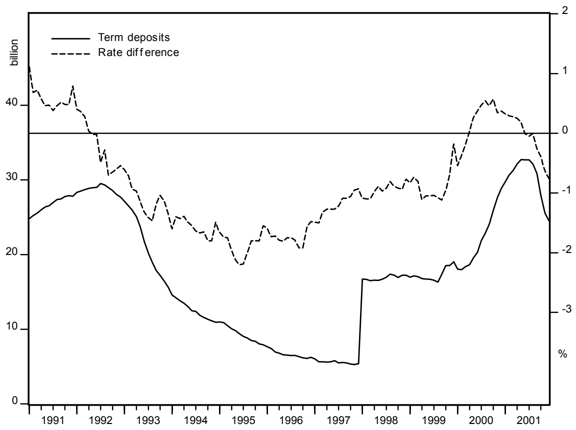
Sample: 1991:1 2001:12
Included observations: 132

Autocorrelation	Partial Correlation	Lag
0.985	0.985	1
0.965	-0.220	2
0.938	-0.172	3
0.906	-0.148	4

We included and excluded a constant and trend term and applied several lag terms. In all cases the results (not shown here) indicate the presence of a unit root. What we did until now was to difference the series and estimate a model for the first difference. However, due to the different pattern in term deposits volume over time, we now take a somewhat different approach.

If we again take a look at the term deposits volume over time (see Figure 3.3 on page 92) and ignore the regime shift in January 1998 we see that term deposits volume seems to have a sort of minimum volume and some changes around that minimum. Furthermore, term deposits volume seems highly correlated with the difference between the term deposits rate and the savings rate over time as can be seen from Figure 3.15 below. In this figure one can clearly see the resemblance in the lines.

Figure 3.15 Term deposits volume versus the difference between the term deposits rate and savings rate



As a result, we decide to estimate a model for term deposits volume, where we include a constant and the difference, between the term deposits rate and the savings rate. Furthermore, to deal with the regime shift in January 1998, we include a dummy variable, which has the value one in January 1998 and zero otherwise. Finally, to prevent volume from becoming less then zero, we use the natural logarithm of term deposits volume. Therefore, the model becomes

$$\ln TD_t = \beta_0 + \beta_1 \left(r_t^{TD} - r_t^{SA} \right) + \beta_2 \delta_{1998:01} + \varepsilon_t \tag{3.37}$$

where:

$\delta_{1998:01}$ dummy variable, which has the value one in January 1998 and zero otherwise.

Table 3.14 on page 108 shows the estimation results of this model. As we can see, the dummy variable is not significant. Furthermore, the Durbin-Watson statistic is rather low. Therefore, before removing the dummy variable, we first do a serial correlation test. The results, not shown here, indicate first order serial correlation in the model. We therefore decide to include a first order moving average term in the model, instead of removing the dummy variable. The model then becomes

$$\ln TD_t = \beta_0 + \beta_1 \left(r_t^{TD} - r_t^{SA} \right) + \beta_2 \delta_{1998:01} + \varepsilon_t + \alpha_1 \varepsilon_{t-1} . \tag{3.38}$$

Table 3.15 below shows the results. As can be seen all variables are significant now. The Durbin-Watson statistic still indicates some serial correlation, but we decide to leave the model as it is now. Figure 3.16 on page 109 shows the residuals. As one can see the fit is reasonably good.

Table 3.14 Estimation results of term deposits volume model 1 as shown in equation (3.37) above

Dependent Variable: $\ln TD_t$
Method: Least Squares
Sample(adjusted): 1991:07 2001:12
Included observations: 126 after adjusting endpoints

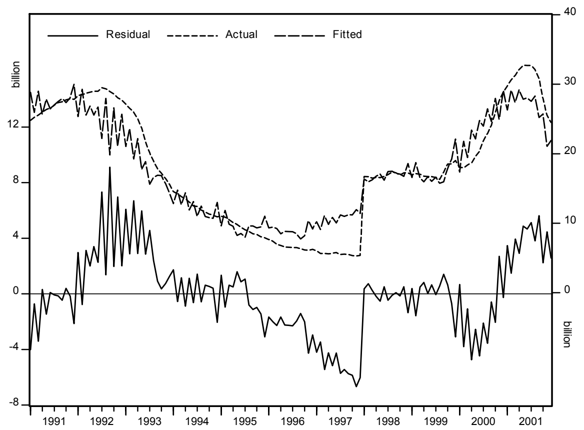
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	3.209638	0.034596	92.77588	0.0000
$r_t^{TD} - r_t^{SA}$	0.595783	0.029533	20.17322	0.0000
$\delta_{1998:01}$	0.333882	0.277964	1.201172	0.2320
R-squared	0.767958	Akaike info criterion		0.291083
Adjusted R-squared	0.764184	Durbin-Watson stat		0.188830
S.E. of regression	0.276607	F-statistic		203.5377
		Prob(F-statistic)		0.000000

Table 3.15 Estimation results of term deposits volume model 2 as shown in equation (3.38) above

Dependent Variable: $\ln TD_t$
Method: Least Squares
Sample(adjusted): 1991:07 2001:12
Included observations: 126 after adjusting endpoints
Convergence achieved after 32 iterations
Backcast: 1991:06

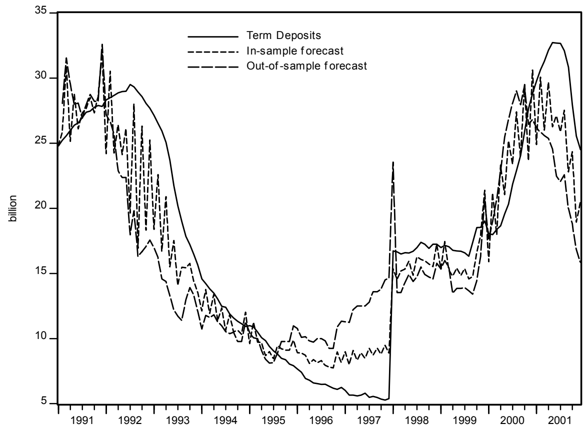
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	3.116703	0.049139	63.42687	0.0000
$r_t^{TD} - r_t^{SA}$	0.464951	0.042366	10.97475	0.0000
$\delta_{1998:01}$	0.548788	0.115263	4.761188	0.0000
ε_{t-1}	0.851595	0.048589	17.52648	0.0000
R-squared	0.853474	Akaike info criterion		-0.163790
Adjusted R-squared	0.850040	Durbin-Watson stat		0.544252
S.E. of regression	0.219643	F-statistic		248.5215
		Prob(F-statistic)		0.000000

Figure 3.16 Residual for term deposits model 2 as shown in equation (3.38) on page 107



Finally, we look at forecasting. This is slightly more difficult than it is for the demand deposits and savings accounts models, because of the $MA(1)$ term. To see the performance of this model in forecasting, we again use a static forecast for an in-sample test and a dynamic forecast for the out-of-sample test. As the results in Figure 3.17 show, the out-of-sample forecasts are good, although the peak in January 1998 is largely overestimated.

Figure 3.17 Forecasts of term deposits volume



3.6.8 Conclusions

In this section we clearly showed the dependency of changes in total volume on changes in GNP and the stock exchange. However, the resulting model will most likely perform poorly in forecasting. The reason is that, if this model is to be used in forecasting, models for predicting GNP and the AEX index have to be estimated first. These models will also have their prediction error, which will result in a wide distribution of total volume.
We have therefore chosen to model demand deposits, savings accounts and term deposits separately. For all we found models that predict reasonably well. More specifically, the demand deposits model explains about 99% of the behaviour of demand deposits volume. The savings account model explains about 66% of the changes in savings account volume. Finally, the term deposit model explains about 85% percent of the behaviour of term deposits volume.
Moreover, the models only depend on one variable that has to be modelled as well, which is the interest rate, which is required for valuation anyway.
Regarding forecasting, the models seem to forecast quite well, under "normal" circumstances. Large peaks, both upward as downward, however, are missed. Most of the time this is because the large peaks are caused by external shocks to the models, such as a change in the tax regime.

3.7 Modelling interest rates

3.7.1 Introduction

In section 3.3 we found that in order to value demand deposits, savings accounts and term deposits we not only require demand models, but also models for the interest rate. That is, the interest rate paid on savings accounts and term deposits, but also a model for the risk-free rate, because that rate is required for discounting. We do not need a model for the interest rate on demand deposits. This rate is either zero or very low, for example 0.25%. We therefore assume that no interest rate is paid on these accounts.
As in section 3.6 we will start with a description of available data (section 3.7.2). Thereafter, we will first estimate a model for the savings rate (section 3.7.3), followed by a model for the term deposits rate (section 3.7.4). Finally, we estimate models for the risk-free rate (section 3.7.5).

3.7.2 The data

Most of our data come from the Dutch Central Bureau of Statistics (CBS). As we will see in sections 3.7.3 and 3.7.4 we used the one-month EURIBOR, the three-month EURIBOR and the yield on a five-year government bond to estimate models for the savings rate and term deposits rate.
We have data on the one-month EURIBOR and three-month EURIBOR rate as of January 1977[111]. Furthermore, we took the yield on Dutch government bonds with a remaining maturity of between four and five years as a proxy of the five-year rate. This series starts as of January 1984.

[111] Before January 1999 this is the one-month AIBOR rate.

Data on savings accounts rates as well as term deposit rates are not available from CBS. We therefore used data of a large Dutch bank. Since the bank has multiple savings products, we used the average volume weighted rate as a proxy for the savings rate. This series starts as of December 1989. For the term deposits rate, the rate differs depending on the maturity of the term deposit and the principal amount. We decided to use the rate that is paid on the shortest term and lowest principal. This series is available as of January 1988.
All series end in December 2001. Because our shortest series is the series on the savings account rate, we limited our sample to the period January 1989 to December 2001. Table 3.16 gives some statistics, whilst Figure 3.18 and Figure 3.19 on page 112 show the developments of these rates over time.

Table 3.16 Statistics for interest rates

Sample: 1989:12 2001:12					
Statistic	r_t^1	r_t^3	r_t^{60}	r_t^{SA}	r_t^{TD}
Mean	5.41	5.45	6.02	4.96	4.29
Median	4.66	4.69	5.29	4.25	3.51
Maximum	9.83	9.82	9.25	8.00	7.98
Minimum	2.57	2.58	3.25	3.05	2.00
Std. Dev.	2.42	2.41	1.77	1.50	2.01
Skewness	0.60	0.63	0.56	0.46	0.69
Kurtosis	1.78	1.82	1.96	1.73	1.85
Observations	145	145	145	145	145

From the mean values in Table 3.16 we learn that the term structure was on average increasing, whilst the term structure of volatility was on average decreasing, with longer term rates having on average a lower volatility. It can also be noted that the shorter rates have larger maximum rates and lower minimum rates, which is also a sign of higher volatility.
Regarding the savings rate and term deposits rate, we see that the maximum rate is far below the maximum of the other rates, which is of course due to the margin taken by the banks. These two rates also have a low volatility, which is visualised in Figure 3.19 compared to Figure 3.18. Finally, Figure 3.18 and Figure 3.19 show that the different rates are highly correlated, which is also shown in Table 3.17.

Table 3.17 Correlations between interest rates

Sample: 1989:12 2001:12					
Rate	r_t^1	r_t^3	r_t^{60}	r_t^{SA}	r_t^{TD}
r_t^1	1	0.998	0.908	0.948	0.988
r_t^3		1	0.921	0.942	0.991
r_t^{60}			1	0.893	0.900
r_t^{SA}				1	0.905
r_t^{TD}					1

Figure 3.18 Market rates over time

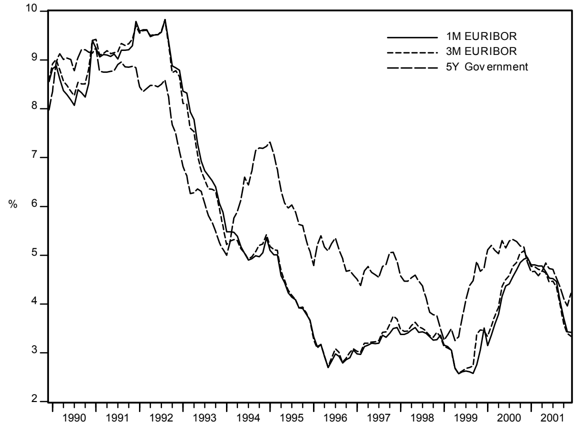
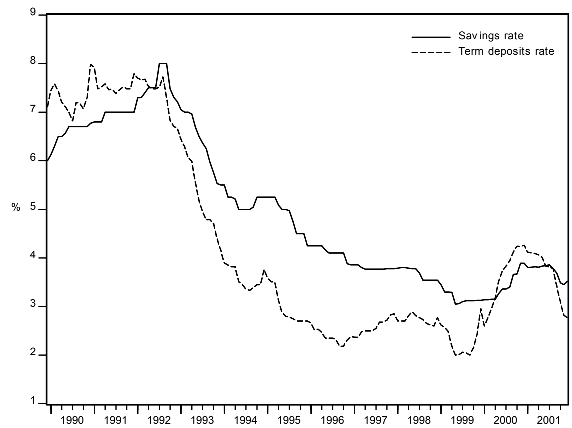


Figure 3.19 Product rates over time



3.7.3 Modelling the savings rate

The savings rate is important when determining the value of savings accounts, because it influences the cash flow. In section 3.4 we described some demand models, including the demand model of Wielhouwer & Van der Ende. In that model, the savings rate is used as one of the explanatory variables for demand. Wielhouwer & Van der Ende, therefore, also specify a model for the savings rate. In that model the savings rate is some mix between a short-term and a long-term rate plus some average margin. Whether the rate is adjusted upwards or downwards is dependent on the return on a portfolio in which the savings accounts are invested. Wielhouwer & Van der Ende assume that banks try to make a constant margin.

If we assume the short-term rate to equal three-month EURIBOR and the long-term rate to equal the rate on five-year government bonds, the savings rate is determined as follows

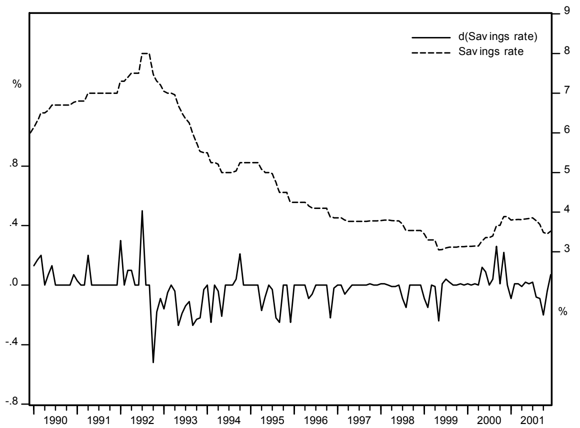
$$\Delta r_t^{SA} = \beta_1 \Delta r_t^3 + \beta_2 \Delta r_t^{60} + \beta_3 \left(\delta r_{t-1}^3 + (1-\delta) r_{t-1}^{60} - r_{t-1}^{SA} - \mu \right) + \varepsilon_t \qquad (3.39)$$

where:

δ	fraction of savings accounts invested in short-term deposits;
$1-\delta$	fraction of savings accounts invested in long-term bonds; and
μ	average margin the bank makes on savings accounts; μ is assumed to be bigger than zero.

A problem with the above model is that it assumes that the savings rate is dependent on the short-term and long-term rate. However, these rates are more volatile than the savings rate as Table 3.16 on page 111 showed. Actually, if we take a closer look at the (changes in the) savings rate over time (see Figure 3.20 below) it is clearly shown that the savings rate is far from volatile. Figure 3.20 shows that there are several time periods in which the savings rate remains stable.

Figure 3.20 The savings rate as well as changes in the savings rate over time



We therefore argue that the moving average of the short-term and long-term rate should be used in models for the savings rate. With $T = 3$ and $T = 60$ for the three-month and five-year rate respectively, the moving average is calculated as in (3.40).

$$\tilde{r}_t^T = \frac{1}{T} \sum_{i=0}^{T-1} r_{t-i}^T \qquad (3.40)$$

Figure 3.21 below shows the moving average rates as well as the savings rate. Table 3.18 and Table 3.19 below show the statistics of these series and their correlation with the savings rate respectively.

Table 3.18 Statistics for the three-month moving average three month EURIBOR rate and the five-year moving average of the five-year Dutch government rate

Sample: 1989:12 2001:12		
Statistic	$\tilde{r}_t^3$	$\tilde{r}_t^{60}$
Mean	5.48	6.42
Median	4.74	6.69
Maximum	9.64	7.92
Minimum	2.63	4.51
Std. Dev.	2.41	1.20
Skewness	0.60	-0.31
Kurtosis	1.77	1.58
Observations	145	145

Table 3.19 Correlations for the three-month moving average three-month EURIBOR rate and the five-year moving average of the five-year Dutch government rate with the savings rate

Rate	r_t^{SA}	$\tilde{r}_t^3$	$\tilde{r}_t^{60}$
r_t^{SA}	1	0.951	0.782
$\tilde{r}_t^3$		1	0.581
$\tilde{r}_t^{60}$			1

We also take a closer look at the changes in the savings rate and the changes in the moving average long-term and short-term rate (see Figure 3.22 and Figure 3.23 on page 115).

Figure 3.21 Moving average rates and the savings rate

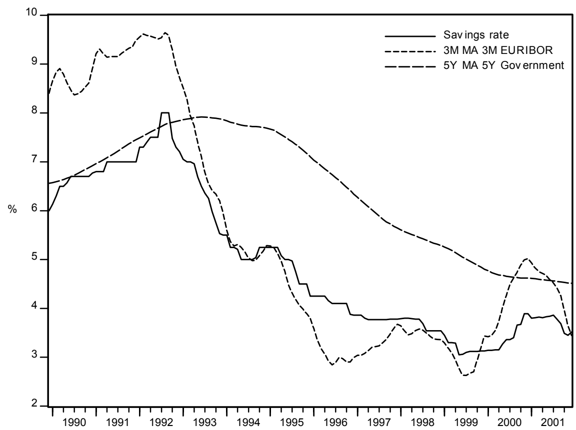


Figure 3.22 Changes in moving average long-term rate and savings rate

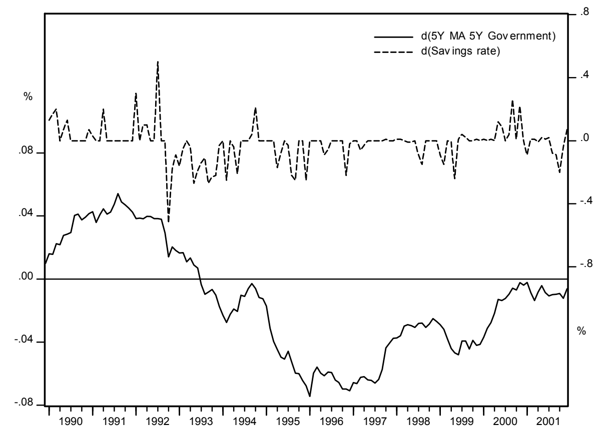
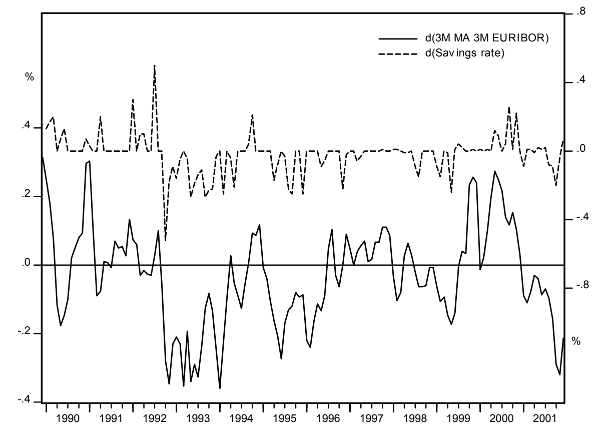


Figure 3.23 Changes in moving average short-term rate and savings rate



From these figures we can see that decreases in the short-term rate in particular are quickly followed by decreases in the savings rate, whereas increases in this rate do not cause immediate increases in the savings rate. The savings rate does not change or only after a (sometimes long) time lag.

Summarising, the savings rate has the following characteristics:

a) low volatility;
b) high correlation with the moving average of the long-term and short-term rate;
c) decreases in the moving average short-term rate are almost always followed quickly; and
d) increases in the moving average short-term rate are only followed after a time lag, if they are followed at all.

Based on the above we estimate four models. The first one is the Wielhouwer & Van de Ende model, but with moving average market rates instead of "normal" rates. Our second model, which we refer to as the low volatility model, just uses the moving averages of the short-term and long-term rate as explanatory variables, thereby capturing characteristics a) and b). Our third model tries to capture all previously stated characteristics.
We finally estimate a fourth model based on our discussions concerning the interest rate setting policy with the head of Asset & Liability Management (ALM) at a large Dutch bank. At this bank the savings rate is calculated as a fraction of the three-month moving average of the three-month EURIBOR and a fraction of the five-year moving average of the EUR swap rate minus a (fixed) margin. Unfortunately we only have a relatively short history of the five-year EUR swap rate, so we decided to use the five-year Dutch government rate, which we already specified above. The adjusted Wielhouwer & Van de Ende model is shown in (3.41), the low volatility models is shown in (3.42), the all characteristics model is shown in (3.43) and, finally, the bank model is shown in (3.44):

$$\Delta r_t^{SA} = \beta_1 \Delta \tilde{r}_t^3 + \beta_2 \Delta \tilde{r}_t^{60} + \beta_3 \left(\delta \tilde{r}_t^3 + (1-\delta) \tilde{r}_t^{60} - r_{t-1}^{SA} - \mu \right) + \varepsilon_t , \tag{3.41}$$

$$\Delta r_t^{SA} = \beta_1 \Delta \tilde{r}_t^3 + \beta_2 \Delta \tilde{r}_t^{60} + \varepsilon_t , \tag{3.42}$$

$$\Delta r_t^{SA} = \beta_1 \delta_{up} \Delta \tilde{r}_t^3 + \beta_2 \left(1 - \delta_{up} \right) \Delta \tilde{r}_t^3 + \beta_3 \Delta \tilde{r}_t^{60} + \varepsilon_t , \tag{3.43}$$

$$r_t^{SA} = \beta_1 \tilde{r}_t^3 + \beta_2 \tilde{r}_t^{60} - \beta_3 + \varepsilon_t \tag{3.44}$$

where:

δ_{up} dummy variable, which has the value one when the change in $\tilde{r}_t^3$, $\Delta \tilde{r}_t^3$, is positive, and zero otherwise.

We start with the adjusted Wielhouwer & Van der Ende model. We slightly rephrase the model in order to estimate the parameters. The model becomes

$$\Delta r_t^{SA} = \beta_1 \Delta \tilde{r}_t^3 + \beta_2 \Delta \tilde{r}_t^{60} + \alpha_1 \left(\tilde{r}_{t-1}^3 - \tilde{r}_{t-1}^{60} \right) + \alpha_2 \left(\tilde{r}_{t-1}^{60} - r_{t-1}^{SA} \right) + \alpha_3 + \varepsilon_t \tag{3.45}$$

with

$$\alpha_1 = \beta_3 \delta \tag{3.46}$$

$$\alpha_2 = \beta_3 \tag{3.47}$$

$$\alpha_3 = -\beta_3 \mu . \tag{3.48}$$

Table 3.20 below shows the results. Clearly, the moving average long-term rate is not significant. We therefore estimate the model again without this variable. Table 3.21 below shows these results. Now all remaining variables are significant. Table 3.22, Table 3.23 and Table 3.24 on page 118 show the results of the other three models.

Table 3.20 Adjusted Wielhouwer & Van der Ende model 1 as shown in equation (3.45) above

Dependent Variable: Δr_t^{SA}
Method: Least Squares
Sample(adjusted): 1990:01 2001:12
Included observations: 144 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_1	0.361935	0.057229	6.324298	0.0000
β_2	-0.718036	0.715909	-1.002971	0.3176
α_1	0.080586	0.026723	3.015636	0.0030
α_2	0.123348	0.040996	3.008800	0.0031
α_3	-0.120403	0.042926	-2.804931	0.0058
R-squared	0.304724	Akaike info criterion		-1.790478
Adjusted R-squared	0.284716	Durbin-Watson stat		1.746796
S.E. of regression	0.097176	F-statistic		15.23013
		Prob(F-statistic)		0.000000

Table 3.21 Adjusted Wielhouwer & Van der Ende model 2 as shown in equation (3.45) but without the change in the five-year moving average of the five-year Dutch government rate

Dependent Variable: Δr_t^{SA}
Method: Least Squares
Sample(adjusted): 1990:01 2001:12
Included observations: 144 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_1	0.363670	0.057204	6.357368	0.0000
α_1	0.060396	0.017575	3.436464	0.0008
α_2	0.105909	0.037127	2.852640	0.0050
α_3	-0.103451	0.039459	-2.621753	0.0097
R-squared	0.299692	Akaike info criterion		-1.797156
Adjusted R-squared	0.284685	Durbin-Watson stat		1.748426
S.E. of regression	0.097178	F-statistic		19.97067
		Prob(F-statistic)		0.000000

Table 3.22 Low volatility model as shown in equation (3.42) on page 116

Dependent Variable: Δr_t^{SA}

Method: Least Squares

Sample(adjusted): 1990:01 2001:12

Included observations: 144 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_1	0.358439	0.057356	6.249347	0.0000
β_2	0.589859	0.219051	2.692789	0.0079
R-squared	0.255782	Akaike info criterion		-1.764120
Adjusted R-squared	0.250541	Durbin-Watson stat		1.813136
S.E. of regression	0.099470	F-statistic		48.80427
		Prob(F-statistic)		0.000000

Table 3.23 All characteristics model as shown in equation (3.43) on page 116

Dependent Variable: Δr_t^{SA}

Method: Least Squares

Sample(adjusted): 1990:01 2001:12

Included observations: 144 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_1	0.315189	0.102835	3.064996	0.0026
β_2	0.379115	0.070485	5.378684	0.0000
β_3	0.565182	0.224948	2.512497	0.0131
R-squared	0.257138	Akaike info criterion		-1.752055
Adjusted R-squared	0.246601	Durbin-Watson stat		1.811486
S.E. of regression	0.099732	F-statistic		24.40320
		Prob(F-statistic)		0.000000

Table 3.24 Bank model as shown in equation (3.44) on page 116

Dependent Variable: r_t^{SA}

Method: Least Squares

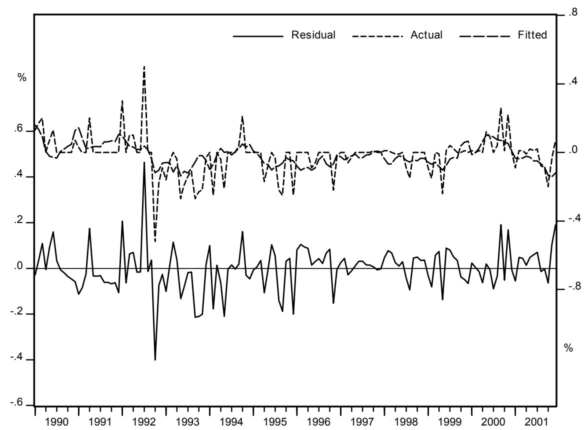
Sample: 1989:12 2001:12

Included observations: 145

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_1	0.466510	0.008032	58.08265	0.0000
β_2	0.432809	0.016170	26.76588	0.0000
β_3	0.379469	0.087456	4.338960	0.0000
R-squared	0.984287	Akaike info criterion		-0.473967
Adjusted R-squared	0.984066	Durbin-Watson stat		0.284342
S.E. of regression	0.188972	F-statistic		4447.587
		Prob(F-statistic)		0.000000

The question now is, which model to use. We found that not all variables are significant in the adjusted Wielhouwer & Van der Ende model. However, removing $\Delta\tilde{r}_t^{60}$ from the model improves the model in the sense that all remaining variables are highly significant. The low volatility model seems inaccurate. Both variables are significant, but we learned from the adjusted Wielhouwer & Van der Ende model that if other significant variables are added, the moving average long-term rate variable becomes insignificant. We therefore conclude that the low volatility model explains a relation, which in reality does not exist, although the F-statistic indicates that the model as a whole is significant. The all characteristics model and the bank model look fine, with all variables significant.
So this basically leaves us with three models, which we can use. We chose the model with the best score on test statistics as the Akaike information criterion and the Durbin-Watson statistic. This clearly excludes the bank model. The adjusted Wielhouwer & Van der Ende model and the all characteristics model perform comparable, although the Akaike information criterion is slightly better in the adjusted Wielhouwer & Van der Ende model. We therefore decided to use this model. The parameter estimates of this model imply a value for $\hat{\delta}$ of about 0.57 and a value for $\hat{\mu}$ of about 0.98 indicating a margin of about 1%. Figure 3.24 shows the residual plot of this model.

Figure 3.24 Residuals for the second adjusted Wielhouwer & Van der Ende model



No particular pattern can be observed in the residuals and although the Durbin-Watson statistics is somewhat low, a Breusch-Godfrey test for serial correlation does not indicate any serial correlation in the residuals. We therefore leave this model as it is, and do both an in-sample and an out-of-sample forecast with the model. Figure 3.25 and Figure 3.26 below show the forecast of the change in the savings rate and the savings rate itself respectively. From Figure 3.25 we see that forecasts are reasonable. The direction of the change is followed quite well. From Figure 3.26 it can be seen that the forecasts of the savings rate itself are good also.

Figure 3.25 Forecast of changes in the savings rate based on the second adjusted Wielhouwer & Van der Ende model as shown in equation (3.45) on page 116 but without the change in the five-year moving average of the five-year Dutch government rate

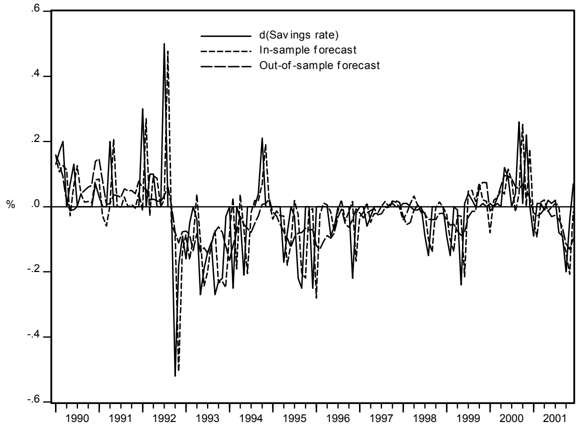
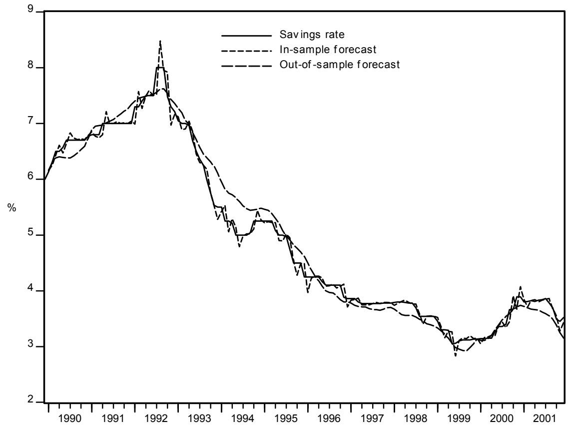


Figure 3.26 Forecast of the savings rate based on second adjusted Wielhouwer & Van der Ende model as shown in equation (3.45) but without the change in the five-year moving average of the five-year Dutch government rate



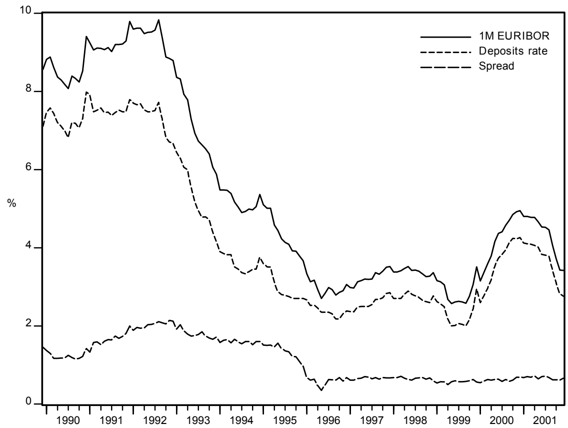
3.7.4 Modelling the term deposits rate

As is the case with the savings rate, there is no such thing as the term deposits rate. The rate on term deposits depends on the notional amount and the maturity of the term deposit. We chose to use the rate that is paid on term deposits with the shortest maturity, which is one month and the lowest notional[112]. We used this term deposit rate, since the bank we got this data from, argued that most term deposits fall in this bucket. We have data on this rate from

[112] Between €10,000.- and €25,000.-. Before term deposits were issued in euros, the lowest notional was *f* 100,000.-.

January 1988 until December 2001, but as argued in section 3.7.2 will use only the series as of December 1989. Figure 3.27 shows this rate, together with the one-month EURIBOR[113] rate for that period and the spread between these rates. As can be seen, the deposit rate follows the one-month EURIBOR rate closely, although the spread seems to widen when rates are higher.

Figure 3.27 Term deposit rate versus one-month EURIBOR. The spread is the difference between the two rates.



Based on the above we decide to estimate a model of Δr_t^{TD} with Δr_t^1 being the explanatory variable. The model therefore becomes

$$\Delta r_t^{TD} = \beta_1 \Delta r_t^1 + \varepsilon_t \,. \tag{3.49}$$

The model assumes that the change in the term deposit rate is a fixed fraction of the change in the one-month EURIBOR rate plus some noise. Based on the statistics above we expect β_1 to be positive and near one. Table 3.25 shows the results of this model.

Table 3.25 Results term deposit rate model as shown in equation (3.49)

Dependent Variable: Δr_t^{TD}

Method: Least Squares

Sample(adjusted): 1988:02 2001:12

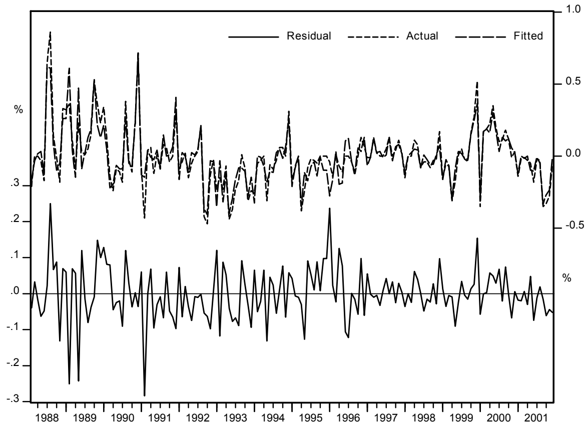
Included observations: 167 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_1	0.813649	0.025103	32.41231	0.0000
R-squared	0.863490	Akaike info criterion		-2.351043
Adjusted R-squared	0.863490	Durbin-Watson stat		2.098695
S.E. of regression	0.074464			

113 Before January 1999 this is the one-month AIBOR rate.

We see that the explanatory variable is highly significant. Furthermore, the statistics look good, and the residuals, shown in Figure 3.28, do not show any particular pattern. Therefore, we decide to use this model.

Figure 3.28 Residuals for term deposit rate model



Finally, we look at in-sample and out-of-sample forecasting. As can be seen from Figure 3.29 and Figure 3.30 on page 123 the forecasts look very good.

Figure 3.29 Forecast of change in term deposit rate

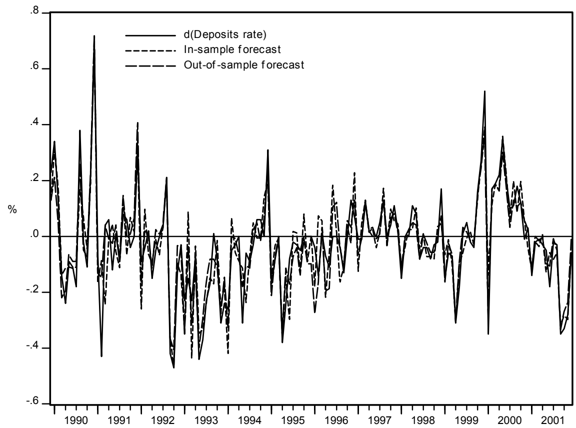
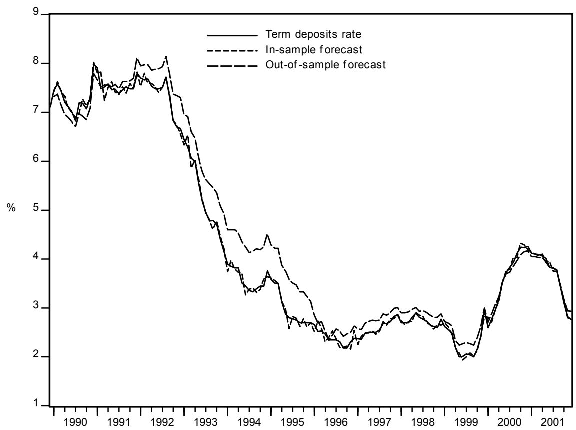


Figure 3.30 Forecast of term deposits rate



3.7.5 Modelling the risk-free rate

Introduction

Finally, we need a model of the risk-free rate. From this model we can calculate the interest rates required for the previously estimated models and we will use the rates produced by this model for discounting.

In section 2.4.3 we described some interest rate models. One of those models is the Vasicek model, which is also used by Jarrow & Van Deventer (1998) in their valuation framework. As was mentioned there the Vasicek model allows for negative rates, which is a reason for us not to choose this model. An alternative is the Cox, Ingersoll & Ross (CIR) model, also described in that section. In this section we will estimate parameters for the CIR model. To overcome the drawbacks of a one-factor interest rate model, we will also estimate a multi-factor model.

Cox, Ingersoll & Ross (1985)

The Cox, Ingersoll & Ross model of the short rate was already given in equation (2.8) on page 38. Using an Euler discretisation (see for example James & Webber, 2000), the model becomes

$$r_{t+\Delta t} = \kappa\theta\Delta t + \left(1-\kappa\Delta t\right) r_t + \sigma\sqrt{r_t}\sqrt{\Delta t}\varepsilon_t . \tag{3.50}$$

Based on Cox, Ingersoll & Ross (1985), with r the short rate and λ the market price of risk, one can calculate the yield at time t for a bond that matures at time T by

$$R\left(r,t,T\right) = \frac{B\left(t,T\right) r_t - \ln A\left(t,T\right)}{T-t} \tag{3.51}$$

where

$$A(t,T)=\left[\frac{2\gamma e^{(\kappa+\gamma+\lambda)(T-t)/2}}{(\kappa+\gamma+\lambda)\left(e^{r(T-t)}-1\right)+2\gamma}\right]^{2\kappa\theta/\sigma^2}, \tag{3.52}$$

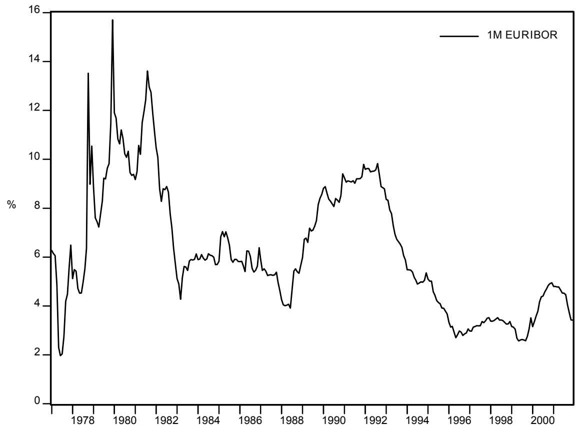
$$B(t,T)=\frac{2\left(e^{r(T-t)}-1\right)}{(\kappa+\gamma+\lambda)\left(e^{r(T-t)}-1\right)+2\gamma} \tag{3.53}$$

and

$$\gamma=\sqrt{(\kappa+\lambda)^2+2\sigma^2}\ . \tag{3.54}$$

We used the one-month EURIBOR rate as the short rate in this case. Since we have monthly data, we use $\Delta t = 1/12$ in the estimation. In Figure 3.18 on page 112 we already showed the market rates, amongst which the one-month EURIBOR rate for a common sample starting at December 1989 and ranging until December 2001. The main reason for this was the fact that we only had data on the savings rate as of that date. In fact, the data we have on the one-month EURIBOR rate ranges from January 1977 to December 2001. Figure 3.31 shows the series, while Table 3.26 on page 125 shows the statistics over that period. We will use this series for the estimation of the CIR model. The main reason is that we think it is better to use as much history as possible when estimating a model which has a mean reversion term.

Figure 3.31 One-month EURIBOR over time as of January 1977 (source: CBS)



From the figure above we can see that there might not be any mean reversion. However, we will estimate the CIR-model, including the mean reversion term, using the maximum likelihood technique (see section 3.5.2 on page 82 for more details). Table 3.27 below shows the results. As can be seen, the mean reversion speed parameter κ is not significant. Furthermore, the value is relatively low, indicating slow mean reversion. The value for the mean reversion rate θ is relatively close to the sample mean, so we feel confident with this number. Regarding the volatility parameter σ we see that it is very different from the sample standard deviation. However, one should bear in mind that σ is only part of the volatility.

Table 3.26 Statistics of one-month EURIBOR rate as of January 1977

Sample 1977:02 2001:12	
Statistics	r_t^1
Mean	6.25
Median	5.70
Maximum	15.7
Minimum	1.97
Std. Dev.	2.60
Skewness	0.69
Kurtosis	2.96
Observations	299

Table 3.27 Results of Cox, Ingersoll & Ross model estimation

Method: Maximum Likelihood (Marquardt)
Sample: 1977:02 2001:12
Included observations: 299
Evaluation order: By observation
Convergence achieved after 346 iterations

Parameter	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
κ	0.292784	0.166435	1.759150	0.0786
θ	5.868497	1.958594	2.996281	0.0027
σ	0.919079	0.009292	98.90906	0.0000
Log likelihood	-288.8420	Akaike info criterion		1.952120

Now we have estimated the parameters in equation (3.50) on page 123, we must check whether the model can reach zero for this set of parameter values. According to James & Webber (2000), the model's behaviour at rate zero must be specified if

$$\frac{2\kappa}{\sigma^2} \leq 1. \tag{3.55}$$

With our parameter values, this is the case, so we have to specify the model's behaviour at zero. We simply assume that when the short rate hits zero, the next movement will be up.
Finally, we can estimate λ, which appears in equations (3.52) to (3.54) (see pages 124-124). There are several ways to estimate this parameter. We decided to use the method explained in Cox, Ingersoll and Ross (1985). They state that the yield on a perpetual bond is not dependent on the level of the short rate now, but only on the parameters in the CIR process. That is,

$$R(t,\infty) = \frac{2\kappa\theta}{\kappa+\gamma+\lambda}. \tag{3.56}$$

With all parameters estimated, the only unknown is λ which we can then calculate iteratively from the equation above. For this, we used the average rate on Dutch government perpetual bonds from January 1977 to December 2001. This data is also available from the Dutch Central Bureau of Statistics. The average perpetual yield $\overline{R}(t,\infty)$ in the above mentioned sample is 5.88%. Using Mircosoft Excel's goal seeker we found an estimate for $\hat{\lambda}$ of -1.4459.

With all parameters of the CIR model estimated we can use it for simulation. We used the software package Crystal Ball 2000 to simulate 1000 scenarios. Four of the resulting paths of the short rate are given in Figure 3.32 as an example. We see a rich pattern of paths. Figure 3.33 gives the development of the mean, the 5% confidence and 95% confidence level over time. Finally, with the parameter estimates and expressions (3.51) to (3.54) (see pages 123-124) we can calculate the yields on longer maturities. Figure 3.34 on page 127 shows a few examples of resulting yield curves for different values of the short rate. Clearly one can observe that all yield curves converge to the same rate.

Figure 3.32 Four sample paths for the short rate using the Cox, Ingersoll & Ross model

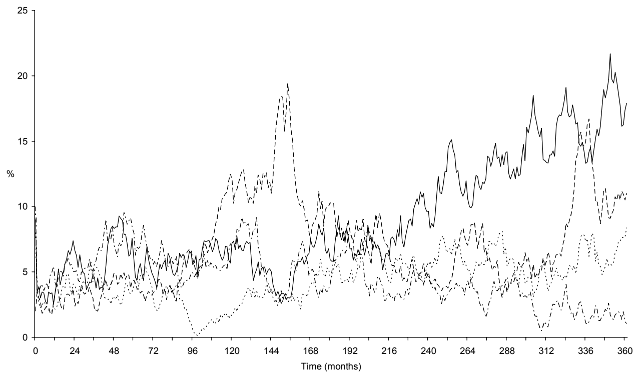


Figure 3.33 Confidence bands for the short rate using the Cox, Ingersoll & Ross model. The chance of interest rates below the dotted line equals 5%. The chance of interest rates above the dashed line equals 5% as well. The solid line indicates the expected interest rate. Clearly we see the mean reverting character of the model.

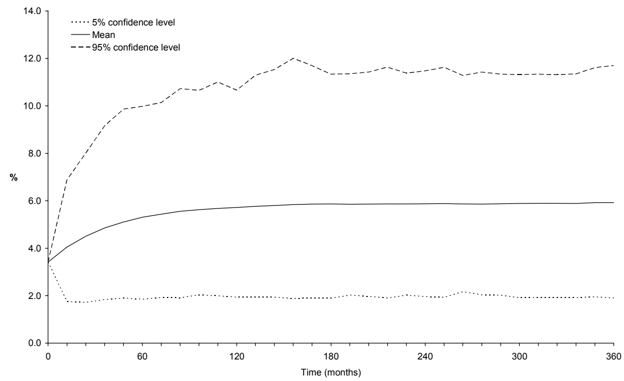
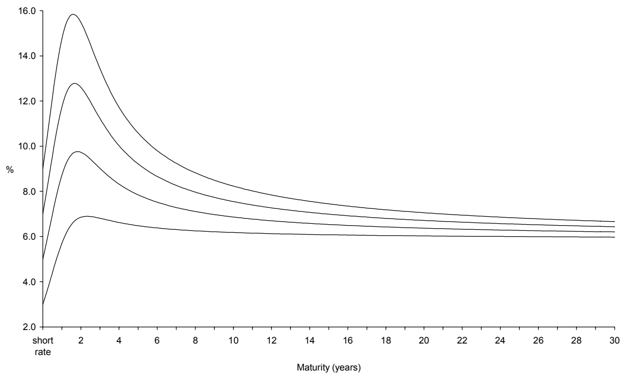


Figure 3.34 Example of yield curves calculated using the Cox, Ingersoll & Ross short rate. The yield curves for different starting values for the short rate are given.



Multi-factor interest rate model

Introduction

For the reasons laid out in the introduction to this section, we also estimate a multi-factor interest rate model. That is, we will not estimate a single rate model based on multiple factors, but instead simultaneously estimate three one-factor models. Each of these one-factor models simulates one point on the maturity vertex. These types of models are used by, for example, Bams (1999), Boughanmi (2001) and De Feijter (2002).

Base case model

All the above mentioned models are defined in terms of mean reversion and volatility. They differ in the way the mean reversion rate and/or volatility is defined and also in their estimation technique. However, the general form of models is

$$r_t = \mu + \gamma\left(r_{t-1} - \mu\right) + \varepsilon_t \tag{3.57}$$

with

$$\varepsilon_t \sim N\left(0, r_{t-1}^{\alpha}\sigma^2\right) \tag{3.58}$$

where r_t denotes a particular interest rate at time t, which is mean reverting to μ at a speed γ. Superimposed on this deterministic part of the model is a stochastic component ε_t, which can be regarded as innovation or an error term. The level of volatility $r_{t-1}^{\alpha}\sigma^2$, gives the possible level of this stochastic component.

As mentioned, the models differ in the way the mean reversion rate and/or volatility is defined. Boughanmi (2001) and De Feijter (2002), for example regard the mean reversion rate as constant, whereas Bams (1999) defines the mean reversion rate as a cubic function of the interest rate. Furthermore, Boughanmi, does not regard the error terms to be heteroskedastic, therefore $\alpha = 0$ in his model. De Feijter uses a CIR innovation term, that is $\alpha = \frac{1}{2}$, whilst Bams does not make up-front assumptions on the level of α. We will use De Feijter's assumption, because the estimation of the CIR model clearly showed the significance of this assumption.

De Feijter (2002)

The base case model above only captures univariate time series behaviour and does not take term structure behaviour into account. De Feijter's model simultaneously captures three time series, viz. the one-month, one-year and ten-year interest rate. The two shorter term rates are EURIBOR rates[114], whereas the latter is the ten-year government rate[115]. The model is in fact an extended version of the base case model specified above and reads

$$\mathbf{R}_t = \boldsymbol{\mu} + \boldsymbol{\Gamma}\left(\mathbf{R}_{t-1} - \boldsymbol{\mu}\right) + \boldsymbol{\varepsilon}_t \,. \tag{3.59}$$

In this model $\mathbf{R}_t$ is a vector of the interest rates mentioned above, $\boldsymbol{\mu}$ is a vector of mean reversion rates, $\boldsymbol{\Gamma}$ is a (3×3) matrix with mean reversion speeds, where the non-diagonal elements are assumed to be zero and $\boldsymbol{\varepsilon}_t$ is a vector of a stochastic error terms. It is assumed that $\boldsymbol{\varepsilon}_t \sim N\left(0, \boldsymbol{\Sigma}_t\right)$ where $\boldsymbol{\Sigma}_t$ is the variance/co-variance matrix. $\boldsymbol{\Sigma}_t$ is represented by $\Sigma_{ij} = \rho_{ij}\sqrt{\sigma_i^2 \mathrm{R}_{i,t-1}}\sqrt{\sigma_j^2 \mathrm{R}_{j,t-1}}$ with $(i, j) \in (1,2,3)$ and ρ_{ij} denoting the correlation between $R_{i,t}$ and $R_{j,t}$. It is assumed that ρ_{ij} is constant over time.

By allowing for separate mean reversion and variance parameters, as well as including heteroskedasticity and correlation factors in the model, the model incorporates some characteristics of interest rate observed in the real world:

1. the yield curve is increasing on average;
2. the term structure of volatilities is decreasing on average;
3. yields lie on a smooth curve, hence yields that differ little in their time to maturity are highly correlated;
4. the volatility is higher when rates are higher; and
5. mean-reversion is stronger when the rate is further away from its mean-reversion level.

Term structure modelling

The above model basically gives us three points on the maturity vertex. The interest rates for other maturities will be estimated using the Nelson Siegel function (see for example Nelson & Siegel (1987) or James & Webber (2002))

$$\mathrm{R}_t = \beta_0 + \beta_1 \frac{1 - e^{-t/\tau}}{t/\tau} + \beta_2 \left[\frac{1 - e^{-t/\tau}}{t/\tau} - e^{-t/\tau} \right]. \tag{3.60}$$

114 Before January 1st 1999 these are AIBOR rates.

115 Due to a lack of a sufficient history of the ten-year swap rates.

In this functional form β_0 represents the yield to infinity R_∞, $\beta_0 + \beta_1$ represents the infinitesimal short-term rate R_0 and β_2 is the parameter that determines the amount of curvature in the term structure. Finally, τ determines where this curvature in the term structure is located. De Feijter considers τ to be constant and equal to two (years). This way, with $R_{1/12}$, R_1 and R_{10} the one-month, one-year and ten-year rate respectively the parameters β_i are estimated by

$$\begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \end{bmatrix} = \mathbf{X}^{-1} \begin{bmatrix} R_{1/12} \\ R_1 \\ R_{10} \end{bmatrix} \tag{3.61}$$

where

$$\mathbf{X} = \begin{bmatrix} 1 & \dfrac{1-e^{\frac{1}{12}/\tau}}{\frac{1}{12}/\tau} & \dfrac{1-e^{\frac{1}{12}/\tau}}{\frac{1}{12}/\tau} - e^{\frac{1}{12}/\tau} \\ 1 & \dfrac{1-e^{1/\tau}}{1/\tau} & \dfrac{1-e^{1/\tau}}{1/\tau} - e^{1/\tau} \\ 1 & \dfrac{1-e^{10/\tau}}{10/\tau} & \dfrac{1-e^{10/\tau}}{10/\tau} - e^{10/\tau} \end{bmatrix}. \tag{3.62}$$

Estimation

The parameters of the model are estimated using 15 years of monthly observations. The results are taken from De Feijter and shown in Table 3.28 below to Table 3.30 on page 130. Clearly we can see that the term structure is increasing on average, because of the increasing value of μ_i for longer term maturities. Furthermore, we see that the term structure of volatilities is decreasing, with longer term rates having a lower volatility.

Table 3.28 Parameters of multi-factor interest rate model

		Γ		
	μ	1 month	1 year	10 year
1 month	3.63%	0.974	0.000	0.000
1 year	5.86%	0.000	0.991	0.000
10 year	6.15%	0.000	0.000	0.956

Table 3.29 Unweighted variance/co-variance matrix

	1 month	1 year	10 year
1 month	0.0111	0.0084	0.0030
1 year		0.0106	0.0055
10 year			0.0061

Table 3.30 Correlation matrix

	1 month	1 year	10 year
1 month	1.000	0.771	0.369
1 year		1.000	0.685
10 year			1.000

Now the model is parameterised, we can use it for simulation. The figures below show some example paths for the one-month, one-year and ten-year rate respectively (see Figure 3.35 to Figure 3.37 below). Furthermore, the expected path of the term structure is given in Figure 3.38 on page 131. From this figure we see that we expect interest rates to increase. Furthermore we see that we expect the short-term interest rates to increase less than the long-term interest rates. As a result the curve becomes steeper in the shorter-term part, while it flattens in the longer-term part.

Figure 3.35 Four sample paths for the one-month rate using the interest rate model of De Feijter (2002)

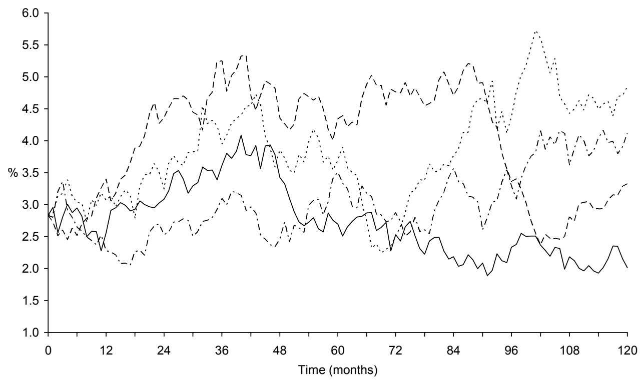


Figure 3.36 Four sample paths for the one-year rate using the interest rate model of De Feijter (2002)

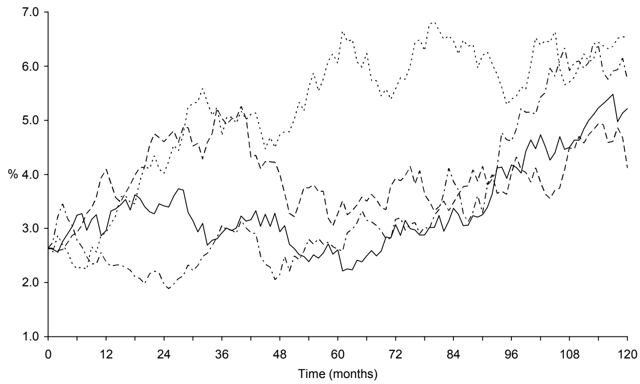


Figure 3.37 Four sample paths for the ten-year rate using the interest rate model of De Feijter (2002)

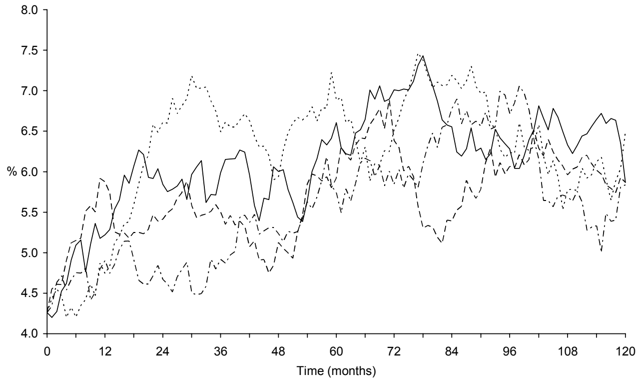
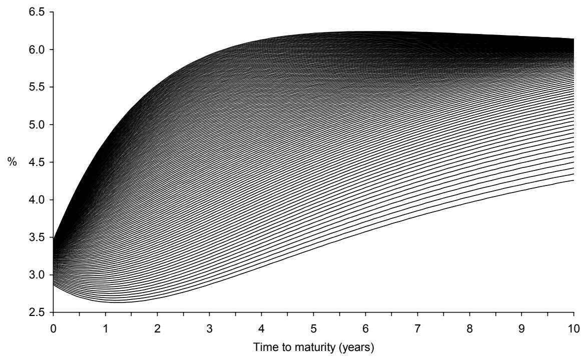
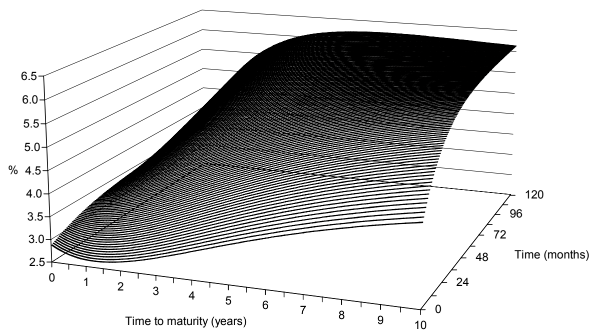


Figure 3.38 Future expected curves
Since current intrest rates are below their long-term average, we expect interest rates to increase.
We see that the term structure is expected to steepen in the shorter-term part,
while it is expected to flatten in the longer-term part.
In the lower pane a third axis shows the time in months.
Therefore, the development of the term structure over time can be seen.





3.8 Conclusions

In this chapter we tried to answer the question how to measure the effects of the withdrawal option. Since this option is present in demand deposits and savings accounts, answering this question in fact means that we are trying to explain saving behaviour.

A well known study on saving behaviour is Keynes' study of individuals' liquidity-preference (Keynes, 1936). According to Keynes, an individual basically makes two decisions. The first is how much of his income he will consume and how much he will reserve in *some form* for later consumption. The second decision is in *what form* he will store this reserved part. Keynes distinguishes between three divisions of liquidity-preference, which he calls (1) the transactions-motive or income- or business-motive; (2) the pre-cautionary-motive and (3) the speculative-motive. The first motive can be explained: individuals store money in cash to bridge the interval between the receipt of income and its imbursements. The second motive can also be explained: individuals want security about the future cash equivalent of their resources today to provide cash for sudden expenditures. Finally, the third motive can be explained by individuals wanting to make a profit by investing their money. It is not the immediate availability of money without the risk of losing some that is important here, but the return. The amounts of money stored by the first two motives are not expected to be very sensitive to interest rate changes, whereas the money used for the speculative-motive is.

When this is applied with respect to the withdrawal option, we can identify the same three classes. First of all, "saving" by individuals to pay for their bills is done on a demand deposit. Interest rates on these accounts are low or zero. The amounts on these accounts are expected to be relatively interest rate insensitive – people have to pay for their bills anyway. However, with the introduction in the Netherlands of telebanking and internet banking, this might have changed. That is, because it has become easier to transfer amounts between a demand deposit and a savings account and vice versa, often within a day, people might have become more interest rate sensitive and thus try to minimize the amounts on their demand deposits. Due to a lack of data the impact of this effect is not modelled.

A second class of savings are the "normal" savings. People save on their savings accounts for later big consumptions. Savings in this category are expected to be moderately interest sensitive.

The above two categories of savings are typically done on products, which include the withdrawal option. The third category, that is the speculative savings, is somewhat different. As mentioned, it is not the type of product that is important here, but the return. In this category, people are expected to switch relatively quickly between products. Investments in stocks or stock options are found in this category. And also investments in term deposits or ordinary savings accounts, depending on the expected return.

Our ultimate goal was to value Dutch demand deposits, savings accounts and term deposits. To do this, we first did a literature study and found a number of valuation methods. We described three of them in a little more detail. The first was Wilson's replicating portfolio method. The second approach was the Hutchison and Pennacchi approach. They use an equilibrium approach for the valuation of indeterminate deposits. Jarrow and Van Deventer on the other hand use a non-arbitrage approach and was third method which was studied .

After studying these techniques, we decided to use the Jarrow-Van Deventer approach. The reason being that this model is easily implemented in simulation, as well as the underlying theory, which captures the demand characteristics of demand deposits and savings accounts.

Since the Jarrow-Van Deventer approach requires demand models, we then focussed on modelling savings demand. Some demand models found in literature were described, like the Wilson model, the Jarrow-Van Deventer model and others.
However, we decided not to use any of these models. One of the reasons for not choosing one of these models was that most of them use previous month's volume (amongst other variables) to estimate current month's volume. Whilst volume from month to month shows a large correlation, there is the danger of a unit root in the series, causing the series to be non-stationary. Due to this non-stationarity, general assumptions of least squares regression do not hold and the resulting statistics of the regression must be handled with care. In our data, we also found unit roots. This was the case for both savings volume and term deposits volume.
Therefore, we estimated our own models. Before estimating our own models, we first studied the determinants of saving behaviour. Based on several studies the following indicators were identified:

- household income;
- the level of interest rates on savings accounts;
- expected return on the stock market;
- the marginal tax rate; and
- several demographic factors such as:
  - age;
  - social background;
  - family composition; and
  - region.

Then we started with a model for total volume, which is the sum of demand deposits, savings accounts and term deposits. We limited our analysis to the retail sector. Unfortunately, we did not have data on client level, so we can not take the previously mentioned demographic factors as well as household income into account. For the latter the gross national product (GNP) was used, since GNP can be regarded as a proxy for income. Because we only had quarterly data on GNP, we estimated a quarterly model. For the demographic and other economic factors, we used a linear time trend, although this trend did not show up in our final model.
Because of the unit root we estimated a model of the first difference of total volume ΔTV_t.
In our final model, significant variables are the first difference GNP, the change in the AEX index in six months, dummy variables for the first and second quarter to reflect seasonality and the one-month lagged change in total volume itself.
Although the resulting model gives intuitive results and the explanatory power is around 80%, we doubt the forecasting performance. Since the model includes GNP and AEX variables, which have to be modelled themselves, the forecasts will most likely show a large variance.
As a result, we estimated models for demand deposits, savings accounts and term deposits separately. The demand deposits series does not show a unit root, whereas the series of savings accounts and term deposits do. We therefore estimated a model of DD_t instead of ΔDD_t.

Significant variables in the final model are the one month lagged volume of demand deposits, a constant and time trend and dummy variables for May, July and August. These dummy variables can be economically explained by the fact that most Dutch employees get a holiday allowance in May, while they spend it in July and August. The explanatory power is very good with an adjusted R^2 of about 99%. Because of this high explanatory power, the forecasts, both in–sample and out-of-sample are good as well.

The series for savings accounts shows a unit root, as was mentioned above. Therefore, we estimated a model for the first difference in savings accounts volume ΔSA_t. We found the one month lagged change in savings volume ΔSA_{t-1}, the one month lagged change in term deposits volume ΔTD_{t-1} and dummy variables for December and January (interest payments) and May and June (holiday allowance) to be significant. The explanatory power is reasonable, with about 66% explanation. With regard to forecasting, we see that the model performs well on average, although the large jump in January 2001 is missed, in both in-sample and out-of sample forecasting. The major reason is that the huge increase in savings volume in January 2001 is most likely caused by a change in the tax regime, which is not captured in the model. This causes an underestimation of the resulting savings volume, although there is some recovery in the time after. In the end, the results are satisfactory.

The term deposits series also shows a unit root. However, this time, we don't solve this by trying to estimate a model on the first difference ΔTD_t. The reason is that the time series of term deposits shows a different pattern than the times series of demand deposits and savings accounts. Whereas these series show an (upward) trend, term deposits volume seems more cyclical. We therefore estimated a model where we use a constant to represent the "minimum" volume of term deposits. Furthermore, we included the difference between the term deposits rate and the savings rate. A third variable that is included, is a dummy variable that has the value one if the observation is for January 1998 and zero otherwise. This dummy is to take into account the regime change as of that date. Finally, we included a first order moving average term. To prevent term deposits volume from becoming less than zero, we estimate the model on the natural logarithm of term deposits volume.

The explanatory power of the model is very good with an adjusted R^2 of about 85%. Regarding the forecasting power of the model, it turns out that both the in-sample and out-of-sample forecasts are reasonably good.

We then estimated models for the savings rate, the term deposits rate and the market rate. Regarding the savings rate, we tried several models, amongst which the Wielhouwer & Van der Ende model. This model explains changes in the savings rate by changes in the short-term rate and long-term rate as well as a factor, which compares the assumed return on savings accounts with the current savings rate and a constant margin. We adjusted the model to use moving average short-term and long-term rates. After estimating the model, the change in the moving average long-term rate was not significant, so we removed it from the model. The remaining model we referred to as the adjusted Wielhouwer & Van der Ende model. In this model the margin turned out to approximately 1%, which is a reasonable value. Although the explanatory power is about 30%, the model performs quite well in forecasting.

For the term deposits rate, we only tried one model, which gave acceptable results. In this model, the term deposits rate is a fixed fraction of the one-month EURIBOR rate, indicating higher margins at higher rates and vice versa. The model fits well with an adjusted R^2 of about 86%. The model's forecasting capabilities are reasonable as well.

Finally, for the market rate, we decided to use both a one-factor model, the well-known Cox, Ingersoll & Ross (CIR) model as well as a multi-factor model, for which we used De Feijter's three-factor model (De Feijter, 2002). That is, De Feijter's model simultaneously estimates three points on the term structure. Other maturities are then calculated by applying the Nelson-Siegel function. This models is capable of capturing the most important empirical phenomena that have been observed: (1) the yield curve is increasing on average; (2) the term structure of volatilities is decreasing on average; (3) yields lie on a smooth curve, hence yields with little differences in their time to maturity are highly correlated; (4) interest rates are more volatile when the interest rate level is high; and (5) mean-reversion is stronger in cases where interest rate levels are further away from the mean-reversion level.

We estimated the CIR model using the Maximum Likelihood technique. The results indicated weak evidence for the mean reverting character of the model. However, the model provides reasonable patterns for the short rate.

Regarding the multi-factor model, we used the parameter values estimated by De Feijter (2002). This model is capable of producing a rich variety of yield curve shapes, as was clearly shown in Figure 3.38 on page 131.

4

Effects of the prepayment option

4.1 Introduction

In this chapter we study how the effects of the prepayment option can be modelled. The prepayment option is embedded in a mortgage contract. A mortgage contract is an agreement which authorises the lender (the mortgagee) to sell the mortgaged property and foreclose the loan if the borrower (the mortgagor) fails to make the agreed upon payments (Van Bussel, 1998). The prepayment option gives the mortgagor the right to prepay his mortgage if he wishes to do so. Of course this creates a risk for the mortgagee, since generally a mortgage will only be prepaid if it is financially wise to do so[116].

Before describing some recent Dutch studies regarding prepayment behaviour in section 4.3, we will first give a brief overview of the Dutch mortgage market and the type of products sold on that market in section 4.2. Finally, section 4.4 concludes.

4.2 The mortgage market in the Netherlands

4.2.1 Developments in the market

The mortgage market in the Netherlands has experienced large growth recently as Figure 4.1 below shows. The total outstanding amount is still growing, with the total market equalling €341 billion at the end of the third quarter of 2002. This growth in the 1990s can be explained by a number of factors. Alink (2002), for example, mentions interest rates, economic growth, demographic developments, housing supply, development of lenders and government policy.

All these factors made it possible and attractive for people to increase their mortgage, for example to buy a bigger house, while the monthly payments remained the same. Figure 4.2 below shows that especially in 1999 the number of renewals and second mortgages grew fast. This is a sign that prepayment in the Netherlands is becoming more and more important.

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[116] Empirical studies show that the assumption of optimal prepayment behaviour can not explain all prepayments. We will study this is more detail in section 4.3.

Figure 4.1 Outstanding mortgage loans on residential properties in the Netherlands (Source: CBS)

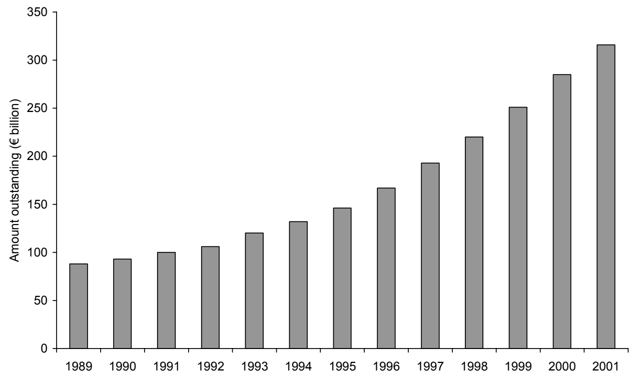
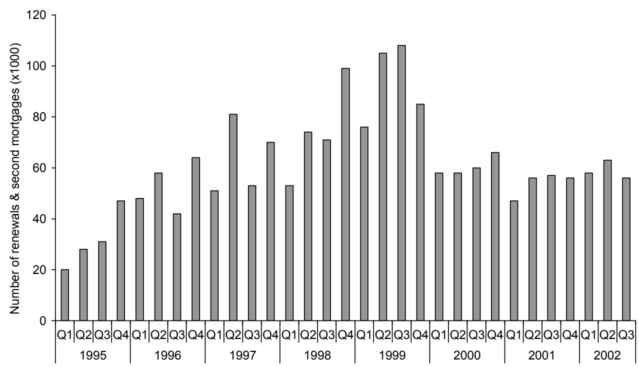


Figure 4.2 Number of renewals and second mortgages (Source: CBS)



4.2.2 *Product types*

Several types of mortgage products are sold in the Dutch mortgage market. They differ mainly in their repayment and interest rate characteristics. To start with the latter, one can opt for an adjustable rate mortgage, which frequently resets to the market rate or a rate that is fixed for a certain period. This period can be anything between six months and thirty years, depending on the mortgagee, but mostly terms of five or ten years are chosen. The ten years interest rate fixed period became popular in the second half of the 1990s, since mortgage rates reached an all-time low then.

Regarding the repayment characteristics one can distinguish between amortising and non-amortising types as well as custom-made mortgages. Alink (2002), Doff (2001) and Van Bussel (1998) describe the different mortgages extensively. We briefly summarise this below, where we use the naming used by Alink. Van Bussel also mentions some exotic types, which are rarely sold in today's market. For more details on these types we therefore refer to Van Bussel (1998).

Traditional mortgages

Traditional mortgages are characterised by amortisation during the life of the loan (Alink, 2002). One can distinguish between linear amortisation and level pay amortisation. Linear amortisation means that the amount repaid is equal for each period. Since the notional amount decreases interest payments decrease over time, thus lowering total monthly instalments. For a level pay mortgage the monthly instalments remain constant over the life of the mortgage[117]. Every period, both interest and redemption is paid. The interest part decreases and the redemption part increases per period, instead of being constant in a linear mortgage.
These mortgage types are not that popular anymore. The most important reason is that other mortgage types make more efficient use of the current tax regime in the Netherlands (see below).

Savings and investment mortgages

Savings mortgages and also investment mortgages do not amortise during their life. Therefore interest payments remain constant over the life of the mortgage. However, at maturity the principal amount must be paid back. This is where the two differ. In the savings mortgage the mortgagor pays amounts into a savings account or insurance policy. Because the rate paid on the savings account or in the insurance policy equals the mortgage rate, it is fairly easy to calculate these monthly premiums. At the end of the life of the mortgage, the mortgagor knows for sure that he can repay his mortgage. In an investment mortgage the mortgagor pays a monthly amount which is invested in bonds or stocks. This means a higher risk for the mortgagor, since the return on this invested capital is not known for sure. If the return is lower than expected, the mortgagor can not fully repay his mortgage at the end of its life.
Since the return on the "redemption" payments in a savings or investment mortgage is not taxed, whereas the interest payments on the mortgage are tax deductible, these mortgage types use the Dutch tax possibilities to a full extent[118]. Because of this, they have become more popular since the late 1980's (savings mortgages) and late 1990s (investment mortgages). Due to the bad stock market climate in the early years of the new millennium, investment mortgages are not that popular nowadays.

Interest only mortgages

In this type, no redemption payments are made at all. At the end of the life of the mortgage the mortgagor has to pay back the whole mortgage in lump sum. Usually, the mortgagor will take out a new mortgage to repay the old one.

Doff (2001, p. 13) shows that about 75% of all mortgages are either interest only, savings or investment mortgages. When looking at principal value this percentage grows to 85%.

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[117] That is, at least during the interest rate fixed period.

[118] Because of this, prepaying when mortgage rates are higher than the current coupon of the mortgage can be beneficial for mortgagors having this type of mortgage. However, as we will see in section 4.3 none of the studies described there notice this.

4.3 Modelling prepayment

4.3.1 Introduction

Studies about the prepayment behaviour of mortgagors are numerous in the US. As Alink (2002, p. 43) states most American literature on prepayment distinguishes between "optimal call" and empirical models. Van Bussel (1998) uses the terms endogenous and exogenous models. Endogenous or "optimal call" models assume rational client behaviour and use option theory to value the prepayment option. Prepayment will happen as soon as the option is in-the-money. As a result, prepayment only depends on market interest rates.
However, empirical evidence shows that prepayment does not always happen when it is optimal to do so (Charlier & Van Bussel, 2001). Endogenous models can not explain this behaviour. Therefore, empirical methods have been used. These exogenous models can take two forms (Van Bussel, 1998). First, endogenous models have been extended with exogenous variables. Second, strictly empirical models have been developed. A limitation of empirical models is that it is difficult to predict prepayment behaviour if contracts are issued with different conditions (Van Bussel, 1998, p. 175).

The reason why the prepayment option is so well-studied in the US is probably caused by the well-developed secondary market. Most American mortgagees sell their mortgages to this secondary market in the form of so-called Mortgage Backed Securities (MBSs). This means that the mortgagee only services the loan; that is collecting the interest payments and instalments. These payments minus a servicing fee are then passed through to the holders of the MBSs, who bear all risks, including prepayment risk. Of course, this leads to interest in the prepayment behaviour of American mortgagors.
In the Netherlands the secondary market is not that well developed and most mortgages are still on the balance sheet of the mortgagee. However, the market is increasing (Alink, 2002, p. 3).
Another difference between the US market and the Dutch market is the prepayment penalty. In the Netherlands only 10% to 20% of the original principal can be prepaid freely per calendar year. If the mortgagor wants to prepay more, he faces a penalty, which is normally the present value of the difference between the old and the new mortgage.
The only cases in which prepayment is free of charges are (Alink 2002):

- when the new rate is higher than the old rate;
- when the mortgagor sells his house;
- at the rate reset date of the mortgage;
- at destruction of the underlying property; or
- when the mortgagor dies.

Finally, another difference between the Dutch and American market is the types of mortgages that are sold. In both markets the legal term of a mortgage is usually 30 years. However, most American mortgages are either fixed for the whole term, or adjustable. That is, mortgages are either Fixed Rate Mortgages (FRMs) or Adjustable Rate Mortgages (ARMs). Although these types are also sold in the Netherlands, the numbers sold in recent years are negligible.

Because of these differences American prepayment models can not be used for the Dutch market, which encouraged research on Dutch prepayment figures. The most important studies are described in section 4.3.2.

Regarding US studies, we briefly describe the research of Kang & Zenios (1992), because of the impact it had on further research, on prepayment, including Dutch research.

The Kang and Zenios (1992) model is an empirical model and often referred to as the "Wharton" prepayment model. The Wharton model uses four variables to explain prepayment behaviour, which can be found in almost all successive models. The four variables in the Wharton model are:

a) refinancing incentive;
b) seasonality;
c) seasoning; and
d) burnout.

Ad a) Refinancing incentive

The refinancing incentive measures the difference between the prevailing mortgage rate R and the coupon C the mortgagor pays on his mortgage. One can use the absolute difference, $C-R$, or the relative difference, C/R. Normally, the relative difference gives better results. The variable captures the financial reasons to prepay.

Ad b) Seasonality

Seasonality captures the effect that prepayments tend to be highest in the summer and lowest during the winter months.

Ad c) Seasoning

Seasoning captures the effect that prepayment tends to be low in the early years of a mortgage and then tends to increase.

Ad d) Burnout

Burnout is an aging effect as is seasoning. However, burnout captures the opposite effect, that is that prepayments tend to diminish when the mortgage ages further. The reason of these decreasing prepayment rates can be explained by numerous factors. For example, if a certain refinance factor occurs some mortgagors will prepay, while others don't, because they might expect even lower rates in the (near) future, or because they don't pay attention to rates, or because they don't qualify for a new loan. As a result the most active mortgagors leave the mortgage pool first, leaving the less active. If the same refinance incentive occurs a while later, the remaining mortgagors are less likely to prepay. Furthermore for an older mortgage, the time to maturity, or rate reset is less. This means that the advantage of prepaying is lower than for a younger mortgage, causing lower prepayment rates.

4.3.2 Dutch studies on prepayment behaviour

Introduction

Having briefly described the building blocks of nearly all prepayment models, we turn our focus to recent Dutch research on mortgage prepayment. We will describe these studies in a chronological order. We start with Van Bussel's study on valuation of Dutch mortgages in which he uses an endogenous approach to model prepayment (Van Bussel, 1998). Van Bussel is the first research, known to us, on Dutch prepayment. We then focus on Doff, who uses an empirical approach (Doff, 2001). An empirical approach is also used by Charlier and Van Bussel (Charlier & Van Bussel, 2001).We end with the research on prepayment by Alink (Alink, 2002). Alink also uses an empirical approach.

Van Bussel (1998)

In his thesis, Van Bussel (1998) studies the valuation and interest rate risk of Dutch mortgages. To find an accurate value and accurate risk measures, it is important to take into account the effects embedded options can have. Van Bussel states that a mortgage can be seen as a risk-free asset with various embedded options. Therefore most mortgage valuation models are based on bond option pricing techniques.

Valuing a mortgage requires information on the dynamics of the short-term rate, the term structure of interest rates, a model that relates mortgage rates to this term structure and a model on prepayment behaviour.

In order to describe the dynamics of the short-term rate, Van Bussel first uses three one-factor models, viz. the Cox, Ingersoll & Ross (CIR) model, a non-linear model and a non-parametric model. All other interest rates, including the mortgage rate, are based on the outcome of the above mentioned models of the short rate. Van Bussel finds that the interest rate risk measures found are especially sensitive to the applied model.

Van Bussel also uses a three factor model, including the short-term rate, the long-term rate and the mortgage rate to model the mortgage rate dynamics. It is found that this three-factor model describes these dynamics more accurately.

Which model to use, depends on the purpose. All models yield approximately the same mortgage value, although the risk measures, and therefore the hedging strategy to apply, differ substantially.

Regarding prepayment, Van Bussel first takes an endogenous approach. More specifically, Van Bussel distinguishes between an optimal call prepayment rule and a rule based on a "moneyness boundary". Under optimality, prepayment is triggered when the present value of the mortgage, if left uncalled, exceeds the outstanding debt plus any refinancing costs associated with refinancing the loan. The "moneyness boundary" prescribes prepayment when it reduces the future costs for the mortgagor (Van Bussel, 1998, p. 194). Using these prepayment rules the prepayment option is valuable. For example the value of a 10% penalty-free prepayment option equals 25% of the value of a prepayment option without any prepayment limitations. For a 20% penalty free prepayment option the value even equals 50% of the value of a prepayment option without prepayment limitations.

A drawback of the endogenous approaches mentioned above is that empirical evidence shows that prepayment also occurs when it is not optimally to do so. Only empirical models can explain this behaviour. Van Bussel therefore also conducts an empirical study. A problem, however, is that he has data on only 333 mortgages, which are all in their first 5½ years of the contract. Despite this limited dataset, Van Bussel finds that the refinancing incentive is an important factor in determining prepayment behaviour. Furthermore, the seasonal pattern observed shows that prepayment rates are lowest in early spring, after which they increase to peak in July. Furthermore, a smaller peak in December can be seen[119]. Other variables suggested by literature[120], such as the age of the mortgage contract, the loan-to-value ratio (see Alink below) and housing price fluctuations have less pronounced effects. Van Bussel argues that this is probably caused by the limitations of his dataset.
Van Bussel does not use his empirical model for the valuation of mortgage contracts.

Doff (2001)

Contrary to Van Bussel (1998) who only had 333 mortgages at his disposal, Doff (2001) had access to all the mortgages of Rabobank, the largest Dutch mortgagee, on an individual loan basis. However, the dataset was limited in the number of variables (also see Alink (2002)).
To model prepayment behaviour Doff used survival analysis[121]. Survival analysis is a technique, normally used in the medical science to predict survival rates of ill people. The technique uses two functions. One is called the survival function, the other the hazard function. In terms of mortgage prepayment, one can define the survival function as the chance that a mortgage still exists at a certain point in time, whereas the hazard function models the chance of prepaying the next period, conditional on the mortgage not being prepaid in the time before. Doff uses a fully parametric survival model to estimate prepayment behaviour.
Doff distinguishes between three types of mortgages, viz. interest only mortgages, savings mortgages and fully redemption mortgages (also see section 4.2.2). For each of these types he estimates a separate model. The models only differ by the parameter values for the different variables. One of the variables that Doff uses is the refinancing incentive, measured by the relative difference between the contract rate and the market rate. Seasoning is taken into account by including the age of the contract. Seasonality is not that evident in Doff's dataset. Prepayment does not seem to peak in any particular period, although prepayments are lowest during September, October and November. Therefore, Doff includes a dummy variable that has the value one if the month of observation is one of the above and zero otherwise. Finally, Doff takes another dummy variable into the model, which has the value one if the mortgage has a so-called interest rate consider period option and zero if not[122]. Mortgages that have such an option prepay faster than mortgages that don't have such an option.

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[119] Van Bussel argues that this peak finds its origin in Dutch tax law at that time and the fact that the mortgage is only partially callable in a calendar year (see Van Bussel, 1998, p. 197).

[120] A thorough study of variables causing prepayment is performed by Alink (2002).

[121] For a more elaborate explanation on survival analysis, see Doff (2001).

[122] See section 5.2 for more on the interest rate consider period option.

Doff's models perform reasonably well. The only limitation is that, regarding to Doff, the models should only be used for mortgages with an age lower than 120 months (see Doff, 2001, p. 42). Based on Doff's model, prepayment in the Netherlands is quite large. Approximately 80% of the interest only and savings mortgages have been prepaid within five years. Traditional mortgages such as the full redemption mortgages only prepay about 25% within five years (Doff, 2001).

A remark on this is, that the latter mortgage type is not that popular anymore. Therefore, it might be that the full redemption mortgages in Doff's dataset are more seasoned that the other mortgage types, which only became popular during the last five to ten years. Taking into account that Doff had data as of December 1997 (Doff, 2001, p. 42), the burnout factor, not explicitly modelled by Doff, could have caused these lower prepayment rates.

Charlier & Van Bussel (2001)

Contrary to his 1998 research where he only had data on 333 individual mortgages (see above), Van Bussel, together with Charlier, now has data to his disposal of over 100,000 individual mortgages originated by the large Dutch pension fund ABP between January 1989 and June 1999.

On this data Charlier and Van Bussel estimate a prepayment model using proportional hazard techniques. In their baseline hazard, Charlier and Van Bussel capture seasoning by including the age of the mortgage (Charlier & Van Bussel, 2001, p. 10). Other variables are used in the proportionality factor. These variables include a refinancing incentive, a burnout factor, the age of the mortgagor and its square. Furthermore, Charlier and Van Bussel add dummy variables to capture seasonality. Another dummy variable is added to distinguish between mortgagors who have an apartment and those who don't. The expectation is that apartment owner prepay faster due to so-called upgrading[123]. Two other variables are the number of parts the mortgage loan exists off and the number of subsidies the mortgagor gets[124]. Finally, dummies are added for each year Charlier and Van Bussel analyse, starting from 1992. Their argument is that these year dummies can capture the media effect. During the 1990s intermediaries became more important on the Dutch mortgage market. Since intermediaries get paid for each mortgage contract they sell, they are very active in telling mortgagors about their prepayment option, for example by calling or writing mortgagors. This became known as the media effect. Another part of the media effect is the media writing about the historical low mortgage rates during the 1990s. For a thorough description of the variables, we refer to Charlier and Van Bussel (2001).

With these variables, Charlier and Van Bussel estimate prepayment models for savings mortgages and interest only mortgages. In fact, they estimate two models for each mortgage type, one including and the other excluding burnout.

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[123] Upgrading is the process of moving to better, bigger houses during the years.

[124] In the Netherlands, mortgagors can sometimes get government subsidy when they take out a loan. This subsidy is called the "Nationale Hypotheek Garantie".

Regarding savings mortgages, they find that prepayment rates increase with the age of the mortgage contract. If burnout is excluded, they also find a positive relation between prepayment and the refinance incentive. However, when burnout is included, the effect of the refinancing incentive disappears and is taken over by burnout. When looking at seasonality, the dummies indicate that prepayment is higher than average in the month December. For savings mortgages, prepayment is lower than average in January and February. Also the apartment dummy is significant, indicating that apartment owners prepay faster than other mortgagors. For interest only mortgages, similar conclusions hold. However, the parameter values are different and the upgrading effect, that is the effect of the apartment dummy, is less prevalent (Charlier & Van Bussel, 2001, p. 23).

Alink (2002)

Of all Dutch research on mortgage prepayment, Alink (2002) focused most on variables that influence mortgage prepayment. Based on literature and interviews with experts, Alink finds numerous variables. However, not all variables are present in Alink's data[125]. Therefore, Alink restricts himself to variables available in his dataset. For all these variables, Alink states a proposition, before analysing the data. In Table 4.1 on page 146 we reproduce these propositions. For a description of the variables and the derivation of the propositions we refer to Alink (2002).

Before developing models of prepayment behaviour, Alink considered developing a model for each mortgage type or just one model for all mortgage types. Alink argued that both approaches have advantages as well as disadvantages. He decided to do both, developing separate models for six types of mortgages[126] and one model for all types. In the end Alink concluded that based on the statistics, the individual models perform slightly better than the general model. However, the differences are small and Alink therefore decided to use the general model (Alink, 2002, p. 120).

In developing the models Alink took several steps. He used a technique called logistic regression to test the significance of each variable stated in Table 4.1. Then, all significant variables were taken into a multi-factor model. Using stepwise techniques, Alink removed and/or re-entered variables into this model, until the best model remained in terms of log likelihood. For this, Alink had data of the SNS bank at his disposal.

After developing the preliminary model, the model was back-tested on another part of the SNS dataset, as well as on data from DBV Verzekeringen and Rabobank. Based on these back tests, Alink adjusted his model and concluded that the model performed reasonably well for the most common mortgage types in the Netherlands at that time. The back-test on the DBV Verzekeringen data, showed that if the mortgage type under consideration differs a lot from the mortgage types on which the model was estimated, predicting prepayment becomes more difficult.

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[125] Alink uses data from SNS bank on all mortgages originated between January 1993 and May 2001. These mortgages exclude mortgages granted to SNS employees and corporate clients (Alink, 2002, p. 95).

[126] These six mortgage types are savings mortgages, level payment mortgages and interest only mortgages, all with a interest fixed period of 5 and 10 years.

Variables in his final model are seasoning, refinance incentive, loan-to-foreclosure-value[127], age of the borrower, interest rate movement, the market rate and the rank of the mortgage. Furthermore, there are dummy variables for whether or not the mortgage is sold via an intermediary, the property type, mortgage type and whether the mortgage is in its second or third interest rate fixing period. For a more detailed description of these variables, as well as their parameter values, we refer to Alink (2002, p. 128).

Table 4.1 Set of possible variables for mortgage prepayment, including the proposition of the precise effect. (Source: Alink (2002), table 3-10)

Variable	Proposition
Refinancing incentive[128]	Higher incentive leads to faster prepayment.
Property price	Limited effect of increasing housing prices on prepayment. In the case of decreasing housing prices, slower prepayment.
Burnout	Limited effect on prepayment.
Steepness of yield curve	Minor effect; steeper yield curve will increase prepayment rates.
Level of interest rates	Low mortgage rates increase prepayment speed.
Direction of interest rates	If rates decrease, prepayments are postponed.
Seasoning[129]	Prepayment rates increase during the first two to three years.
Seasonality	Prepayment rates are higher during the summer and in December.
Age of the borrower	Younger borrowers prepay faster.
Loan-to-Value ratio	Higher ratios indicate financial awareness of borrower; this increases prepayment speed.
Size of the loan	Higher loans prepay faster than smaller loans but effect is limited.
Distribution channel	Loans originated via intermediaries prepay faster.
Mortgage rank	Second ranking loans prepay faster than first ranking loans.
Mortgage guarantee	No effect on prepayment.
Mortgage type	Different mortgage types have different effects on the refinancing incentive. Prepayment rates therefore differ per mortgage type.
Interest type	After an interest fixed period, prepayment rates will drop since there will be no incentive.
Income	Borrowers with higher incomes will prepay faster.
Property type	Borrowers living in apartments are expected to prepay faster.
Urban area	No effect on prepayment.
Property use	Mortgages vested on properties not used for living prepay faster.
Geographic location	No effect on prepayment.

[127] The difference between the loan-to-value and the loan-to-foreclosure-value is that the first uses the market value of the house as the value, whereas the latter uses the value of the house in a stress sale as the value. This stress value is referred to as the foreclosure value.

[128] Measured as the ratio of the coupon rate and the one-month lagged market rate (Alink, 2002, p. 115).

[129] Seasoning is measured as a linear function of time for 36 months, after which there is no further seasoning (Alink, 2002, p. 115).

4.4 Conclusions

In this chapter we studied and described research on the prepayment option embedded in a mortgage contract. A mortgage is a contract which authorises the lender (the mortgagee) to sell the mortgaged property and foreclose the loan if the borrower (the mortgagor) fails to make the agreed-upon payments (Van Bussel, 1998). The prepayment option grants the mortgagor the right, not the obligation, to prepay (parts of) his loan. In the Netherlands this option is restricted to only 10% or 20% of the original notional of the loan. That is, if the mortgagor wants to prepay a larger percentage, he has to pay a prepayment penalty, which is normally the present value of the difference between the value of the old and the new mortgage. The penalty does not have to be paid, when the new rate is higher than the old rate, when the mortgagor moves or when the mortgagor dies.

We first described the mortgage market in the Netherlands and the main differences between the Dutch and the US market. We noticed that the market is booming, with the numbers of mortgages as well as the outstanding amount, increasing rapidly. We further described a couple of mortgage types, where we noticed that so-called traditional mortgages, like linear and level pay mortgages, have become less popular during the 1990s whereas new mortgage types as savings and investment mortgages as well as interest only mortgages became more popular.

Regarding the differences between the US and Dutch market, we concluded that the products sold differ substantially, as well as the prepayment option itself, because there is no prepayment penalty in the US.

Despite the differences between the Dutch and US market, most Dutch researches start with a study of US research. The reason is that there is a vast amount of US research on the prepayment option. Usually, there is a distinction between endogenous or optimal call models and exogenous or empirical models for prepayment behaviour. The first category assumes that prepayment rates depend only on prevailing interest rates. As soon as some pre-defined criteria are met, for example the option is in the money, prepayment is triggered. However, empirical evidence shows that this kind of optimal behaviour does not explain all prepayments. It often occurs that the option is exercised when it is not optimal to do so and vice versa. Empirical models try to explain this behaviour by linking variables to historical prepayments.

Recently, some Dutch studies on the prepayment option have been performed. We therefore decided to focus on Dutch studies only. The only US study we studied more closely is the 1992 paper of Kang & Zenios. The reason is that this study more or less forms the basis for nearly all subsequent empirical research regarding prepayment behaviour, including the Dutch.

Kang & Zenios' study became known as the "Wharton" model on prepayment. In this model prepayment is explained by four factors, viz. refinance incentive, seasonality, seasoning and burnout. The refinance incentive measures the financial gain of prepayment. Seasonality measures seasonal fluctuation in prepayment rates. Seasoning and burnout are aging effects. Seasoning describes the effect that prepayment is usually low for a new loan, after which prepayment rates start to increase during the next three to five years. After that period, the loan is called seasoned, that is that prepayment rates do not increase anymore. Burnout is the opposite effect, that is, that prepayment rates tend to decrease as mortgages age. The reason for this is that more active mortgagors have probably prepaid already, leaving the less active (Kang & Zenios, 1992).

We then turned our focus to Dutch studies on prepayment behaviour. We started with the first study known to us, which is Van Bussel's 1998 research on the valuation and interest rate risk of mortgages (Van Bussel, 1998). Van Bussel uses an endogenous approach. More specifically, Van Bussel distinguishes between an optimal call prepayment rule and a rule based on a "moneyness boundary". Under optimality, prepayment is triggered when the present value of the mortgage, if left uncalled, exceeds the outstanding debt plus any refinancing costs associated with refinancing the loan. The "moneyness boundary" prescribes prepayment when it reduces the future costs for the mortgagor. Using these prepayment rules, Van Bussel (1998) concludes that the value of a 10% penalty-free prepayment option equals 25% of the value of a prepayment option without any prepayment limitations. For a 20% penalty-free prepayment option the value even equals 50% of the value of a prepayment option without prepayment limitations. Van Bussel also developed an empirical model, but its use and explanatory power are limited due to the fact that he only had 333 mortgages in their first 5½ years of origination at his disposal to base his model on.

In 2001, Doff studied prepayment behaviour of Dutch mortgagors again. Doff had access to individual mortgage data of Rabobank, the largest Dutch mortgagee, from December 1997 until December 2000. Using a statistical technique called survival analysis, Doff estimated models for three types of mortgages, viz. full redemption mortgages, savings mortgages and interest only mortgages. Doff's models use the following variables: refinance incentive, seasoning, seasonality and whether or not the mortgage has an interest rate consider period option. The latter two variables are measured using dummy variables. Although all models use the same variables, the importance of the variables differs in each model.

In 2001 as well, Charlier and Van Bussel also studied prepayment rates. They developed separate models for savings mortgages and interest only mortgages. Regarding savings mortgages, they find that prepayment rates increase with the age of the mortgage contract. If burnout is excluded, they also find a positive relation between prepayment and the refinance incentive. However, when burnout is included, the effect of the refinancing incentive disappears and is taken over by burnout. When looking at seasonality, the dummies indicate that prepayment rates are higher than average in the month of December. For savings mortgages, prepayment is lower than average in January and February. Also the apartment dummy is significant, indicating that apartment owners prepay faster than other mortgagors. For interest only mortgages, similar conclusions hold. However, the parameter values are different and the upgrading effect, that is the effect of the apartment dummy, is less prevalent (Charlier & Van Bussel, 2001, p. 23).

Finally, we described the research undertaken by Alink (2002). Alink develops both a general model and separate models for different mortgage types using logistic regression. Because the separate models perform only slightly better than the general model, Alink decided to use the general model. The model was estimated on SNS bank data and back-tested on data of DBV Verzekeringen and Rabobank. After these back tests, the model was slightly adjusted. Variables in this final model are seasoning, refinance incentive, loan-to-foreclosure-value, age of the borrower, interest rate movement, the market rate and the rank of the mortgage. Furthermore, there are dummy variables for whether or not the mortgage is sold via an intermediary, the property type, mortgage type and whether the mortgage is in its second or third interest fixed period.

Concluding on the above, we see that the Dutch empirical models become better, due to an increasing history and quality of data. However, this data still does not contain all variables that might explain prepayment behaviour, as is shown by Alink (2002). Therefore, data should no longer be deleted, but stored for historical analysis. A second conclusion is that the prepayment option does have a significant effect. All researches find significant prepayment rates. Bearing this in mind, we can conclude that the most expensive type of prepayment option is the "movement" option, since in this case prepayment is penalty-free.

So how does this study helps in finding an answer to research question four, which read: "in what way can the effects of embedded options in the retail banking book be measured?". Basically, what we have learned from the study performed in this chapter is that one can either use endogenous and exogenous methods for predicting mortgage prepayment. Both have their advantages and disadvantages. Most recent researches use exogenous methods. Usually, prepayment rates are modelled and forecasted by using survival techniques. The performance of such models is reasonably good, if the correct variables are included. However, we need to be careful in using these models in situations that differ substantially from the situation in which the models were estimated. For example, most models are estimated using data from a period in which mortgage rates decreased to an all time low, causing prepayment rates to increase. The question now is, what the performance of these models will be in increasing rate environments, for example.

How this helps us in measuring the effects of the prepayment option on interest rate risk and economic capital will be handled in chapter 6.

5

Other embedded options

5.1 Introduction

In section 2.3.2 we introduced six types of embedded option in products in the retail banking book. Chapters 3 and 4 already discussed the withdrawal and prepayment option. In this chapter we discuss the other four. We start with the so-called interest rate consider period option in section 5.2. Embedded caps and floor are the subject of section. 5.3. In that same section the quotation rate option will be studied, due to its similarities with an embedded cap. The last option, the choice option is the subject of section 5.4. Finally, section 5.5 concludes.

5.2 Interest rate consider period option

An interest rate consider period option is an embedded option in mortgages. In the Netherlands this option is referred to as the "rentebedenktijd optie". It is also sometime referred to as the $x + y$ option. It gives the mortgagor the right, but not the obligation, to reconsider his interest rate fixed period after x years for a period of y years. At each month during those y years, the mortgagor can exercise the option and choose another rate fixed period or even convert to an adjustable rate. In general the mortgagor pays a fee for this option of 20 basis points on top of the contract rate.

One way to determine the risk of the option, as well as the consequences of it, on the value of a mortgage is to use the approach described by, for example, Cohen (1991), Kalotay et al. (1993) and Wilson (1994). They argue that if it is possible to create a mix of products that exactly replicates all possible cash flow patterns of the product with the embedded option, the value of that mix must be equal to the value of the product with the embedded option. If not, arbitrage is possible.
To clarify this, we will give a simplified example. Figure 5.1 below shows possible cash flow patterns of a $3 + 2$ mortgage from the mortgagees point of view. Although in reality the mortgagor can exercise the interest rate consider period option monthly, we assume semi-annual exercise possibilities and coupon payments in this example. Furthermore, we assume that the loan disappears when the option is exercised. The mortgage has a principal P and a coupon C. It is assumed that the principal does not amortize. The figure gives the cash flow patterns if the option is exercised at time six and seven and when the option is not exercised at all.

Figure 5.1 Possible cash flow patterns of a 3+2 mortgage,
where *C* denotes a coupon payment and *P* denotes the repayment of the principal amount.

Called at time 6

Time	1	2	3	4	5	6	7	8	9	10
Cash flow	C	C	C	C	C	C+P	-	-	-	-

Called at time 7

Time	1	2	3	4	5	6	7	8	9	10
Cash flow	C	C	C	C	C	C	C+P	-	-	-

Not called

Time	1	2	3	4	5	6	7	8	9	10
Cash flow	C	C	C	C	C	C	C	C	C	C+P

Now, assume a portfolio of a non-callable bond with principal P and coupon C and a maturity of five years and a short option, which grants the right to sell a loan with principal P and coupon C at any time between three and five years from now. Some of the resulting cash flow patterns are shown in Figure 5.2 below.

Figure 5.2 Possible cash flow patterns of a long non-callable bond and short option position.
Again *C* denotes a coupon payment and *P* denotes payments of the principal amount.

Excercise option at time 6

Time	1	2	3	4	5	6	7	8	9	10
Cash flow bond	C	C	C	C	C	C	C	C	C	C+P
Cash flow option	-	-	-	-	-	P	-C	-C	-C	-C-P
Resulting cash flow	C	C	C	C	C	C+P	-	-	-	-

Excercise option at time 7

Time	1	2	3	4	5	6	7	8	9	10
Cash flow bond	C	C	C	C	C	C	C	C	C	C+P
Cash flow option	-	-	-	-	-	-	P	-C	-C	-C-P
Resulting cash flow	C	C	C	C	C	C	C+P	-	-	-

Never exercise option

Time	1	2	3	4	5	6	7	8	9	10
Cash flow bond	C	C	C	C	C	C	C	C	C	C+P
Cash flow option	-	-	-	-	-	-	-	-	-	-
Resulting cash flow	C	C	C	C	C	C	C	C	C	C+P

As one can see this portfolio generates the same cash flow patterns as the mortgage that has the embedded option in it. As a result the value of this portfolio must equal the value of the mortgage with the embedded option. If one knows the value of a mortgage without the option, the value of the option itself is known.
A drawback of this approach is that it is difficult to construct the replicating portfolio, since the mortgage also has other embedded options, such as the prepayment option.

Another way to look at this option is as some sort of prepayment option. Once the embedded option is exercised, the mortgage is assumed to be prepaid. This suggests that the prepayment models studied in chapter 4 could be used. However, there are differences. For example, the mortgagor does not pay an up-front fee for the prepayment option, whereas the mortgagor with an embedded interest rate consider period option pays 20 basis point on top of the contract rate, as already stated above. As a result, the prepayment option is present in each mortgage, whereas the interest rate consider period option is only sold in small numbers. Another difference is that the prepayment option grants the right to prepay 10% to 20% of the notional value of the mortgage per calendar year during the whole life of the mortgage. The interest rate consider period option on the other hand grants full "prepayment" of the mortgage during y years of the mortgage after x years. All this might cause the prepayment models described earlier not to be accurate in explaining the behaviour of a mortgagor with an interest rate consider period option.

A third way to model this option is by use of simulation. This requires assumptions on when the mortgagor exercises his option. Furthermore, depending on the length of the simulation, one also needs to determine what the mortgagor does when he exercises his option. An example of this approach is Van Mullem[130] (1998). Van Mullem defines four exercise models. The first is a model in which the mortgagor acts when he is in the middle of his interest rate consider period, regardless of the prevailing interest rates. In the second model, the mortgagor acts as soon as the prevailing market rate for the mortgage he has is lower than the current coupon. The third model assumes that the mortgagor does not act as long as interest rates decrease. However, as soon as interest rates do not move or increase, the option is exercised. Finally, the fourth model assumes that the mortgagor is only interested in minimum costs, and only acts when this reduces the present value of his future costs. Implicitly, this last model assumes that the mortgagor knows where interest rates will move to.

To determine what the mortgagor will do after exercising his option, Van Mullem defines three models. In the first model the time horizon lies at 15 years and the mortgagor always chooses the interest rate fixing period that is equal to the remaining period until the time horizon. For example, if the mortgagor acts after six years, the next mortgage will have an interest rate fixing period of nine years[131]. The next model uses a thirty year horizon. It assumes that the mortgagor follows an optimal path. As the fourth exercise model, this model assumes that the mortgagor has full knowledge of future interest rates. Finally, the third model assumes that the mortgagor either chooses a mortgage with a short or a long interest rate fixing period. Short means five years, long is ten years. The choice depends on the level of interest rates. If the ten year rate is above its own average, then interest rates are considered high, otherwise they are considered low. In the first case the mortgagor is assumed to choose a short-term mortgage, in the latter situation a long-term mortgage.

With combinations of these models and the exercise models described above, Van Mullem investigates whether the price of 20 basis points is sufficient for the mortgagee. He finds that, except for the $0+1$ and $0+2$ mortgages, the price is always sufficient to take into account possible losses due to the option, even when it is assumed that the mortgagor follows a, for the mortgagor, optimal path. The reason is, according to Van Mullem (1998), that the mortgagor makes the up front payments. Due to these payments, interest rates have to drop considerably in order to take advantage of the interest rate consider period option. Therefore, the conclusion is that the risk caused by this option is relatively low.

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[130] Van Mullem abstracts from other embedded options as well as transaction costs.

[131] These models all assume that the mortgagor will not chose another interest rate consider period option in a new mortgage.

5.3 Embedded caps and floors & quotation rate option

Caps and floors are interest rate derivatives. A cap prevents interest rates becoming too high. In other words, a cap tells what the maximum rate will be. A floor, on the other hand, gives the minimum rate. Caps and floors are frequently embedded in American adjustable rate mortgages (ARMs). Usually, there is a distinction between a so-called life cap and floor and a period cap and floor. The first category provides the maximum and minimum coupon during the life of the mortgage, whereas the latter limits the maximum increase and decrease of the coupon on a rate reset date. The period caps and floor are usually measured in basis points, whereas the life cap and floor are usually measured in percentages.
Embedded caps and floors as such are not present in Dutch mortgages, although one could see the prepayment option, the interest rate consider period option and the quotation rate option as a form of caps. For the first two options, if the market rate is considerably below the coupon rate and the mortgagor exercises the option, one could more or less say the option capped the coupon to the prevailing market rate. However, this is not exactly the same as what an embedded cap does, because it prevents rates from becoming too high. It does not lower the coupon rate if it is higher than the prevailing market rate.
The quotation rate option on the other hand in fact is an embedded cap, because it guarantees the mortgagor that the rate he will pay once a mortgage contract is offered will be the offered rate at a maximum. To be precise, the quotation rate option grants the holder the right, but not the obligation, to get a mortgage for the terms specified in the quotation. Usually, an option like this has a maturity of three months, but longer periods are also possible. Basically, what the option does is insure the mortgagor against interest rate increases, so the customer knows the maximum interest rate he has to pay. However, if interest rates drop during these three months the mortgagor profits, because the rate he gets when he decides to accept the quotation is the lowest rate between the quotation date and the lock-in date. Basically, the client gets a cap on his rate. Usually, this option is free for the first three months.
There are two methods to measure the effects of this options. The first one is similar to the method of Cohen (1991), Kalotay et al. (1993) or Wilson (1994) explained in section 5.2. A second method is by simulation. A difficulty with simulation is that one needs to know what percentage of quotations actually becomes a mortgage. Another difficulty is that one needs to know against what rates the quotations are locked in. A simple assumption is to take the lowest rates in the previous three months. A difficulty with the replicating portfolio approach is, as with the interest rate consider period option, the other embedded options in a mortgage contract. We would therefore prefer to use simulation.

5.4 Choice option

Finally, the last embedded option which one can identify is the choice option. This option is embedded in mortgages in the Netherlands. Mortgages usually have a legal maturity of 30 years, but the fixed period is normally shorter. As soon as the rate has to be set again, the client has the right, but not the obligation, to decide for another fixed period. For example, assume that a client has a mortgage with a five year fixed period. After five years, he can decide to enter into a new five year fixed period, but he can also choose for another term, or even a variable rate.

We think the risk due to this option is not that high, since the bank can adjust its funding to the choice of the customer. Furthermore, since a bank will not usually fund a mortgage on a loan-by-loan basis but on a portfolio level, the risk is further mitigated.

5.5 Conclusions

In this chapter we studied the effects of four embedded options, viz. interest rate consider period option, embedded caps and floors and the quotation option as well as the choice option. Regarding the interest rate consider period option, we found that there are basically three approaches to model the effects. The first is a replicating portfolio technique as proposed by, for example, Cohen (1991), Kalotay et al. (1993) and Wilson (1994). The second approach is to view the interest rate consider period option as a form of prepayment. The third approach is to use simulation. An example of this approach is given by Van Mullem (1998). Comparing these techniques, we concluded that simulation seems best. The reasons are the differences between the interest rate consider period option and the prepayment option as well as the difficulty in finding a replicating portfolio, due to other embedded options in a mortgage. In simulation one can take the effects of these options into account as well, although one needs to make assumptions on the behaviour of mortgagors.

The risk of the interest rate consider period option is low though. The main cause for this is that the mortgagor needs to pay fees during the fixed period of the mortgage with the embedded interest rate consider period option. Usually this fee is 20 basis points. One of the conclusions of Van Mullem (1998) is that this fee is enough to hedge the risk of exercising whatever the mortgagor chooses[132]. Furthermore, mortgages with this option embedded are only sold in small numbers.

Embedded caps and floors as such are not common in Dutch mortgages. Usually, these options can be found in American adjustable rate mortgages (ARMs), where they limit the risk of interest rate increases for the mortgagor, while at the same time limiting the risk of interest decreases for the mortgagee. The only cap that is present in Dutch mortgages is the quotation option. Once the mortgagee offers the mortgagor a mortgage, this offer usually contains a quotation rate option. Effectively, this option insures the mortgagor against interest rate increases during the quotation period. On the other hand, the mortgagor profits to a full extent from interest rate decreases. The coupon on the mortgage once the offer is locked in is the lowest between the quotation date and the lock-in date. Although this option is present in all quotes, the risk is fairly small, due to the fact that (1) the quotation often has a maturity of only three months, (2) that mortgage rates are usually not that volatile and (3) the risk of this option can be hedged by the bank. Using the lowest mortgage rate in the past three months in simulation will probably model the risk of this option well.

Finally, we described the choice option. We concluded that the risk in this option will be low, since the bank can adjust its funding to the choice of the mortgagor. Furthermore, mortgages are usually funded on a portfolio level, which further mitigates this risk.

[132] The only exceptions are the $0+1$ and $0+2$ mortgages.

6

Consequences for interest rate risk management and economic capital

6.1 Introduction

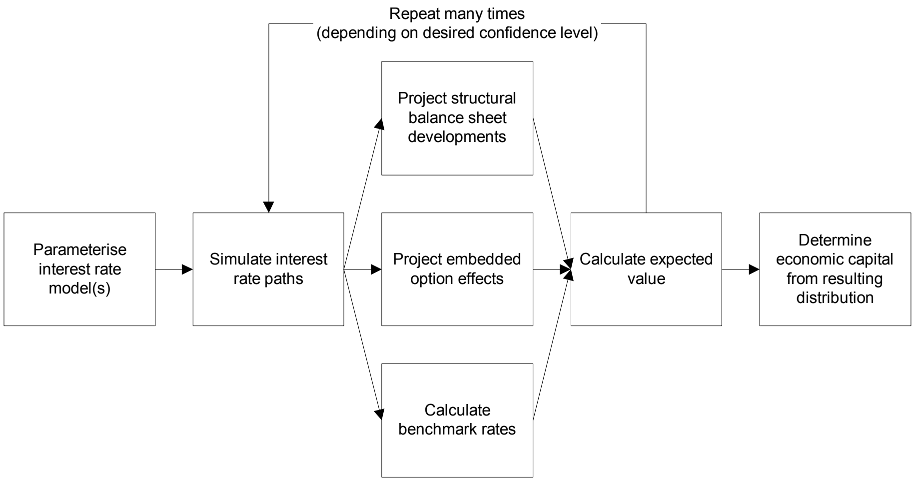
Now we have studied how we can measure the effects of the individual embedded options in the retail book, we will focus on the consequences for interest rate risk management and economic capital in this chapter. At the end we will have answered research question five, which read: *what are the effects of embedded options in the retail banking book on interest rate risk and economic capital?*

In chapter 2 we studied the concepts of interest rate risk and economic capital in some detail. In section 2.3 we found that several sources of interest rate risk exist, viz. repricing risk, yield curve risk, basis risk and embedded option risk. Furthermore, we saw that there are several methods for quantifying interest rate risk, both from an accruals perspective as from a mark-to-market perspective. These methods can be either static or dynamic.

In section 2.4 we studied the concept of economic capital. We defined economic capital as the amount of equity needed to match the risk profile of the bank. After studying the economic capital models of Matten (1996), Bessis (1998), Oliver, Wyman & Company (2001) and Emmen (2001) & Boughanmi (2001), we concluded that economic capital is usually associated with the loss in value of a portfolio over a specified period at a certain confidence level. The latter depends on the rating of the bank. We finally combined the models to a generic model, which is (again) shown in Figure 6.1 below.

The reason that most economic capital models use a value approach is that value gives more information than accruals income, since values are forward-looking. An example of this is the Savings & Loans crisis in the 1980's in the USA. During that period short-term interest rates rose rapidly. The Savings & Loans banks all had long-term assets and short-term liabilities, the rates of which had been fixed in the past. On an accruals basis the banks therefore still looked profitable. However, as soon as the liabilities started to reprice against the then higher market rates, profits dropped rapidly, and a number of these banks went bankrupt. On a value basis profits dropped earlier, because positions are discounted against the market rates. The result was that the value of some banks' capital was below zero for a long time, before the banks actually went bankrupt. Therefore, it can be concluded that a value approach can act as an early warning system, whereas an earnings approach cannot.

Figure 6.1 General economic capital calculation framework



The question then becomes, how to calculate the value of products in the retail banking book with embedded options, and how the studies in chapters 3, 4 and 5 can help.

In general the present value of an instrument is the present value of its future cash flows. If we have a financial instrument i, with monthly cash flows CF_t and maturity of T months, using a discounting rate r_t at time t, the present value PV_i is calculated as below

$$PV_i = \sum_t^T \frac{CF_t}{\left(1+r_t\right)^{t/12}} . \tag{6.1}$$

Since the discounting rate r_t can be regarded as a given from the market[133] and embedded options do not influence this rate, we will have to take the effects of embedded options into the cash flow of the instrument[134].

We start the chapter with a study of the impact of the individual embedded options on interest rate risk and economic capital. Therefore, in section 6.2 we will ignore the correlation between the embedded options. In that section we will use the same categories as in chapters 3, 4 and 5.

Since a zero correlation between the options is highly unlikely, we study portfolio effects in section 6.3. In that section we use an assumed balance sheet of a retail bank. Finally, we conclude in section 6.4.

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133 Although if we are going to simulate the future we will need a model for the discounting rate.

134 This is not completely true. If there is a secondary market it might be possible to calculate an option adjusted spread (OAS), which is the spread required to value the product at par. In The Netherlands, though we don't see a matured secondary market. Therefore it is more difficult, if possible at all, to calculate an OAS. Therefore, instead of adjusting the discount rate for optionality, we adjust the cash flows.

6.2 *Effects of the individual options*

6.2.1 Withdrawal option

Introduction

With the demand and interest rate models estimated in chapter 3, we can model the development of the cash flows of products that have the withdrawal option: demand deposits and savings accounts; and one alternative savings product: term deposits.
As already stated in section 3.1 on page 74, a complexity of these products is that they usually do not have stated maturities, with the exception of term deposits. We therefore use an approximation to value these products as given by Jarrow & Van Deventer (1998).
With $V_0^{B^j}$ the present value of a B_0^j balance at time zero, $B_{n,t}^j$ the balance of product j in path n at time t, $r_{n,i,1}^{rf}$ the one-month risk-free interest rate in path n at time i, τ the time horizon and N the number of simulated paths, the equation below shows the Jarrow-Van Deventer valuation formula again with a slightly adjusted notation

$$\begin{aligned} V_0^{B^j} &= B_0^j + \tilde{E}_0\left(\sum_{t=1}^{\tau-1}\frac{B_t^j - B_{t-1}^j}{P_t}\right) - \tilde{E}_0\left(\frac{B_{\tau-1}^j}{P_\tau}\right) - \tilde{E}_0\left(\sum_{t=1}^{\tau}\frac{r_{t-1}^j B_{t-1}^j}{P_t}\right) \\ &\approx B_0^j + \frac{1}{N}\sum_{n=1}^{N}\sum_{t=1}^{\tau-1}\frac{B_{n,t}^j - B_{n,t-1}^j}{\prod_{i=1}^{t}\left(1+r_{n,i,1}^{rf}\right)} - \frac{1}{N}\sum_{n=1}^{N}\frac{B_{n,\tau-1}^j}{\prod_{i=1}^{\tau}\left(1+r_{n,i,1}^{rf}\right)} - \frac{1}{N}\sum_{n=1}^{N}\sum_{t=1}^{\tau}\frac{r_{n,t-1}^j B_{n,t-1}^j}{\prod_{i=1}^{t}\left(1+r_{n,i,1}^{rf}\right)} \end{aligned} \quad (6.2)$$

The formula should be read as follows: the net present value of product j is approximately equal to its current balance plus the present value of balance growth minus the present value of the end volume[135] minus the present value of interest payments.
Before we give the results of the simulation, we first briefly summarize the results of chapter 3, more specifically sections 3.6 and 3.7. We estimated demand models for demand deposits, savings accounts and term deposits. Furthermore, we estimated models for the savings rate, term deposits rate and two models for the risk-free rate. We assumed interest rate on demand deposits to be zero.
With reference to the notation as provided in section 3.2, the model for demand deposits demand is $DD_t = \beta_0 + \beta_1 DD_{t-1} + \beta_2 t + \beta_3\delta_5 + \beta_4\delta_7 + \beta_5\delta_8 + \varepsilon_t$. The model for savings accounts demand is $\Delta SA_t = \beta_1\Delta SA_{t-1} + \beta_2\Delta TD_{t-1} + \beta_3\delta_1 + \beta_4\delta_5 + \beta_5\delta_6 + \beta_6\delta_{12} + \varepsilon_t$. Finally, the model for term deposits demand is $\ln TD_t = \beta_0 + \beta_1\left(r_t^{TD} - r_t^{SA}\right) + \beta_2\delta_{1998:01} + \varepsilon_t + \alpha_1\varepsilon_{t-1}$.
Regarding the product interest rates, the model we estimated for the savings and term deposits rate were $\Delta r_t^{SA} = \beta_1\Delta\tilde{r}_t^3 + \alpha_1\left(\tilde{r}_{t-1}^3 - \tilde{r}_{t-1}^{60}\right) + \alpha_2\left(\tilde{r}_{t-1}^{60} - r_{t-1}^{SA}\right) + \alpha_3 + \varepsilon_t$ and $\Delta r_t^{TD} = \beta_1\Delta r_t^1 + \varepsilon_t$ respectively.

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135 It is assumed that the outstanding balance is paid back at an assumed maturity.

For the risk-free rate we estimated a one-factor interest rate model, the well-known Cox, Ingersoll & Ross (CIR) model (1985), as well as a three-factor model, for which we used the model of De Feijter (2002). The CIR model is specified as $r_{t+\Delta t} = \kappa\theta\Delta t + (1-\kappa\Delta t)r_t + \sigma\sqrt{r_t}\sqrt{\Delta t}\varepsilon_t$, while the model of De Feijter is defined as $\mathbf{R}_t = \boldsymbol{\mu} + \boldsymbol{\Gamma}(\mathbf{R}_{t-1} - \boldsymbol{\mu}) + \boldsymbol{\varepsilon}_t$, where $\boldsymbol{\varepsilon}_t$ is a vector of heteroskedastic error terms. The reason we use two interest rate models is that we want to see what influence a model has on the outcome. For the parameter values we refer to sections 3.6 and 3.7.

In order to value the various products, we now only need to make assumptions on what interest rate to use for discounting, which day count convention to use and what the time horizon should be. According to Jarrow & Van Deventer, one must use the price of a default-free bond paying one at time t P_t for discounting. Since we have a monthly model, this would imply that we require the prices of Dutch Government bonds maturing one month from now, two months from now, and so on. As we don't have that kind of data, we decided to use the next best rate, which is the one-month interbank offer rate: 1M EURIBOR r_t^1. Regarding the day count convention ,we decided to use simple 30/360. Finally on the time horizon τ, we chose ten years, which implies $\tau = 120$. The main reasons for choosing this time horizon were hardware and software limitations. Another reason was that some models have been estimated on a fairly short history. Forecasting for (very) long periods then results in questionable results.
We created the Jarrow-Van Deventer valuation model in Excel and used Crystal Ball 2000 for simulation. For each of the interest rate models we did 100,000 simulations. In the remainder of this section we will give the results of these simulations for interest rates, product rates, demand and value. We only give the mean and 5% and 95% confidence levels. Finally, we conclude.

Interest rate models

As mentioned for both interest rate models we did 100,000 simulations. For the Cox, Ingersoll & Ross model this resulted in 100,000 paths for the short rate. For each path we used equation (3.51) (see page 123) to calculate the longer term rates. More specifically, we calculated the one-month, three-month and five-year rate, since we require those for our other models. Figure 6.2 and Figure 6.3 below show the resulting expected path and 5% and 95% confidence levels. Clearly, we see that the short rate will be increasing on average, due to the mean reversion character of the CIR model. We also see this in the calculated rates. Furthermore, we see that the term structure is much steeper directly from the start of our simulated period (see Figure 6.3). This can be explained from the fact that our calculated interest rate does not depend on the current term structure but solely on the parameters of the CIR model. As a result we get some unlikely interest rate jumps at the start. We don't see this in the multi-factor model, as can be seen from Figure 6.4 below.
In Figure 6.4 we not only see the simulated one-month, one-year and ten-year rate, but also the calculated three-month and five-year rate. As mentioned, the term structure is much smoother.

Figure 6.2 Confidence bands for the short rate using the Cox, Ingersoll & Ross model.
The chance of interest rates below the dotted line equals 5%. The chance of interest rates above the dashed line equals 5% as well. The solid line indicates the expected interest rate. Clearly we see the mean reverting character of the model.

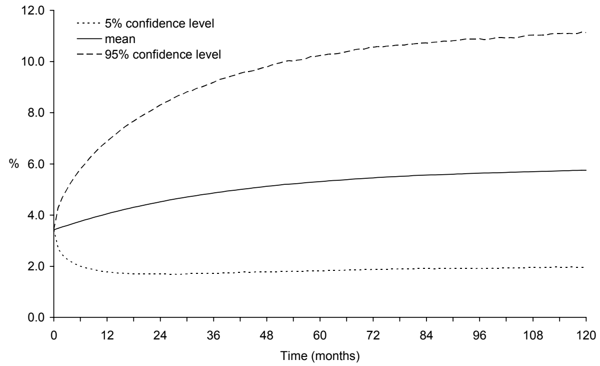


Figure 6.3 Risk free rates based on the Cox, Ingersoll & Ross process.
Again, for all rates the expected path as well as lower and upper confidence levels are provided.

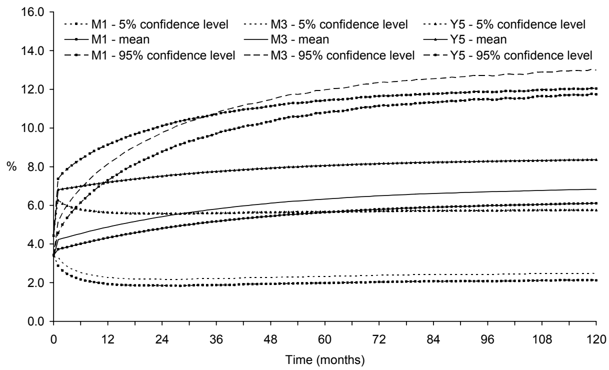
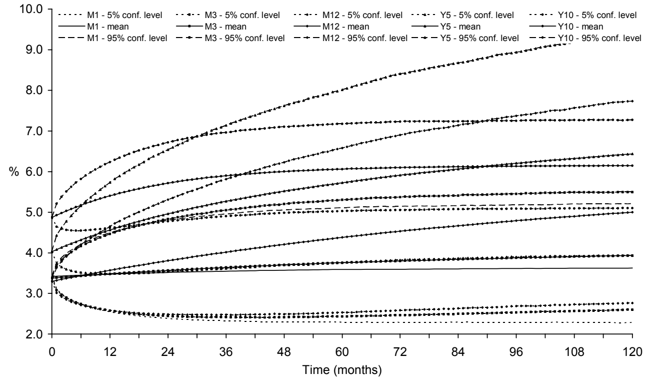


Figure 6.4 Term structure in multi-factor model. For five interest rates the expected path and the lower and upper cofindence levels are given, using the term structure model of De Feijter (2002).



Product rates

Also for both models we simulated the savings accounts rate and the term deposits rate. For these rates the simulated rates above are important, especially the three-month and five-year rate for the savings accounts rate and the one-month rate for the terms deposits rate. Clearly, we see the differences in the figures below. The CIR model results in far more volatile product rates. This can be explained by the difference in the underlying models for the interest rate, as was shown in Figure 6.3 and Figure 6.4 above. The multi-factor model seems to show product rates that are more in the range of what rates have been in the last ten years.

Figure 6.5 The figure shows the expected and lower and upper confidence levels for both the savings and term deposits rate as forecasted using the models as shown in equations (3.45)[136] (see page 116) and (3.49) (see page 121) respectively. The Cox, Ingersoll & Ross interest rate model was used to generate the input for the models.

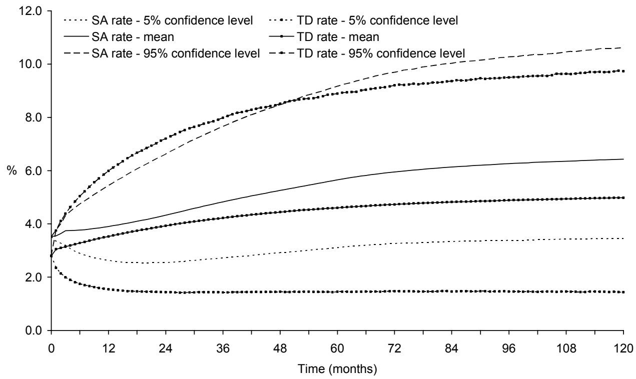
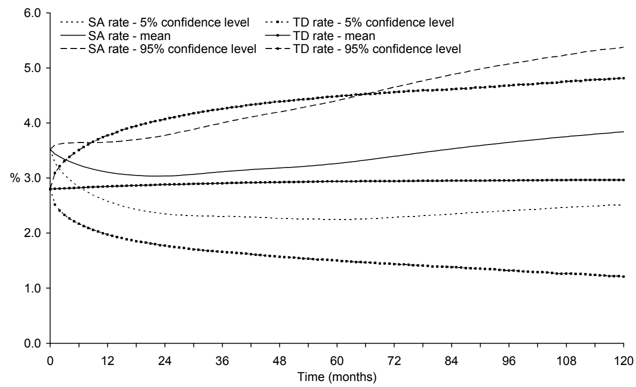


Figure 6.6 Basically, this figure is similar to Figure 6.5, but the multi-factor interest rate model of De Feijter (2002) was used to generate the input for the models.



136 Actually, in the final savings rate model, the change in the five-year moving average of the five-year Dutch government rate is left out.

Demand

We also see the difference in the underlying interest rate model in the simulated demand (see Figure 6.7 and Figure 6.8 below). Where demand is not dependent on interest rates as is the case with demand deposits, we see equal results, with a slightly increasing volume, with some seasonality on top of it. For term deposits, however, we can see that the underlying interest rate model has significant influence on forecasted demand. Although the change in deposits volume is one of the explanatory variables in the demand model for savings accounts, the differences in forecasted savings volume are small between the interest models. This is evidence of the smaller interest rate sensitivity of savings accounts. In the end, the differences between the models, however, do not have a big influence on forecasted total demand.

Figure 6.7 The figure shows the expected development as well as lower and upper confidence levels of demand for demand deposits, savings accounts, term deposits and total volume. Where interest rates are used, they are generated by using the Cox, Ingersoll & Ross model.

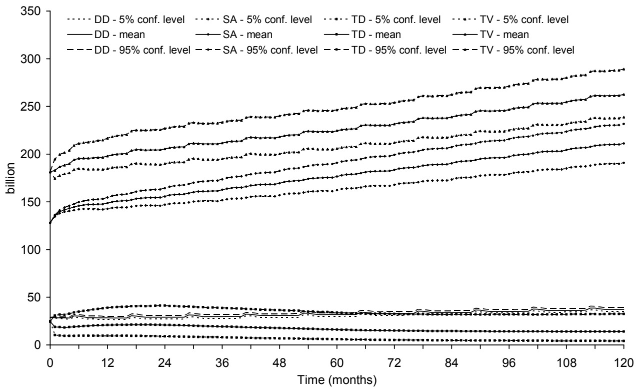
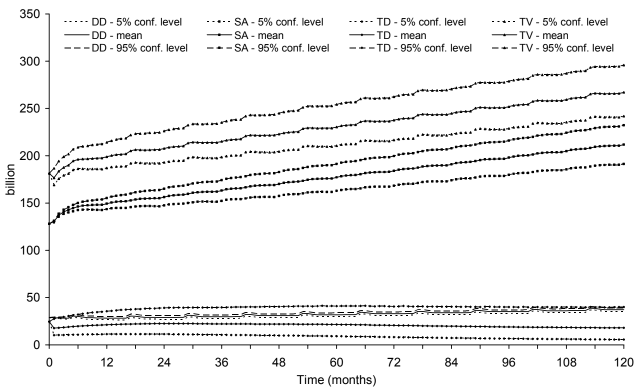


Figure 6.8 The figure shows the expected development as well as lower and upper confidence levels of demand for demand deposits, savings accounts, term deposits and total volume. Where interest rates are used, they are generated by using the multi-factor model of De Feijter (2002).



Value

Finally, with the forecasted demand and the forecasted product rates, we can calculate the value of the products. The values are visualised in Figure 6.9 on page 165 to Figure 6.16 on page 170. In all these figures we see five categories, representing the parts of the Jarrow – Van Deventer formula. These are the time zero volume of the product, the present value of volume growth, the present value of the volume after ten years and the present value of the interest rate payments. Finally, the total net present value of the product is given. This total net present value has to be regarded as the value of the net gain or loss of the product. The higher this value the better. We can show this easily. If the value of today's volume of, for example, demand deposits is equal to the current balance minus the present value of profits, we can see that the value is low, when the present value of profits are high. Assuming a constant value of a bank's assets, a lower value of liabilities increases the value of equity and vice versa.

For all these parts we show the mean value and the value at the 5% and 95% confidence levels. One should take into account that only the values for the mean scenario add up to the total net present value. This is not necessarily true for the values at the 5% and 95% confidence levels. The reason is, that these values do not necessarily have to be taken from the same scenario.

Since we require economic capital for unexpected losses, we calculate the economic capital requirement as the difference of the expected net present value of the product and the net present value of the product using the lower 5% confidence level[137] (also see section 2.4.4 from page 46).

We start with demand deposits. Again we see differences between the models. In this case, since demand deposits are assumed to be interest rate insensitive, the difference is solely due to differences in the discount rate. We saw higher rates with the Cox, Ingersoll & Ross interest rate model. It is therefore not surprising that the present value of volume growth, as well as the present value of the end volume is lower.

As a result, due to the structure of the Jarrow & Van Deventer model, the net present value of demand deposits is higher in the multi-factor situation. The differences are high. Therefore, the choice of an interest rate model has a big influence on the value of demand deposits, and thus on economic capital. If we use the multi-factor model and agree on the assumptions of the Jarrow – Van Deventer framework, economic capital for demand deposits is nearly two billion. That is, it is the difference between the expected net present value and the net present value in the 5% confidence case.

[137] The net present value of the product will only be lower than the net present value at the lower 5% confidence level in 5% of the time.

Figure 6.9 Expected value of demand deposits as well as lower and upper confidence levels using the Cox, Ingersoll & Ross interest rate process

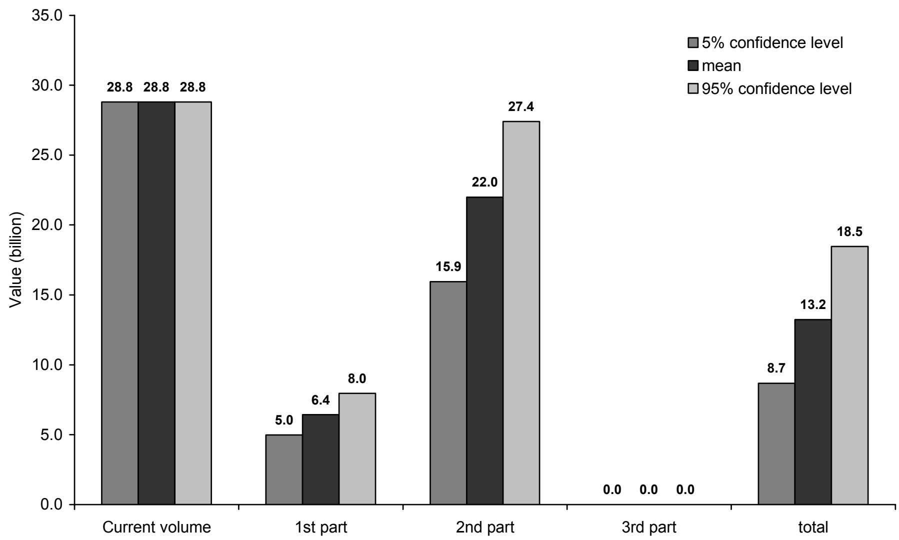
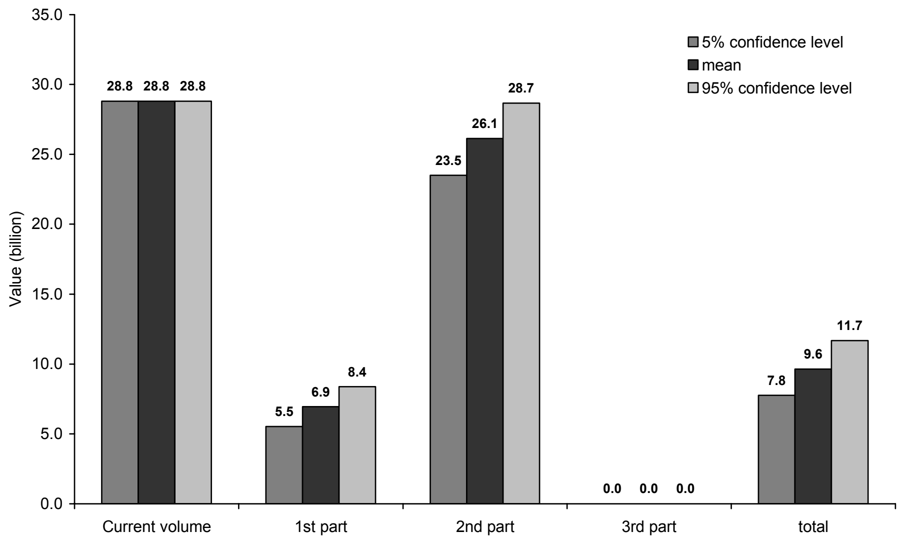


Figure 6.10 Expected value of demand deposits as well as upper and lower confidence levels using the multi-factor interest rate model of De Feijter (2002)



We then look at savings accounts. We see differences between the models in this case also. However, the differences are not only due to differences in the discount rate, but also in the savings rate as well. We saw higher rates with the Cox, Ingersoll & Ross interest rate model and as a result also higher savings rates. It is therefore not surprising that the present value of volume growth, as well as the present value of the end volume are lower in that case. On the other hand it is also logical that the present value of interest payments is higher with the CIR interest rate model.

As a result, due to the structure of the Jarrow & Van Deventer model, the net present value of savings accounts is higher in the multi-factor situation. Again, the differences are high. Therefore, the choice of an interest rate model again has a big influence on the value of savings accounts, and thus on economic capital.

Furthermore, we see that the net present value of savings accounts can become negative, indicating that the current volume plus the value of volume growth is lower than the present value of the volume at the time horizon plus the value of the interest payments.

If we use the multi-factor model and agree on the assumptions of the Jarrow – Van Deventer framework, economic capital for savings accounts is nearly nine billion. That is, it is the difference between the expected net present value and the net present value in the 5% confidence case.

Figure 6.11 Expected value of savings accounts as well as lower and upper confidence levels using the Cox, Ingersoll & Ross interest rate process

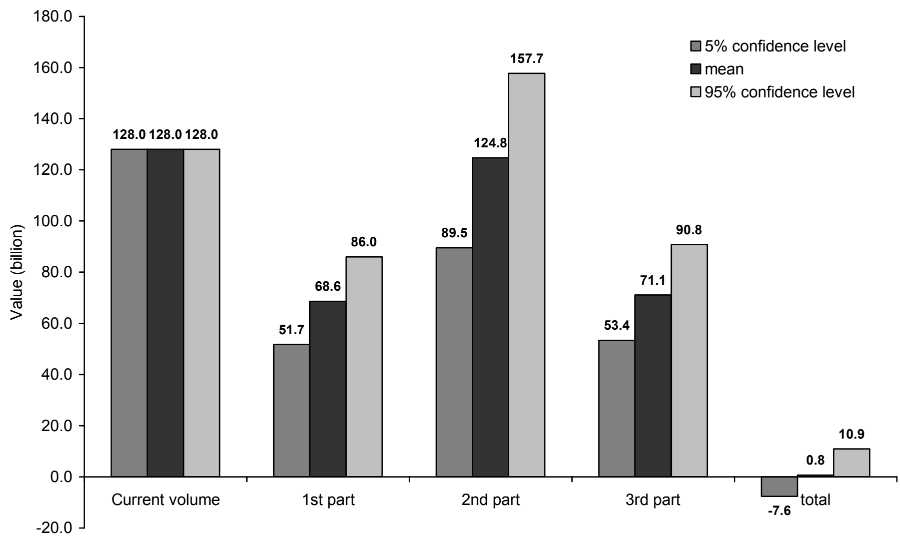
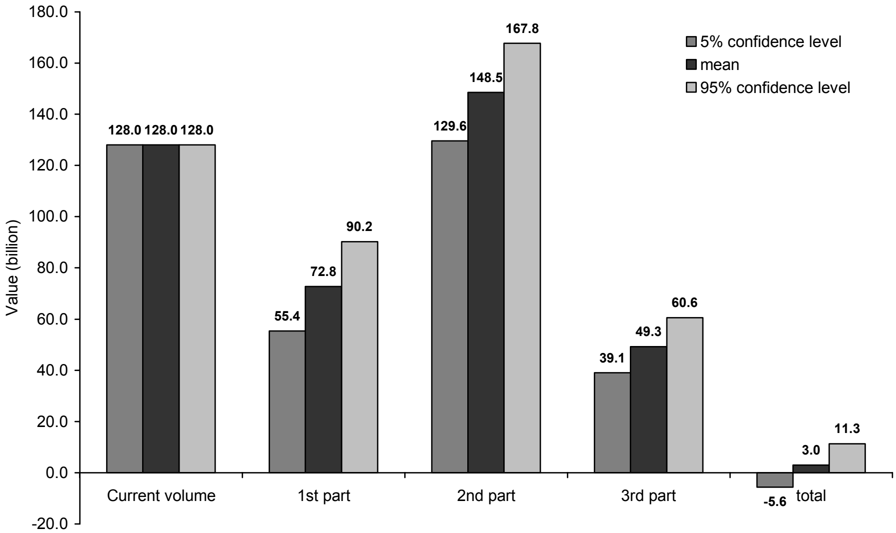


Figure 6.12 Expected value of savings accounts as well as upper and lower confidence levels using the multi-factor interest rate model of De Feijter (2002)



The next product type is term deposits. Not surprisingly, we see differences between the models in this case again. The differences are not only due to differences in the discount rate, but also in the term deposits rate and the difference between the term deposits rate and the savings rate as well. Although we see that the differences in the total net present value are small, the differences between the separate parts of that net present value are bigger. In general we see that the value of volume growth and the value of the volume at the end of the planning horizon are bigger – or less negative – when the multi-factor model is used, whereas we see the opposite for the value of interest payments. This can be explained from the differences in forecasted product rates, as well as the forecasted discount rates. At the end, both models give, as mentioned, comparable values for the net present value of term deposits. If we, again, use the multi-factor model and agree on the assumptions of the Jarrow – Van Deventer framework, economic capital for term deposits is nearly 1.5 billion. That is, it is the difference between the expected net present value and the net present value in the 5% confidence case.

Figure 6.13 Expected value of term deposits as well as lower and upper confidence levels using the Cox, Ingersoll & Ross interest rate process

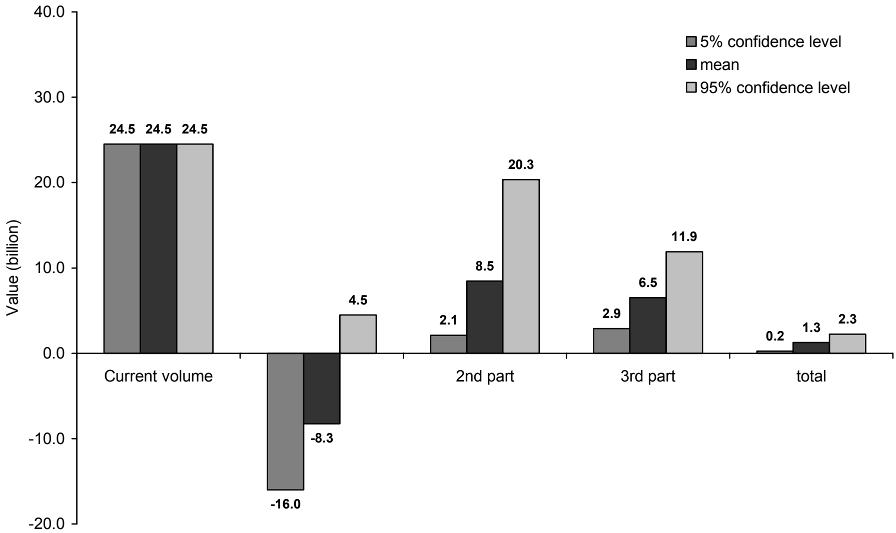
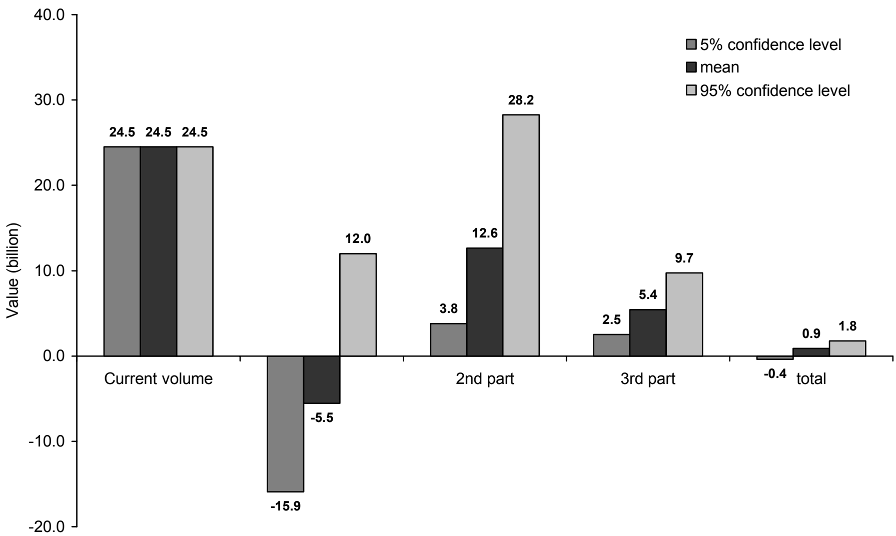


Figure 6.14 Expected value of term deposits as well as upper and lower confidence levels using the multi-factor interest rate model of De Feijter (2002)



We finally look at total volume, which is the sum of demand deposits, savings accounts and term deposits. Mostly, we see a similar pattern as with savings accounts, which is not surprising, since savings accounts form the largest part of total volume.

We see differences due to the interest rate models in this final case as well. Because we saw higher rates with the Cox, Ingersoll & Ross model, it is not surprising that the present value of volume growth, as well as the present value of the end volume are lower in the CIR case. On the other hand it is also logical that the present value of interest payments is higher with the CIR interest rate model.

For the net present value we see a mix. For the 5% confidence case, using the multi-factor interest rate model gives a higher net present value, but for the mean and 95% confidence case, the CIR model gives higher values.

If we use the multi-factor model, as we did above, and agree on the assumptions of the Jarrow – Van Deventer framework, economic capital for total volume is nearly ten billion. That is, it is the difference between the expected net present value and the net present value in the 5% confidence case. We clearly see the mitigating portfolio effect here. Economic capital for the separate items of total volume total to 11.7 billion, opposed to the 9.8 billion we find here.

Figure 6.15 Expected value of total demand using the Cox, Ingersoll & Ross interest rate process, as well as lower and upper confidence levels.

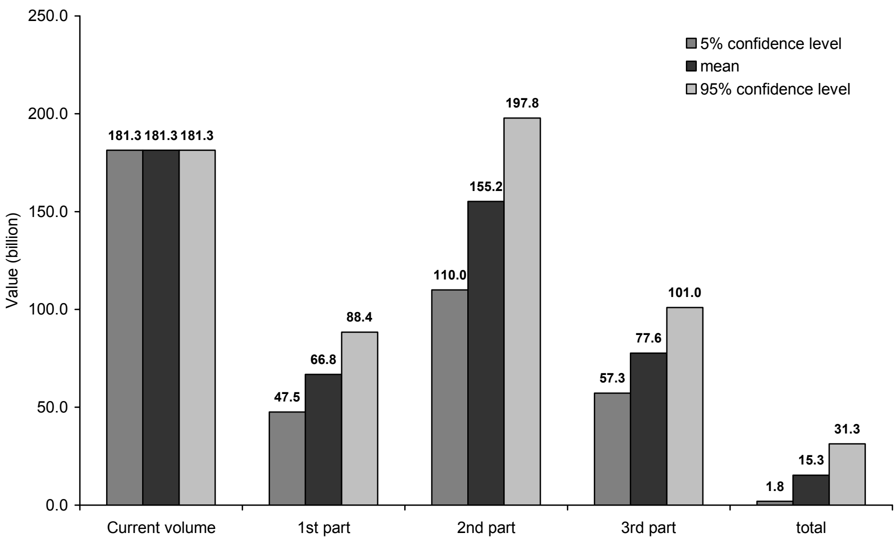
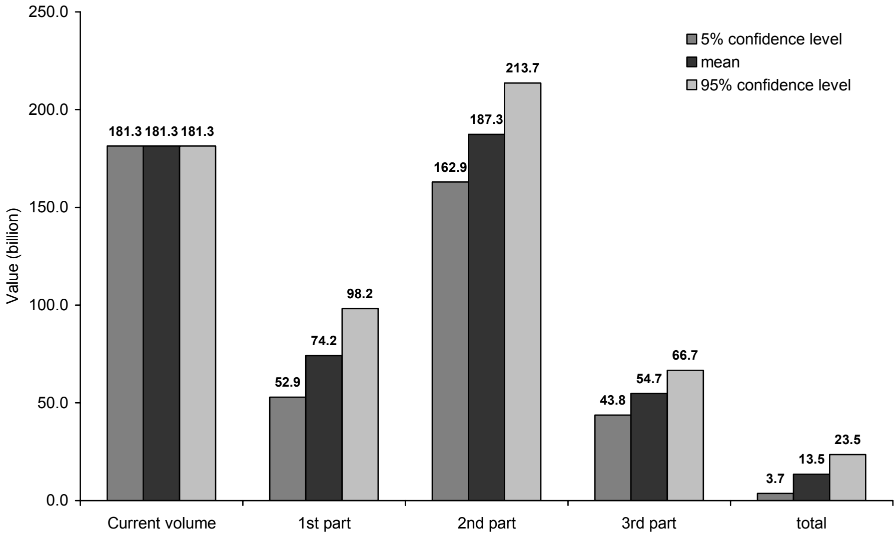


Figure 6.16 Expected value of total demand as well as upper and lower confidence levels using the multi-factor interest rate model of De Feijter (2002)



Conclusions

Summarising, we can state that the choice of the interest rate model, used for discounting and to generate the other interest rates from has a major impact on the calculation as laid out in this section. Regarding this, we conclude that it would be best to chose the De Feijter model. Because this model is multi-factor, it is capable of showing a much wider range of yield curves as opposed to the one-factor Cox, Ingersoll and Ross model. Furthermore, we can conclude that a portfolio of demand deposits, savings accounts and term deposits has a lower economic capital requirement than the separate items. Finally, we found that the net present value of savings accounts and demand deposits can become negative under unfavourable conditions. This is mainly due to the assumption that all outstanding savings accounts and term deposits volume at the assumed time horizon is paid back. An assumed higher time horizon might change this, although we may expect the volume to increase as well. Furthermore, the bank will have to pay interest for a longer period.

6.2.2 Prepayment option

The second embedded option we studied was the prepayment option. We described some studies on prepayment behaviour in chapter 4 and now ask ourselves the question what the implication of the prepayment option on the risk profile of the bank is and consequently on economic capital requirements.

First, we could ask whether the prepayment option is material. According to the studies described in chapter 4 the answer would be yes. Using an endogenous approach, Van Bussel (1998) finds the prepayment option in the Netherlands valuable, which of course means that

it influences the mortgage value, since it is embedded in the mortgage. Doff (2001), using his empirical model, finds high prepayment rates, concluding that about 80% of the savings and interest only mortgages prepay within five years of origination.
Answering positively to the question of materiality, yields a second and third question; how to manage prepayment risk and what are its effects on economic capital requirements.

Basically, the models of, for example, Doff (2001) and Alink (2002) calculate the Single Monthly Mortality (SMM), which is the monthly prepayment rate based on a number of parameters. If one of those models is going to be used, we will have to collect relevant data and can then apply the model to calculate the SMM. This SMM gives us the expected monthly prepayments over time. We can use this information in adjusting the cash flows and therefore the value. We will clarify the above with an example.

Consider an interest only mortgage with a principal P equal to 100 and a coupon C of 6% that has a remaining fixed rate period of five years or 60 months. Assume that the discount rate r_t stays constant over the coming five years at 5%. Furthermore, assume that the expected SMM is 0.01% at the start. This number grows linearly to 1.85% in three years due to seasoning, after which it stays at that level. We using equation (6.1) on page 158 to calculate the present value. The cash flows are determined by

$$CF_t = \begin{cases} C \cdot P_{t-1}/12 + \text{SMM}_t \cdot P_{t-1} & \text{if } t < 60 \\ C \cdot P_{t-1}/12 + P_{t-1} & \text{if } t = 60 \end{cases} \tag{6.3}$$

and

$$P_t = \begin{cases} 100 & \text{if } t = 1 \\ \left(1 - \text{SMM}_t\right) \cdot P_{t-1} & \text{if } t > 1 \end{cases}. \tag{6.4}$$

If we ignore prepayment ($\text{SMM}_t = 0$), we find a present value of almost 105. If we take expected prepayment into account, we find a present value of almost 104. The difference in the net present value is about 20%.

If we generalize the example, we see that models of prepayment behaviour help us in predicting prepayments. Based on the model outcome we can adjust the cash flows and find a value or interest income, which include the effects of prepayments. Again, if our prepayment model is interest rate dependent and we simulate numerous interest rate paths, we can construct a value distribution and we find the amount of economic capital for the prepayment option.

6.2.3 *Other options*

With the withdrawal and prepayment option we have the most common options. The remaining embedded options are not that important. As was mentioned in section 5.2 Van Mullem (1998) shows that even if the mortgagor knows the future interest rates and acts optimally, the interest rate consider period option is more expensive than the gain he gets from it, provided that mortgage rates are low at the start, which they currently are. Thus, the

risk of this option and therefore its influence on an economic capital requirement is negligible. However, if rates are high and a drop is expected at some time, the option might have some advantages. Because of this the capital charge will not be zero.
Again as for the withdrawal option and the prepayment option, the capital charge can be calculated by applying simulation techniques and derive economic capital from the resulting distribution. In order to take into account the effects of the embedded option, one can either use a method like Van Mullem (1998) or use a replicating portfolio technique as proposed by, for example, Cohen (1991), Kalotay et al. (1993) and Wilson (1994). A third approach is using the same techniques as are used in modelling prepayment behaviour. Instead of calculating a hazard function for prepayment, one should calculate a hazard function for exercising the interest rate consider period option. In this case one looks at the option as a penalty free prepayment option in the last y years of the mortgage. Due to the small numbers of mortgages which have this option embedded it might be hard to get a sufficiently large data set.

Embedded caps and floors as well as quotation rate options are expected to have minor impact on interest rate risk management and economic capital. The reason is twofold. First of all, as mentioned already in section 5.3 embedded caps and floors as such are not common in Dutch mortgages. That means, that although they exist, these mortgages are sold in small numbers and therefore are not material at the portfolio level. Furthermore, the risk of these embedded caps can be hedged by (a mix of) caps and swaptions. Quotation rate options are common on the Dutch market and usually have a maturity of three months which can be extended, but then the mortgagor has to pay a fee. Again the influence on interest rate risk management is expected to be small. The reason for this is that the maturity of the option is short. Taken into account that the mortgage rate is not that volatile, the expected value change due to the quotation rate option is small. A second reason is that the risk again can be hedged by buying a swaption. If this is not done and one wants to take the risk into account, this can be done by using the lowest mortgage rate of the past three months and apply this rate to all new mortgages. This way we are overestimating the risk. But again, due to the short time horizon the risk will not be substantial.

Finally, there is the choice option. As we already stated in chapter 5 the option in fact is not material, since the bank can adjust its funding to the choice of the customer. The impact on risk management and economic capital therefore is negligible.

6.3 Portfolio effects

Having described the effects of the individual embedded options on interest rate risk and economic capital, we now focus on portfolio effects. That is, we answer the question what the joint impact of the embedded options together on the risk of a portfolio is and how the joint effects impact the economic capital requirement.
We only do this for the prepayment option and the withdrawal option. The reason is that we argued in section 6.2 that the other embedded options are not material. So basically, in this section we assume a portfolio of mortgages (and cash) on the asset side and demand deposits, savings accounts, term deposits and capital on the liability side.

If mortgage rates decrease, we will see more prepayments and vice versa. Regarding demand deposits, we have argued that its volume is not sensitive to interest rate changes (see section 3.1). So no matter how interest rates change, we will probably always see a little growth in demand deposits volume. For savings accounts we found that they are moderately interest rate sensitive. That is, if the savings rate increases, we see an increased growth in savings accounts volume, whereas a decrease in savings rates shows a decreased growth in savings accounts volume. Of all 'savings' products, we found term deposits to be the most interest rate sensitive, as we expected. If the spread between the term deposits rate and savings rate is positive, we see a growth in term deposits volume, whereas a negative spread is followed by a decrease in term deposits volume. Furthermore, we learned that if term deposits volume decreases, this volume flows mostly into savings accounts.

Regarding the product rates of mortgages and the savings products, all can be set by the bank. However, there will be a different rate setting policy. Mortgage rates depend on long-term rates. Upward movements will be followed with a short delay, downward movements with a longer delay. On the other hand, the term deposit rate depends on the short-term rate. Because of this, the rate is more volatile. In this case, downward movements will be followed with only a short, if any, delay, whereas upward movements will be followed with a longer delay. The same holds for the savings rate, although the savings rate depends on a mix of a longer term and shorter term rate.

How does this impact the value of mortgages and savings products respectively? If the market rate used for discounting increases, this leads to a decrease in the value of the mortgage portfolio, which is disadvantageous to the value of capital. On the other hand, if the relevant rate in the market decreases, the value of the mortgage portfolio increases. But, because the chance of prepayment increases also with lower market rates, the potential maximum increase in value will not be reached.

For demand deposits, although its volume is not expected to be interest rate sensitive, its value can be. Since interest rates on demand deposits are assumed to be zero, the only cash flow that occurs is the repayment of the principal at the assumed maturity. The discounting factor at that time will be low, assuming that the cash flow will occur at some time in the future. However it is still about 31% if a discount rate of 4% and a 30 year horizon is used. A 100 bp. shift up or down changes the discount factor to 23% or 41% respectively. As a result the value will also change significantly and therefore the value of capital will change as well.

The value of savings accounts will decrease if the benchmark rate, used for discounting, increases. From a bank's perspective this is advantageous. However, in the end a bank will have to increase the savings rate as well, especially when competitors do. Because of this the value of savings accounts will increase again. In case of a decrease of the benchmark rate, the value of savings accounts increase, which is disadvantageous. A bank can prevent this by simultaneously decreasing the savings rate. However, if the savings rate becomes too low (compared to competitors) or if other products offer a higher return with comparable percepted risk, this could lead to a slower growth in volume, as mentioned above. As a result, the bank might need additional funding from the market, which in general will be more expensive than savings accounts.

Finally, we have term deposits. Although this product does not have the embedded withdrawal option, it is an alternative for saving. If interest rates increase, the value of term deposits will decrease. Assuming that investors in term deposits are more interest rate sensitive, they will only invest in term deposits again after the maturity of their current term deposits, if the rate is adjusted. Therefore, either the value of term deposits will increase again, assuming that the money is reinvested at the now higher rates, or to a large extent they will disappear. The latter obliges the bank to find alternative funding, which, in general, will be more expensive.

If rates decrease, the value of term deposits will increase. The bank can limit the impact of this by lowering the term deposits rate. However, as we have seen in our data, this will significantly decrease term deposits volume. Based on our models this will lead to a further increase in savings accounts in which case the bank does not need alternative funding. However, if the savings rate is even lower, the flow towards savings accounts might not occur, in which case additional, more expensive funding will be required.

We will clarify the above with an example. Figure 6.17 on page 175 shows the (simplified) balance sheet of a retail bank on January 1st. Figure 6.18 on page 176 and Figure 6.19 on page 177 show the same balance sheet on December 31st after a 100 bp. parallel shock-up and shock-down respectively.

A couple of simplifying assumptions were used in constructing the balance sheets below. First of all, we assume a time horizon of ten years. Second, we assume that the mortgages have a rate fixing of ten years. A third assumption regarding the mortgages is that we do not take any prepayment because of seasoning into account. In the shock down-scenario we assume 4% prepayment per year. A fourth assumption is that no matter what happens, demand deposits will grow by five. Regarding the savings accounts, we assume growth of five in the shock-down scenario, whereas we expect growth of ten in the shock-up scenario. With respect to term deposits we expect an increase in volume of five in the shock-up scenario, whereas we expect a decrease in volume of five in the shock-down scenario. The principal value of capital remains ten in all scenarios, although we take into account an amount of retained earnings of one in all scenarios; we assume that any excess funding will be used to sell new mortgages. Furthermore, we assume that in the shock-down scenario all prepayments are used to take out new mortgages and that the growth in mortgage volume will at least be equal to the growth in mortgage volume in the shock-up scenario. Any required extra funding will be from interbank lending. We assume that the value of the cash equals its principal value in each scenario. Therefore, in the middle balance sheets of Figure 6.18 and Figure 6.19 we use capital as a balancing item. The lower balance sheets in these figures show the differences compared to the opening balance sheet. Finally, Table 6.1 below shows the results for all six scenarios we applied.

From the figures and the table below, we learn that a bank requires profitable growth in order to be able to take interest increases. In the 100 bp. up scenario the bank is able to do so, whereas in the other shock-up scenarios the growth is not sufficient to take the increased value of the liabilities and therefore we see a decrease in the value of capital. In the shock-down scenarios we don't see this problem. Since the remaining assets become more profitable, whereas the liabilities become cheaper, the bank is able to take the increased value of the liabilities, due to volume growth, and an increase in the value of capital remains.

Table 6.1 Results for various scenarios

Scenario	Value Capital	Δ(Base Case)
Base case	24.23	
100 up	26.08	1.85
200 up	23.60	-0.63
300 up	21.23	-3.00
100 down	29.95	5.72
200 down	31.95	7.72
300 down	34.03	9.80

Figure 6.17 Base case scenario
We see the opening balance sheet on January 1st,
both based on historic cost, as well as marked-to-market.

Assumptions	Rate	Discount rate
Mortgages	6.00%	5.00%
Savings accounts	3.50%	4.50%
Term Deposits	3.50%	4.00%
Demand deposits	0.00%	4.50%

Balance sheet January 1st (Historic Cost)

Mortgages	100.00	Capital	10.00
Cash	10.00	Savings Accounts	60.00
		Term Deposits	10.00
		Demand Deposits	30.00
Total	**110.00**	**Total**	**110.00**

Balance sheet January 1st (MtM)

Mortgages	105.18	Capital	24.23
Cash	10.00	Savings Accounts	57.42
		Term Deposits	9.79
		Demand Deposits	23.74
Total	**115.18**	**Total**	**115.18**

Figure 6.18 Balance sheet after +100 bp. parallel shock. We see increased balances of the savings products due to the increased interest rate. The excess funding is used to sell new mortgages. These new mortgages are still profitable and the increase in value of these new mortgages correct for a large part the increase in value of the increased liabilities. As a result, we see a small increase in the value of capital.

Assumptions	Rate	Discount rate
Mortgages	7.00%	6.00%
Savings accounts	4.50%	5.50%
Term Deposits	4.50%	5.00%
Demand deposits	0.00%	5.50%

Balance sheet December 31st (Historic Cost)

Mortgages	120.00	Capital	10.00
Cash	11.00	Retained Earnings	1.00
		Savings Accounts	70.00
		Term Deposits	15.00
		Demand Deposits	35.00
Total	**131.00**	**Total**	**131.00**

Balance sheet December 31st (MtM)

Mortgages	123.23	Capital	26.08
Cash	11.00	Retained Earnings	1.00
		Savings Accounts	66.95
		Term Deposits	14.67
		Demand Deposits	25.54
Total	**134.23**	**Total**	**134.23**

Difference with base case (MtM)

Mortgages	18.05	Capital	1.85
Cash	1.00	Savings Accounts	9.53
		Term Deposits	4.87
		Demand Deposits	1.80
Total	**19.05**	**Total**	**19.05**

Figure 6.19 Balance sheet after -100 bp. parallel shock. We see a decreased term deposits volume leading to a loss in value. Mortgage volume increases. Additional funding is required for this new production. As a result a large part of the gain in value of the mortgages is lost, but a gain in capital remains.

Assumptions	Rate	Discount rate
Mortgages	5.00%	4.00%
Savings accounts	2.50%	3.50%
Term Deposits	2.50%	3.00%
Demand deposits	0.00%	3.50%
Interbank	3.00%	2.50%

Balance sheet December 31st (Historic Cost)

Mortgages	125.00	Capital	10.00
Cash	10.00	Retained Earnings	1.00
		Savings Accounts	65.00
		Term Deposits	5.00
		Demand Deposits	35.00
		Interbank	19.00
Total	**135.00**	**Total**	**135.00**

Balance sheet December 31st (MtM)

Mortgages	135.66	Capital	29.95
Cash	10.00	Retained Earnings	1.00
		Savings Accounts	61.83
		Term Deposits	4.89
		Demand Deposits	28.49
		Interbank	19.51
Total	**145.66**	**Total**	**145.66**

Difference with base case (MtM)

Mortgages	30.49	Capital	5.72
Cash	-	Savings Accounts	4.41
		Term Deposits	4.91-
		Demand Deposits	4.76
		Interbank	19.51
Total	**30.49**	**Total**	**30.49**

Of course, this is just one example and other assumptions would have lead to other numbers, but in general we can state the following: although the withdrawal option is present in two large products on the liability side of the balance sheet, savings accounts and demand deposits, its influence is marginal. In the past ten years we have witnessed declining interest rates in the market, as well as for these products, whereas the volume of savings accounts and demand deposits has grown. Therefore, although the potential risk caused by the withdrawal option is large, since the bank can loose the biggest part of its balance sheet, the actual risk is considered small[138]. Regarding the prepayment option, we can state that this risk is more significant. We have seen in the late 1990's that prepayment rates went up, because of historically low mortgage rates. Since large parts of bank's mortgage portfolios have been renewed since then, prepayments are not going to be very likely in the near future. However, when mortgage rates go up again, prepayment might become more important again.

6.4 Conclusions

After we studied methods to measure the effects of embedded options on interest rate risk and economic capital in chapters 3 to 5, we focussed on actual measurement in this chapter. We started with a study of each option's individual effect. We argued that only the withdrawal option as well as the prepayment option have a potential large impact on interest rate risk and economic capital. The interest rate consider period option is only sold in small numbers and on top of that a fee is charged for this option. As a result the risk of this option, although not zero, is negligible. Embedded caps and floors are not common in Dutch mortgages. Therefore, the number of mortgages sold with such features are negligible and so is the impact of embedded caps and floors on interest rate risk and economic capital. The quotation rate option on the other hand is common and usually free for a period of three months. However, due to its short maturity, the risk is small. Furthermore, the risk can be simulated by applying the lowest rate of the past three months to new mortgages in the portfolio. Finally, we have the choice option. In fact, this option is risk-free, because a bank can always act based upon the choice of the mortgagor.

This leaves us with the withdrawal option and the prepayment option. The withdrawal option is associated with savings products. Based on Keynes' liquidity preference theory (see chapter 3 on page 73 for more details) we identified three typical savings products. With increasing interest rate sensitivity these are: demand deposits, savings accounts and term deposits. The latter does not have the embedded option, but is taken into consideration as an alternative product[139]. We developed models for these products in chapter 3. We saw empirical evidence for Keynes' theory. Apart from seasonal disturbances, we saw a slow increase in demand deposits volume over time, no matter what the interest rate was. Savings products are more sensitive and closely correlated with term deposits. That is, when the term deposits rate is higher than the savings rate, we see that savings volume increases more slowly, then when the reverse is true in which case we see a rapid decrease in term deposits.

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[138] Although the actual risk is likely to increase if it is made easier to switch banks.

[139] In fact, other alternative products should be taken into consideration as well, for example investments in the stock market. Unfortunately, we did not have that data to our disposal.

In this chapter we used the models of chapter 3 to simulate the developments of these products over a period of ten years. Summarising, we can state that the choice of the interest rate model, used for discounting and to generate the other interest rates from, has a major impact on the calculation as laid out in this chapter. Furthermore, we can conclude that a portfolio of demand deposits, savings accounts and term deposits has a lower economic capital requirement than the separate items. Finally, we found that the net present value of savings accounts can become negative under unfavourable conditions. This is mainly due to the assumption that total savings accounts volume is paid back at the assumed time horizon. An assumed higher time horizon might change this, although we may expect the volume to increase as well. Furthermore, the bank will have to pay interest for a longer period.
Concluding, we state that the risk is fairly small. In fact, no matter what the savings rate is, we always see some growth in its volume. Term deposits are more volatile, but only form a small part of the balance sheet. Furthermore, this product does not include the withdrawal option. Therefore, we conclude that the impact on interest rate risk and economic capital due to the withdrawal option is small. This is reflected by most banks' policy to treat demand deposits and savings accounts as partial long-term funding and partial short-term funding, where the long-term part is usually larger. The biggest potential risk is a new competitor who offers an extremely high interest rate on his savings account. Due to the moderate interest rate sensitivity of savings accounts an outflow of funds could occur.

With the studies described in chapter 4 we estimated the impact on interest rate risk and economic capital of the prepayment option in this chapter. We used a simplified example to show how the models of prepayment behaviour work. From this example we learned that the change in value of a mortgage portfolio due to prepayment can be substantial. In our example the net present value of a mortgage decreased by 20%, which of course is a substantial amount.

After studying the individual effects, we focussed on the joint effects and looked at the balance sheet of a typical retail bank in section 6.3. We then applied six simple parallel shock scenarios to this balance sheet using several simplifying assumptions. From the resulting figures, we learned that a bank requires profitable growth in order to be able to take interest increases. In the 100 bp. up scenario the bank is able to do so, whereas in the other shock-up scenarios the growth is not sufficient to take the increased value of the liabilities and therefore we see a decrease in the value of capital. In the shock-down scenarios we don't see this problem. Since the remaining assets become more profitable, whereas the liabilities become cheaper, the bank is able to take the increased value of the liabilities, due to volume growth, and an increase in the value of capital remains.
Of course, this is just one example and other assumptions would have led to other numbers, but in general we feel we can state the following: although the withdrawal option is present in two large products on the liability side of the balance sheet, savings accounts and demand deposits, its influence is marginal. In the past ten years we have witnessed declining interest rates in the market, as well as for these products, whereas the volume of savings accounts and demand deposits has grown. Therefore, although the potential risk caused by the withdrawal option is large, since the bank can loose the biggest part of its balance sheet, the actual risk is considered small. As already mentioned the biggest risk occurs when a (new) competitor

suddenly offers an extremely high interest rate on comparable savings accounts. Due to the moderate interest rate sensitivity this might lead to a potentially large outflow of funds.
Regarding the prepayment option, we can state that this risk is more significant. We have seen in the late 1990's that prepayment rates went up, because of historical low mortgage rates. Since large parts of bank's mortgage portfolios were renewed since then, significant prepayment rates are not going to be very likely in the near future. However, when mortgage rates go up again, prepayment might become more important again. The worst case scenario for prepayment is when rates first go up significantly and then decrease again.

7

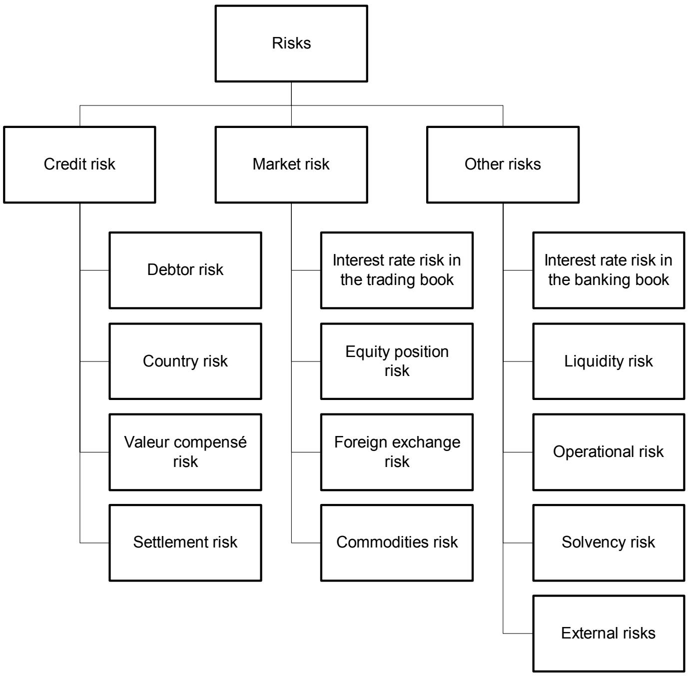
Conclusions and recommendations

7.1 Conclusions

Now, being at the end of our thesis, we can look back and see whether we found answers to our research questions and whether we reached the goal with which we started this thesis. Below we draw our conclusions on each research question separately.

Our first question read: *what risks can be identified in banking?* We answered this question in chapter 2. We studied several risk typologies found in literature and derived a general risk typology from that. We concluded that there are three main risk categories: credit risks, market risks and other risks (see Figure 7.1 below). Other risks include interest rate risk in the banking book, liquidity risk and operational risks.

Figure 7.1 General risk typology



Research question two read: *what is interest rate risk in the retail banking book and how is it measured?* This question was also answered in chapter 2. First of all we gave a definition of interest rate risk in the retail banking book, which reads:

Negative effects in accrual income of and/or negative value changes in on- and off-balance-sheet positions in the retail banking book due to unexpected changes of interest rates.

We concluded that it is not necessary to bear an actual loss to speak of interest rate risk in the retail banking book. A decline in earnings or value due to interest rate changes is also interest rate risk. Furthermore, the change in interest rates has to be unexpected, since one can anticipate on expected rate changes.

The banking book was defined as the portfolio in which the bank tries to profit from the margin between what is earned on assets and paid on liabilities. It was stated that the banking book can be split into wholesale and retail. Since our goal is to find the effects of embedded options and most embedded options can be found in typical retail instruments, this thesis focussed on the retail banking book.

Studying interest rate risk in the banking book in greater detail made clear that it can be caused by a difference in the repricing characteristics of assets and liabilities (repricing or mismatch risk and yield curve risk). Another cause can be basis risk. Finally, embedded optionality in retail banking book products like mortgages, savings accounts and demand deposits can also cause interest rate risk. A total of six embedded options were identified, which are:

a) withdrawal option;
b) prepayment option;
c) interest rate consider period option;
d) embedded caps and/or floors;
e) quotation rate option; and
f) choice option.

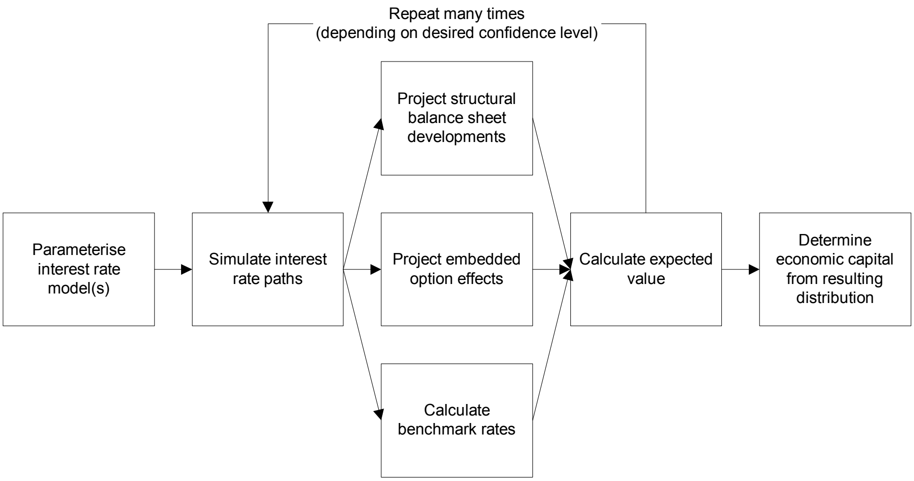
In order to measure interest rate risk in the banking book, we found that a number of techniques have been developed in the past to quantify the amount of interest rate risk (in the banking book). Techniques like gap analysis, earnings at risk, duration analysis, and value at risk were studied in some detail in section 2.3.3. All these techniques take either a value or an income approach. This means that the magnitude of interest rate risk is related to the chances of decreases in either the value of a portfolio or the (accrual) income in that portfolio. Furthermore, techniques could be used statically or dynamically. Static approaches use predetermined scenarios (if any), whereas dynamic approaches use some form of simulation. All techniques have their pros and cons. We noticed a trend towards more sophisticated value based methods.

Finally, chapter 2 focussed on research question three, which read: *what is economic capital and why is it important?* We split that question in two. First we studied the concept of economic capital and economic capital models, then we focussed on why economic capital is so important.

It was shown that within the banking industry three concepts of capital can be identified, which are accounting capital, regulatory capital or solvency and economic capital. Economic capital is defined as the amount of equity that is required to cover for unexpected losses within a certain confidence level and a certain time period. From a management control perspective, economic capital is a useful concept, because it allows for good risk-reward trade-offs.

Although current accounting practice in the retail banking book is usually income based (accrual), interest rate risk is usually measured using both earnings based and value based methods, with the latter becoming more and more important. Regarding economic capital models, we see that the majority of the approaches is value based. This can be explained from the fact that the economic capital concept is relatively new, and only recently has got more attention. Because new regulation is becoming value based more and more and focussing on bank's internal capital adequacy models - economic capital – these models are likely to be value based too. Another advantage of a value approach is that changes in market interest rates have a more direct influence on the exposure of a bank (see for example footnote 84 on page 67). As a result, we developed a general economic capital framework as laid out in Figure 7.2.

Figure 7.2 General economic capital calculation framework



We then had to find an answer to the second part of research question three, i.e. why economic capital is so important. We studied capital and accounting regulation to find an answer.

Starting with capital adequacy regulation, it was shown that the capital adequacy regulation becomes more risk-based, focused on internal models and that more risk types are included. As a result regulatory capital more closely resembles economic capital.

Studying the international accounting regulation for banks, it can be concluded that International Accounting Standard 39 (IAS 39) will have a big impact on current accounting practices within banks. The first big change is that under IAS 39 all financial instruments, including derivatives, must be recognised in the balance sheet. As a result off-balance-sheet items will not exist anymore. Furthermore, all assets must be valued at fair value, except for three categories:

a) loans and receivables originated by the enterprise and not held for trading;
b) other fixed maturity investments, that the enterprise intends and is able to hold to maturity; and
c) financial assets whose fair value cannot be reliably measured.

On the other hand, financial liabilities should always be measured at original amount less principal repayments and amortisation. Only derivatives and liabilities held for trading should be measured at fair value.
Summarising, IAS 39 will have a big impact on banks and probably on risk management as well. Currently, the retail banking book is usually accounted for on an accruals basis, or in other words, based on historic costs. With IAS 39 this might change with (fair) value becoming more and more important and sometimes even obligatory, at least for derivatives.
Typical instruments on the asset side of the retail banking book are mortgages and other loans. These are originated loans in IAS 39 terms, which allows the bank either to carry them at historic costs or at fair value.
On the liability side, the situation is slightly different, because only instruments explicitly held for trading should be measured at fair value, all others at historic costs, or better at amortised costs. That means that typical retail banking book instruments on the liability side on the balance sheet as savings accounts or demand deposits will be valued on a amortised cost basis. The difference between the asset and liability side of the balance sheet might lead to perverse incentives and is not defensible from a management control perspective. It would be better to value both sides analogously.

Based on the above, we see a tendency in both capital as well as accounting regulation to focus more and more on market value approaches and “real” risks. All this calls for a risk management and economic capital framework that is capable of giving correct risk and economic capital figures. In fact, what we see is that the capital concepts we defined earlier (see section 2.4.2) are becoming more alike. As a result, economic capital is becoming more important.

With research questions one, two and three answered, we started to focus on the effects of embedded options in interest rate risk in the retail banking book and economic capital. We started with answering research question four, which read: *in what way can the effects of embedded options in the retail banking book be measured?* In chapters 3 and 4 we studied how to measure the effects of the withdrawal and prepayment options respectively. In chapter 5 we focussed on the other options.

The withdrawal option is present in demand deposits and savings accounts. So answering this question in fact means that we are trying to explain saving behaviour. A well known study on saving behaviour is Keynes’ study of individuals’ liquidity-preference (Keynes, 1936). According to Keynes, an individual basically makes two decisions. The first is how much of his income he will consume now and how much he will reserve in *some form* for later consumption. The second decision is in *what form* he will store this reserved part.

Keynes distinguishes between three divisions of liquidity-preference, which he calls (1) the transactions-motive or income- or business-motive; (2) the pre-cautionary-motive and (3) the speculative-motive. The first motive can be explained, because individuals store money in cash to bridge the interval between the receipt of income and its imbursements. The second motive can be explained, because individuals want security about the future cash equivalent of their resources today to provide cash for sudden expenditures. Finally, the third motive can be explained by individuals wanting to make a profit by investing their money. It is not the immediate availability of money without the risk of loosing some that is important here, but the return. The amounts of money stored by the first two motives are not expected to be very sensitive to interest rate changes, whereas the money used for the speculative-motive is.

When this is applied with respect to the withdrawal option, we can identify the same three classes. First of all, "saving" by individuals to pay for their bills, is done on a demand deposit. Interest on these accounts is low or zero. The amounts on these accounts are expected to be relatively interest rate insensitive – people have to pay their bills anyway. However, with the introduction in the Netherlands of telebanking and internet banking, this might have changed. This is because it has become easier to transfer amounts between a demand deposit and a savings account and vice versa, often within a day, people may become more interest rate sensitive and thus try to minimize the amounts on their demand deposits. Due to a lack of data the impact of this effect is not modelled.

A second class of savings is the "normal" savings. People save on their savings accounts for later big consumptions, for example buying a car. Savings in this category are expected to be moderately interest rate sensitive.

The above two categories of savings are typically done on products, which include the withdrawal option. The third category, that is speculative savings, is somewhat different. It is not the type of product that is important here, but the return. In this category, people are expected to switch relatively quicker between products. In this category investments in stocks and/or stock options are found, as are investments in term deposits and/or ordinary savings accounts, depending on the expected return.

Since we concluded that economic capital should be calculated using a value approach, our final goal in chapter 3 was to find a valuation procedure for Dutch demand deposits, savings accounts and term deposits. To do this, we first did a literature study and found some valuation methods. We described three of them in more detail. The first was Wilson's replicating portfolio method. The second approach was the Hutchison and Pennacchi approach. They use an equilibrium approach for the valuation of indeterminate deposits. Jarrow and Van Deventer on the other hand use a non-arbitrage approach and was third method which was studied .

After studying these techniques, we decided to use the Jarrow-Van Deventer approach because this model is easily implemented in simulation, as well as the underlying theory, which captures the demand characteristics of demand deposits and savings accounts.

Since the Jarrow-Van Deventer approach requires demand models, we then focussed on modelling savings demand. Some demand models found in literature were described, like the Wilson model, the Jarrow-Van Deventer model and others.

However, we decided not to use any of these models. The reason for not doing so was that most of them use previous month's volume (and other variables) to estimate this month's volume. Whilst volume from month to month shows a large correlation, there is the danger of a unit root in the series causing the series to be non-stationary. Due to this non-stationarity

general assumptions of least squares regression do not hold and the resulting statistics of the regression must be handled with care. In our data, we also found unit roots. This was the case for both savings volume and term deposits volume.
Therefore, we estimated our own models. Before estimating our own models, we first studied the determinants of saving behaviour. Based on several studies the following indicators were identified:

- household income;
- the level of interest rates on savings accounts;
- expected return on the stock market;
- the marginal tax rate; and
- several demographic factors such as:
    - age;
    - social background;
    - family composition; and
    - region.

Then we started with a model for total volume, which is the sum of demand deposits, savings accounts and term deposits. We limited our analysis to the retail sector. Unfortunately, we did not have data on the client level, so we can not take the previously mentioned demographic factors as well as household income into account. For the latter the gross national product (GNP) was used, since GNP can be regarded as a proxy for income. Because we only had quarterly data on GNP, we estimated a quarterly model. For the demographic and other economic factors, we used a linear time trend, although this trend did not show up in our final model.
Because of the unit root we estimated a model of the first difference of total volume ΔTV_t. In our final model, significant variables are the first difference of GNP, the change in the AEX index in six months, dummy variables for the first and second quarter to reflect seasonality and the one-month lagged change in total volume itself.
Although the resulting model gives intuitive results and the explanatory power is around 80%, we doubt the forecasting performance. Since, the model includes GNP and AEX variables, which have to be modelled themselves, the forecast will most likely show large variances.
As a result, we estimated models for demand deposits, savings accounts and term deposits separately. The demand deposits series does not show a unit root, whereas the series of savings accounts and term deposits do. We therefore estimated a model of DD_t instead of ΔDD_t. Significant variables in the final model are the one month lagged volume of demand deposits, a constant and time trend and dummy variables for May, July and August. The dummy variables can be economically explained by the fact that most Dutch employees get a holiday allowance in May, whereas they spend it mostly in July and August. The explanatory power is very good with an adjusted R^2 of about 99%. Because of this high explanatory power, the forecasts, both in-sample and out-of-sample, are good as well.

The series for savings accounts shows a unit root, as was already mentioned. Therefore, we estimated a model for the first difference in savings accounts volume ΔSA_t. We found the one month lagged change in savings volume ΔSA_{t-1}, the one month lagged change in term deposits volume ΔTD_{t-1}, and dummy variables for December and January (interest payments) and May and June (holiday allowance) to be significant. The explanatory power is quite good, with about 66% of explanation. Regarding forecasting, we see that the model performs well on average, although the large jump in January 2001 is missed, in both in-sample and out-of sample forecasting. The major reason for this is that the huge increase in savings volume in January 2001 is most likely caused by a change in the Dutch tax regime, which is not captured in the model. This causes an underestimation of the resulting savings volume, although there is some recovery in the time after. In the end, the results are satisfactory.

The term deposits series also shows a unit root. However, this time, we don't solve this by trying to estimate a model on the first difference ΔTD_t. The reason is that the time series of term deposits shows a different pattern than the times series of demand deposits and savings accounts. Whereas these series show an (upward) trend, term deposits volume seems more cyclical. We therefore estimated a model where we use a constant to represent the "minimum" volume of term deposits. Furthermore, we included the difference between the term deposits rate and the savings rate. A third variable that is included is a dummy variable that has the value one if the observation is for January 1998 and zero otherwise. This dummy is to take into account the regime change as of that date. Finally, we included a first order moving average term. To prevent term deposits volume from becoming less than zero, we estimate the model on the natural logarithm of term deposits volume.

The explanatory power of the model is very good with an adjusted R^2 of about 85%. Regarding the forecasting power of the model, it turns out that both the in-sample and out-of-sample forecasts are reasonably good.

We then estimated models for the savings rate, the term deposits rate and the risk-free rate. Regarding the savings rate, we tried several models, amongst which the Wielhouwer & Van der Ende model. This model explains changes in the savings rate by changes in the short-term rate and long-term rate as well as a factor, which compares the assumed return on savings accounts with the current savings rate and a constant margin. We adjusted the model to use moving average short-term and long-term rates. After estimating the model, the change in the moving average long-term rate was not significant, so we removed it from the model. The remaining model we referred to as the adjusted Wielhouwer & Van der Ende model. In this model the margin turned out to be around 1%, which is a reasonable value. Although the explanatory power is about 30%, the model performs quite well in forecasting.

For the term deposits rate, we only tried one model, which gave acceptable results. In this model, the term deposits rate is a fixed fraction of the one-month EURIBOR rate, indicating higher margins at higher rates and vice versa. The model fits well with an adjusted R^2 of about 86%. The model's forecasting capabilities are reasonable as well.

Finally, for the risk-free rate, we decided to use both a one-factor model, the well-known Cox, Ingersoll & Ross (CIR) model as well as a multi-factor model, for which we used De Feijter's three-factor model (De Feijter, 2002). That is, De Feijter's model simultaneously estimates three points on the term structure. Other maturities are then calculated by applying the Nelson-Siegel function. This model is capable of capturing the most important empirical phenomena that have been observed: (1) the yield curve is increasing on average; (2) the term structure of volatilities is decreasing on average; (3) yield lie on a smooth curve, hence yield with little time to maturity are highly correlated; (4) interest rates are more volatile when the interest rate level is high; and (5) mean-reversion is stronger in cases where the interest rate level is further away from the mean-reversion level.
We estimated the CIR model using the Maximum Likelihood technique. The results indicated weak evidence for the mean reverting character of the model. However, the model provides reasonable patterns for the short rate.
Regarding the multi-factor model, we used the parameter values estimated by De Feijter (2002). This model is capable of producing a rich variety of yield curve shapes, as was clearly shown in Figure 3.38 on page 131.
With the demand models and interest rate models estimated, we had all the ingredients for applying the Jarrow – Van Deventer valuation formula. We handled the application of it in chapter 6.

Regarding the prepayment option we studied and described research on the prepayment option embedded in a mortgage contract in chapter 4. A mortgage is a contract which authorises the lender (the mortgagee) to sell the mortgaged property and foreclose the loan if the borrower (the mortgagor) fails to make the agreed-upon payments (Van Bussel, 1998). The prepayment option grants the mortgagor the right, not the obligation, to prepay (parts of) his loan. In the Netherlands this option is restricted to only 10% or 20% of the outstanding notional of the loan. That is, if the mortgagor wants to prepay a larger percentage, he has to pay a prepayment penalty, which is normally the present value of the difference between the value of the old and the new mortgage. The penalty does not have to be paid when the new rate is higher than the old rate, when the mortgagor moves, or when the mortgagor dies.
We first described the mortgage market in the Netherlands and the main differences between the Dutch and the US market. We noticed that the market is booming, with the numbers of mortgages as well as the outstanding amount, increasing fast. We further described the most common mortgage types, where we noticed that so-called traditional mortgages, like linear and level pay mortgages, have become less popular during the 1990s whereas new mortgage types as savings and investment mortgages as well as interest only mortgages became more popular.
Regarding the differences between the US and Dutch market, we concluded that the products sold differ substantially, as well as the prepayment option itself, because there is no prepayment penalty in the US, although this is changing. That is, American mortgagors have the choice to accept restrictions on their prepayment option, and getting a lower mortgage rate in return.
Despite the differences between the Dutch and US market, most Dutch researches start with a study of US research. The reason is that there is a vast amount of US research on the prepayment option. Usually, there is a distinction between endogenous or optimal call models

and exogenous or empirical models for prepayment behaviour. The first category assumes that prepayment rates depend only on prevailing interest rates. As soon as some pre-defined criterion is met, for example the option is in the money, prepayment is triggered. However, empirical evidence shows that this kind of optimal behaviour does not explain all prepayments. It often occurs that the option is exercised when it is not optimal to do so and vice versa. Empirical models try to explain this behaviour by linking variables to historical prepayments.

Recently, some Dutch studies on the prepayment option have been performed. We therefore decided to focus on Dutch studies. The only US study we studied more closely is the 1992 paper of Kang & Zenios. The reason is that this study more or less forms the basis for nearly all subsequent empirical research regarding prepayment behaviour, including the Dutch.

Kang & Zenios' study became known as the "Wharton" model on prepayment. In this model prepayment is explained by four factors, viz. refinance incentive, seasonality, seasoning and burnout. The refinance incentive measures the financial gain of prepayment. Seasonality measures seasonal fluctuation in prepayment rates. Seasoning and burnout are aging effects. Seasoning describes the effect that prepayment is usually low for a new loan, after which prepayment rates start to increase during the next three to five years. After that period, the loan is called seasoned, meaning that prepayment rates do not increase anymore. Burnout is the opposite effect, that is, that prepayment rates tend to decrease as mortgages age. The reason for this is that more active mortgages have probably prepaid, leaving the less active (Kang & Zenios, 1992).

We then turned our focus to Dutch studies on prepayment behaviour. We started with the first study, known to us, which is Van Bussel's 1998 research on the valuation and interest rate risk of mortgages (Van Bussel, 1998). Van Bussel uses an endogenous approach. More specifically, Van Bussel distinguishes between an optimal call prepayment rule and a rule based on a "moneyness boundary". Under optimality, prepayment is triggered when the present value of the mortgage, if left uncalled, exceeds the outstanding debt plus any refinancing costs associated with refinancing the loan. The "moneyness boundary" prescribes prepayment when it reduces the future costs for the mortgagor. Using these prepayment rules, Van Bussel (1998) concludes that the value of a 10% penalty-free prepayment option equals 25% of the value of a prepayment option without any prepayment limitations. For a 20% penalty-free prepayment option the value even equals 50% of the value of a prepayment option without prepayment limitations.

Van Bussel also developed an empirical model, but its use and explanatory power are limited due to the fact that he only had 333 mortgages in their first 5½ years of origination at his disposal to base his model on.

In 2001, Doff also studied prepayment behaviour of Dutch mortgages. Doff had access to individual mortgage data of Rabobank, the largest Dutch mortgagee, from December 1997 until December 2000. Using a statistical technique called survival analysis, Doff estimated models for three types of mortgages, viz. fully redemption mortgages, savings mortgages and interest only mortgages. Doff's models use the following variables: refinance incentive, seasoning, seasonality and whether or not the mortgage has an interest rate consider period option. The latter two variables are measured using dummy variables. Although all models use the same variables, the importance of the variables differs in each model.

In 2001 as well, Charlier and Van Bussel also studied prepayment rates. They developed separate models for savings mortgages and interest only mortgages. Regarding savings mortgages, they find that prepayment rates increase with the age of the mortgage contract. If burnout is excluded, they also find a positive relation between prepayment and the refinance incentive. However, when burnout is included, the effect of the refinancing incentive disappears and is taken over by burnout. When looking at seasonality, the dummies indicate that prepayment rates are higher than average in December. For savings mortgages, prepayment is lower than average in January and February. Also the apartment dummy is significant, indicating that apartment owners prepay faster than other mortgagors. For interest only mortgages, similar conclusions hold. However, the parameter values are different and the upgrading effect, that is the effect of the apartment dummy, is less prevalent (Charlier & Van Bussel, 2001, p. 23).
Finally, we described the research undertaken by Alink (2002). Alink develops both a general model and separate models for different mortgage types using logistic regression. Because the separate models perform only slightly better than the general model, Alink decides to use the general model. The model is estimated on SNS bank data and back-tested on data of DBV Verzekeringen and Rabobank. After these back-tests, the model was slightly adjusted. Variables in this final model are seasoning, refinance incentive, loan-to-foreclosure-value, age of the borrower, interest rate movement, the market rate and the rank of the mortgage. Furthermore, there are dummy variables for whether or not the mortgage is sold via an intermediary, the property type, mortgage type and whether the mortgage is in its second or third interest fixed period.
Concluding on the above, we see that the Dutch empirical models become better, due to an increasing history and quality of data. However, this data still does not contain all variables that might explain prepayment behaviour, as is shown by Alink (2002). Therefore, data should not be deleted, but stored for historical analysis. A second conclusion is that the prepayment option does have a significant effect. All researches find significant prepayment rates. Bearing this in mind, we can conclude that the most expensive type of prepayment option is the “movement” option, since in this case prepayment is penalty-free.
So how does this study helps in finding an answer to research question four, which read: *in what way can the effects of embedded options in the retail banking book be measured?* Basically, what we have learned from the study performed in chapter 4 is that one can either use endogenous and exogenous methods for predicting mortgage prepayment. Both have their advantages and disadvantages. Most recent researches use exogenous methods. Usually, prepayment rates are modelled and forecasted by using survival techniques. The performance of such models is reasonably good, if the correct variables are included. However, we need to be careful in using these models in situations that differ substantially from the situation in which the models were estimated. For example, most models are estimated using data from a period in which mortgage rates decreased to an all time low, causing prepayment rates to increase. The question now is, what the performance of these models is in increasing rate environments, for example?

Finally, we answered research question four for the other embedded options, viz. interest rate consider period option, embedded caps and floors and the quotation rate option as well as the choice option in chapter 5.

Regarding the interest rate consider period option, we found that there are basically three approaches to model the effects. The first is a replicating portfolio technique as proposed by Cohen (1991), Kalotay et al. (1993) and Wilson (1994), for example. The second approach is to view the interest rate consider period option as a form of penalty-free prepayment in the last y years of the rate fixed period. Finally, one can use simulation. An example of this approach is given by Van Mullem (1998). Comparing these techniques, we concluded that simulation seems best. The reason is the differences between the interest rate consider period option and the prepayment option as well as the difficulty in finding a replicating portfolio, due to other embedded options in a mortgage. In simulation one can take the effects of these options into account as well, although one needs to make assumptions on the behaviour of mortgagors. The risk of the interest rate consider period option is low though. The main cause for this is that the mortgagor needs to pay fees during the fixed period of the mortgage with the embedded interest rate consider period option. Usually this fee is 20 basis points. One of the conclusions of Van Mullem (1998) is that this fee is enough to hedge the risk of exercising even if the mortgagor behaves optimal[140]. Furthermore, mortgages with this option embedded are only sold in small numbers.

Embedded caps and floors are not common in Dutch mortgages. Usually, these options can be found in American adjustable rate mortgages (ARMs), where they limit the risk of interest rate increases for the mortgagor, while at the same time limiting the risk of interest decreases for the mortgagee. The only cap that is present in Dutch mortgages is the quotation rate option. Once the mortgagee offers the mortgagor a mortgage, this offer usually contains a quotation rate option. Effectively, this option insures the mortgagor against interest rate increases during the quotation period. On the other hand, the mortgagor profits to a full extent from interest rate decreases. The coupon on the mortgage once the offer is locked in is the lowest between the quotation date and the lock-in date. Although this option is present in all quotes, the risk is fairly small, due to the fact that the quotation often has a maturity of only three months and that mortgage rates are usually not that volatile. Using the lowest mortgage rate in the past three months as the locked-in rate in simulation will probably model the risk of this option well.

Finally, we described the choice option. We concluded that the risk in this option will be low, since the bank can adjust its funding to the choice of the mortgagor. Furthermore, mortgages are usually funded on a portfolio level, which further mitigates this risk.

Finally, in chapter 6 we focussed on the last research question, which read: *what are the effects of embedded options in the retail banking book on interest rate risk and economic capital?*

We started with a study of each option's individual effect. We argued that only the withdrawal option as well as the prepayment option have a potentially large impact on interest rate risk and economic capital.

In chapter 6 we used the models of chapter 3 to simulate the effects of the withdrawal option. We concluded that the choice of the interest rate model, used for discounting and to generate the other interest rates from, has a major impact on the calculations. Furthermore, we can conclude that a portfolio of demand deposits, savings accounts and term deposits has

[140] The only exceptions are the $0+1$ and $0+2$ mortgages.

a lower economic capital requirement than the separate items. Also, we found that the net present value of savings accounts can become negative under unfavourable conditions. This is mainly due to the assumption that total savings accounts volume at the assumed time horizon is paid back. An assumed higher time horizon might change this, although we may expect the volume to increase as well. Furthermore, the bank will have to pay interest for a longer period.
In conclusion, we state that the risk is fairly small. In fact, no matter what the savings rate is, we always see some growth in its volume. Term deposits are more volatile, but only form a smaller part of the balance sheet. Furthermore, this product does not include the withdrawal option. Therefore, we conclude that the impact on interest rate risk and economic capital due to the withdrawal option is small. This is reflected by most banks' policy to treat demand deposits and savings accounts as partial long-term funding and partial short-term funding, where the long-term part is usually larger. The biggest potential risk is a new competitor who offers an extremely high interest rate on his savings account. Due to the moderate interest rate sensitivity of savings accounts an outflow of funds might occur[141].

With the studies described in chapter 4 we estimated the impact on interest rate risk and economic capital of the prepayment option in chapter 6 as well. We used a simplified example to show how the models of prepayment behaviour work. From this example we learned that the change in value of a mortgage portfolio due to prepayment can be substantial. In our example the net present value of a mortgage decreased by 20%, which is a substantial amount.

After studying the individual effects, we focussed on the joint effect and looked at the balance sheet of a typical retail bank. We then applied six simple parallel shock scenarios to this balance sheet using several simplifying assumptions. From the results we learned that a bank requires profitable growth in order to be able to take interest increases. In the 100 bp. up scenario the bank is able to do so, whereas in the other shock-up scenarios the growth is not sufficient to take the increased value of the liabilities and therefore we see a decrease in the value of capital. In the shock-down scenarios we don't see this problem. Since the remaining assets become more profitable, whereas the liabilities become cheaper, the bank is able to take the increased value of the liabilities, due to volume growth, and an increase in the value of capital remains.
Of course, this is just one example and other assumptions would have led to other numbers, but in general we can state the following: although the withdrawal option is present in two large products on the liability-side of the balance sheet, viz. savings accounts and demand deposits, its influence is marginal. In the past ten years we have witnessed declining interest rates in the market, as well as for these products, whereas the volume of savings accounts and demand deposits have grown. Therefore, although the potential risk caused by the withdrawal option is large, since the bank can loose the biggest part of its balance sheet, the actual risk is considered small. As already mentioned the biggest risk occurs when a (new) competitor suddenly offers an extremely high interest rate on comparable savings accounts. Due to the

[141] Although one can argue that this is a form of business risk, the potential outflow of funds is made possible because of the withdrawal option.

moderate interest rate sensitivity this might lead to an potentially large outflow of funds. So although the risk is small, economic capital should be substantial, since economic capital should cover for unexpected events.
Regarding the prepayment option, we can state that this risk is more significant. We have seen in the late 1990's that prepayment rates went up because of historically low mortgage rates. Since large parts of bank's mortgage portfolios were renewed since then, prepayments are not going to be very likely in the near future. However, when mortgage rates go up again, prepayment might become more important again. The worst case scenario for prepayment is when rates first go up significantly and than decrease again. In this case the opposite of the withdrawal option is true. That is, the risk of the prepayment option is substantial, however economic capital can be lower, since prepayment can be predicted relatively well. Since economic capital is only for unexpected events, expected prepayments should be covered by normal risk management procedures.

Finally, we can question whether we reached the goal of our research, which read: **to study the effects of embedded options in the retail banking book on interest rate risk and economic capital**. We can conclude that we reached this goal. For the most important embedded options we either developed our own methods or are able to use models from other researches that are capable of measuring the effects of the embedded options on interest rate risk in the retail banking book as well as economic capital. However, there are still some issues, which we were not able to solve, mostly due to a lack of data. We therefore give some recommendations for further research in the next section.

7.2 Recommendations for further research

Although we feel we have added to the knowledge of interest rate risk and economic capital in general and saving behaviour and the effects of embedded options on interest rate risk in the retail banking book and economic capital in particular, there are still some recommendations for further research.
First of all, we propose that there should be more research on banking risks and most of all that more uniform definitions should be used. As we mentioned in section 2.2 it seems that there are as many risk typologies as there are risk types. Further, it seems that every now and then new risk types (consider for example operational and business risk) are added. But most striking is that every author seems to have his own definitions. This makes it hard to compare different studies. For example, if a bank loses on a loan due to default of the borrower, it is commonly agreed upon that this is credit risk. But what if the borrower was a C-rated counterpart for which the bank's policies would have prescribed close monitoring, which did not happen? Is this still credit risk, or is it operational risk?
A second recommendation has to do with saving behaviour. Although we are confident with the models we estimated, due to the lack of data, we were not able to estimate models on a micro-level as was Alink (2002) able to do for his prepayment models. The proposition in the introduction of chapter 3, that saving behaviour changes due to changes in the products, could therefore not be checked. With data on individual products, preferably from one individual, the interest rate sensitivity of people, instead of products, could be estimated, which is valuable information.

Our third recommendation has to do with the portfolio effects of embedded options in section 6.3. Again, due to a lack of data, we could not estimate real correlations between the different products with embedded options. Because of that we had to make several assumptions on the portfolio effects in that section. If one could get more data on how the different products interact, it would be possible to predict portfolio effects better.

In summary, the concept of economic capital is a useful management tool, provided that management understands the underlying concepts and assumptions. Only then, economic capital can be used as a good indicator of the performance of a bank's entities and products.

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Samenvatting

In dit proefschrift bestuderen we de effecten van embedded options in het retail bankboek op renterisico en economisch vermogen. In hoofdstuk 1 beginnen we met een verkenning van het terrein. Verder definiëren we enkele kernbegrippen en geven we in dat hoofdstuk het doel van het onderzoek en de onderzoeksvragen. Het doel van dit onderzoek is **het bestuderen van de effecten van embedded opties in het retail bankboek op renterisico en economisch vermogen**.
Om dit doel te bereiken hebben we vijf onderzoeksvragen opgesteld. Deze luiden:

1. Welke risico's kunnen in het bankbedrijf worden onderscheiden?
2. Wat is renterisico in het retail bankboek en hoe kan het gemeten worden?
3. Wat is economisch vermogen en waarom is het belangrijk?
4. Op welke manier kunnen de effecten van embedded opties in het retail bankboek gemeten worden?
5. Wat zijn de effecten van embedded opties in het retail bankboek op renterisico en economisch vermogen?

We starten met het beantwoorden van onderzoeksvraag 1 met een studie naar bancaire risico's in het algemeen in hoofdstuk 2. Aan het einde van die studie presenteren we een algemene typologie van bancaire risico's, waarmee we een antwoord vonden. Daarna richten we ons op renterisico in het retail bankboek. De definitie van dat risicotype, die we gebruiken in het onderzoek is:

Negatieve effecten in renteresultaat en/of negatieve waardeveranderingen in zowel on- en off-balance posities in het retail bankboek door onverwachte veranderingen in de rente.

We zien dat renterisico (in het bankboek) vier oorzaken heeft. In de eerste plaats kunnen mismatch en yield curve risico worden onderscheiden, welke beide hun oorzaak hebben in een discrepantie tussen de renteherzieningsdata van activa en passiva. Daarnaast onderscheiden we basisrisico, welke ontstaat door onverwachte veranderingen in de correlatie tussen rentecurves. Tenslotte kan renterisico veroorzaakt worden door effecten van embedded options. We onderscheiden zes verschillende opties:

- direct opneembaarheid van spaargelden (withdrawal option);
- vervroegde aflossingen op hypotheken (prepayment option);
- rentebedenktijd optie (interest rate consider period option);
- ingebouwde renteplafonds, zowel naar boven als beneden (embedded caps and/or floors);
- offerterisico (quotation rate option); en de
- keuze optie (choice option).

Naast het identificeren van de oorzaken van renterisico, beschrijven we ook methoden om renterisico te meten, waarmee we onderzoeksvraag 2 beantwoorden. We onderscheiden diverse methoden en maken uiteindelijk een indeling, waarbij methoden enerzijds gericht zijn op het meten van het renteresultaat (earnings based), en anderzijds gericht op het meten van waarde (value based). Methoden kunnen statisch of dynamisch zijn.
Na de uitgebreide studie van renterisico, richten we onze aandacht op economisch vermogen. We concluderen op de eerste plaats dat het mogelijk is drie vormen van eigen vermogen te onderscheiden in het bankbedrijf. Eén daarvan is economisch vermogen (economic capital), de andere twee het eigen vermogen volgens boekhoudregels (accounting capital) en het eigen vermogen volgens de toezichthouder (regulatory capital). Economisch vermogen is gedefinieerd als de hoeveelheid eigen vermogen die een bank dient aan te houden uit hoofde van onverwachte verliezen gedurende een zekere periode en bij een zekere betrouwbaarheid. We bestuderen enkele modellen om het economisch vermogen te berekenen.
Economisch vermogen wordt steeds belangrijker gevonden. Zo wordt economisch vermogen binnen banken gezien als een goed meetinstrument om de prestaties van verschillende entiteiten te vergelijken. De regelgever ziet het als een goed middel om het werkelijke risico te meten. We zien daarom ook een trend in de regelgeving naar interne modellen, die in de regel gebaseerd zijn op economische risico's. Tenslotte zien we in de externe verslaggeving ook een trend naar het weergeven van de activa en in mindere mate de passiva op basis van hun economische waarde (fair value accounting). Met het definiëren van economisch vermogen, alsmede het aangeven waarom dit concept steeds belangrijker wordt, beantwoorden we onderzoeksvraag 3.
Na deze inleidende studies, starten we met het onderzoek naar de effecten van embedded options in het retail bankboek op het renterisico en economisch vermogen. We splitsen dit onderzoek in twee onderzoeksvragen. Onderzoeksvraag 4 (hoofdstukken 3, 4 en 5) handelt over de manier waarop de effecten gemeten kunnen worden; onderzoeksvraag 5 handelt over het daadwerkelijk weergeven van die effecten (hoofdstuk 6).
We beginnen met het zoeken naar methoden om de effecten van de withdrawal option te meten. Deze optie is aanwezig in producten zonder eindige looptijd, zoals betaal- en spaarrekeningen. We concluderen dat we, om de effecten te kunnen meten, in feite een studie naar spaargedrag dienen te doen. We bestuderen kort de bekende studie van Keynes naar de liquiditeits-preferentie van individuen. Volgens deze theorie maken individuen in feite twee beslissingen. De eerste is hoeveel van zijn inkomen het individu zal consumeren. De tweede beslissing betreft hoe hij met het restant zal omgaan. Afhankelijk van zijn liquiditeits-preferentie zal het individu dit bedrag in contanten bewaren, en/of sparen, en/of investeren.
Wanneer we dit toepassen op de withdrawal option, kunnen we in feite dezelfde drie mogelijkheden onderscheiden. In de eerste plaats kan een individu zijn geld bewaren op een betaalrekening, op de tweede plaats kan hij dat doen op een spaarrekening. Tenslotte kan hij het geld voor langere tijd wegzetten op een termijn deposito of het investeren in bijvoorbeeld aandelen. Deze mogelijkheden worden in oplopende mate geacht rentegevoelig te zijn. Gegevens over investeringen in aandelen hebben we niet tot onze beschikking, zodat we ons dienden te beperken tot termijn deposito's als alternatief product.
Aangezien we in hoofdstuk 2 concluderen dat economisch vermogen het best gemeten kan worden gebaseerd op waarden, is het uiteindelijke doel van hoofdstuk 3 het vinden van een waarderingsregel voor producten zonder eindige looptijd, waarbij de volledige hoofdsom op ieder moment kan worden opgenomen. We hebben enkele waarderingsregels in de literatuur

bestudeerd en besloten uiteindelijk die van Jarrow & Van Deventer te gebruiken. De belangrijkste redenen daarvoor zijn dat het model relatief eenvoudig geïmplementeerd kan worden voor simulatie doeleinden en daarnaast dat de onderliggende theorie het direct opvraagbare karakter van tegoeden op betaalrekeningen en spaarrekeningen goed weergeeft.
De Jarrow-Van Deventer formule vereist modellen voor de vraag naar spaarproducten. Hoewel er reeds literatuur is op dit gebied, hebben we besloten onze eigen modellen te schatten. De belangrijkste reden hiervoor is dat onze data niet zo goed passen op de reeds bestaande modellen. We zijn begonnen met een studie naar mogelijke factoren die spaargedrag kunnen beïnvloeden. Uiteindelijk hebben we de volgende mogelijke variabelen gevonden:

- het gezinsinkomen;
- de hoogte van de rente op spaarrekeningen;
- het verwachte rendement op de aandelenmarkt;
- het marginale belastingtarief; en
- verschillende demografische factoren, zoals:
    - leeftijd;
    - sociale achtergrond;
    - gezinssamenstelling; en
    - regio.

Helaas hebben we niet de beschikking over gedetailleerde informatie, waarmee we de bovengenoemde factoren kunnen toetsen en we hebben daarom besloten modellen te schatten op een hoger aggregatieniveau. Niettemin vinden we modellen met een behoorlijke verklarende capaciteit en een redelijk tot goed voorspellingsvermogen.
Naast modellen voor de vraag heeft de Jarrow-Van Deventer methode ook rentes nodig. Enerzijds zijn dit rentes om de rentebetalingen op bijvoorbeeld spaarrekeningen te berekenen, anderzijds zijn rentes nodig voor disconteren. We doen de aanname dat de rente op betaalrekeningen nul is en schatten daarom hiervoor geen model. Dat doen we wel voor de spaarrente en de rente op termijn deposito's. Tenslotte schatten we ook nog een tweetal modellen voor de disconteringsrente. Deze rente vormt overigens een belangrijke input in de voorgaande twee modellen.
Het eerste model voor de disconteringsrente dat we schatten, is het bekende Cox, Ingersoll & Ross model. Omdat een één-factor model als deze enkele nadelen heeft, schatten we ook nog een drie-factor model. Dit laatste model is in staat om de belangrijkste empirische eigenschappen van rente te laten zien: (1) de rente termijnstructuur is gemiddeld stijgende; (2) de termijnstructuur van de volatiliteit is gemiddeld dalende; (3) rentes liggen op een vloeiende curve, dus rentes welke nauwelijks in looptijd verschillen zijn sterk gecorreleerd; (4) rentes vertonen een hogere volatiliteit wanneer het renteniveau hoger is; en (5) mean-reversion is sterker in die gevallen waar de rente verder van het lange termijn gemiddelde verwijderd is.
Met de geschatte modellen voor de vraag en de rente, kunnen we de Jarrow-Van Deventer methode toepassen op de eerder genoemde producten, waarmee we een antwoord vinden op onderzoeksvraag 4 voor wat betreft de withdrawal option.

Naar vervroegde aflossingen kijken we in hoofdstuk 4. Er is veel onderzoek naar deze optie gedaan in de VS. Echter, door de verschillen tussen de Nederlandse en Amerikaanse hypotheekmarkt, kunnen Amerikaanse modellen niet zonder meer worden toegepast op de Nederlandse situatie.

Niettemin beginnen we, na een korte beschrijving van de Nederlandse hypotheekmarkt, met het beschrijven van het bekende onderzoek van Kang & Zenios, welke bekend staat als het Wharton model. Dit model vormt min of meer de basis voor al het opvolgende empirische onderzoek naar vervroegde aflossingen inclusief het Nederlandse onderzoek. Het Wharton model verklaart vervroegde aflossingen op basis van vier factoren. De eerste is de zogenaamde "refinance incentive" welke het financiële motief voor vervroegde aflossingen weergeeft. "Seasoning" en "burnout" zijn tijdseffecten en in feite elkaars tegenpolen. "Seasonality" tenslotte verklaart seizoensinvloeden.

Na een beschrijving van het Wharton model, bestuderen we het Nederlandse onderzoek. Het meeste onderzoek is empirisch van aard. In feite geven deze modellen een voorspelling van de verwachte maandelijkse vervroegde aflossingen. Op basis van het Nederlandse onderzoek kan worden geconcludeerd dat de optie op vervroegde aflossing waardevol is voor de hypotheekgever. Echter, in acht dient te worden genomen, dat deze modellen zijn geschat over een relatieve korte periode, gedurende welke de hypotheekrentes meestal daalden. Niettemin kunnen de verschillende modellen helpen bij het berekenen van de hoeveelheid economisch vermogen welke benodigd is uit hoofde van de optie op vervroegde aflossing van hypotheken.

Tenslotte beantwoorden we onderzoeksvraag 4 voor de overige embedded opties in hoofdstuk 5. We starten met de rentebedenktijd optie. We concluderen dat er in wezen drie methoden zijn, om de effecten te meten. De eerste is het construeren van een zogenaamde "replicating portfolio". Dat wil zeggen dat geprobeerd wordt een portefeuille van marktinstrumenten te construeren, welke exact hetzelfde risicoprofiel heeft als de hypotheek met de rentebedenktijd optie. Een tweede mogelijkheid is de rentebedenktijd optie te beschouwen als een optie op boetevrij vervroegd aflossen gedurende de laatste y jaar van de rentetypische looptijd. Een derde mogelijkheid is simulatie. We concluderen dat de laatste optie waarschijnlijk het beste is. De reden is dat het heel moeilijk zal zijn een replicating portfolio te construeren, doordat een hypotheek ook nog andere opties kent. Het beschouwen van de rentebedenktijd optie als een optie op vervroegd aflossen zal waarschijnlijk spaak lopen op het feit dat deze optie slechts beperkt verkocht wordt. Daardoor zijn waarschijnlijk te weinig gegevens voorhanden om een model te kunnen schatten. In een simulatie spelen deze zaken niet, alhoewel men aannames zal moeten maken omtrent het klantgedrag. Overigens is het risico door deze optie laag. Dat komt, doordat hypotheekgevers een premie betalen voor deze optie. Een van de conclusies van Van Mullem (1998) is dat de hypotheekgever nooit een voordeel behaalt met deze optie, zelfs als hij optimaal handelt.

Renteplafonds, zowel naar boven als naar beneden, komen nauwelijks voor in Nederlandse hypotheken. De enige optie met een renteplafond die veel voorkomt is de hypotheekofferte. We spreken dan van offerterisico. Zodra een hypotheekofferte is geaccepteerd, is de klant verzekerd tegen rentestijgingen gedurende de offertetermijn. Tegelijkertijd profiteert hij wel van rentedalingen. Hoewel vrijwel alle hypotheken beginnen met een offertetermijn, is het risico klein, vooral vanwege de korte looptijd van de offerte. Wil men het risico meenemen,

dan kan dat door de laagste hypotheekrente gedurende de looptijd van de offerte te nemen in een simulatie.
Tenslotte behandelen we de keuze optie. Het risico uit deze optie is laag, aangezien een bank altijd kan reageren op de keuze van de klant en daarop zijn funding kan aanpassen.
In hoofdstuk 6 beantwoorden we de laatste onderzoeksvraag welke ingaat op de daadwerkelijke effecten van deze opties op renterisico in het retail bankboek en economisch vermogen. We beginnen met een studie naar de effecten van iedere individuele optie. We gebruiken de modellen uit hoofdstuk 3 om het effect van de withdrawal option te simuleren. We concluderen dat de keuze voor het rentemodel een zeer grote invloed heeft op de uitkomsten. Daarnaast concluderen we dat de economische vermogenseis voor de afzonderlijke producten hoger is dan de economische vermogenseis voor het totaal, waaruit de portefeuille effecten blijken. Tenslotte zien we dat de netto contante waarde van de winst uit spaarmiddelen onder nul kan komen. De reden hiervoor is de aanname dat aan het einde van de simulatieperiode het volledige saldo wordt terugbetaald. Een langere horizon zou dit kunnen voorkomen, maar tegelijkertijd zal de bank dan langer rente moeten betalen.
Concluderend stellen we dat het renterisico uit hoofde van de withdrawal option relatief laag is. Dit komt ook tot uiting in het risicomanagement van een bank, dat betaal- en spaarmiddelen meestal als langlopend beschouwt. Het grootste potentiële risico is dat een (nieuwe) concurrent in staat is gedurende een langere periode een significant hogere rente te betalen. Door de middelmatige rentegevoeligheid van de spaarmiddelen, zou dan een relatief grote uitstroom van middelen kunnen ontstaan. De economische vermogenseis uit hoofde van de withdrawal option zal daarom hoog zijn, aangezien een bank in extreme situaties een groot deel van haar balans kan verliezen.
Met de onderzoeken welke in hoofdstuk 4 beschreven zijn, kunnen we de impact van de optie op vervroegd aflossen schatten. We gebruiken een versimpeld voorbeeld, waarin we observeren dat vervroegde aflossingen een potentieel significante invloed hebben op de netto contante waarde van een hypotheek.
We concluderen dat de effecten van de andere opties klein zijn.
Na het bestuderen van de effecten van de individuele opties, bekijken we het effect van de opties gezamenlijk. We beperken ons tot de withdrawal option en de optie op vervroegd aflossen. We doen enkele aannames en passen twee simpele parallelle schokscenario's toe. Uit de resultaten leiden we af dat een opwaartse schok leidt tot een verlies van vermogen, terwijl een neerwaartse schok leidt tot een winst, ondanks vervroegde aflossingen. Het moet benadrukt worden dat dit slechts een voorbeeld is, en dat andere aannames tot iets andere uitkomsten zouden hebben geleid, maar toch kunnen we uit het voorbeeld het volgende afleiden: hoewel de withdrawal option aanwezig is in de twee grootste producten aan de creditzijde van de balans is de invloed van deze optie marginaal. In de afgelopen tien jaar zagen we dalende rentes, terwijl de volumes van zowel de betaal- als de spaarmiddelen gestaag groeiden. Dus hoewel het potentiële risico groot is: de bank kan immers het grootste deel van haar balans verliezen, is het reële risico klein. Het grootste gevaar ontstaat wanneer een (nieuwe) concurrent een veel hogere rente kan bieden. Dus hoewel het risico relatief klein is, is de economisch vermogenseis groot, aangezien economisch vermogen juist deze onverwachte gebeurtenissen moet afdekken.

Met betrekking tot de optie op vervroegd aflossen kunnen we stellen dat dit risico groter is. We hebben hoge vervroegde aflossingen gezien aan het eind van de jaren 90, vooral veroorzaakt door historisch lage hypotheekrentes. Aangezien een groot deel van de hypotheekportefeuille is vernieuwd, zullen vervroegde aflossingen niet zo'n grote rol spelen in de nabije toekomst. Echter, wanneer hypotheekrentes flink stijgen om vervolgens weer te dalen, zullen hoogstwaarschijnlijk ook de vervroegde aflossingen weer stijgen. In dit geval geldt daarom het tegenovergestelde van de withdrawal option. Het risico is aanzienlijk, maar tegelijkertijd hoeft de vermogenseis niet zo hoog te zijn, aangezien vervroegde aflossingen redelijk geschat kunnen worden. Omdat economisch vermogen alleen bedoeld is als buffer voor onverwachte verliezen, dienen verwachte vervroegde aflossingen onder het "normale" risicobeheer te vallen.

Tenslotte kunnen we concluderen dat we enerzijds het doel van het onderzoek: het bestuderen van de effecten van embedded opties op het renterisico in het retail bankboek en economisch vermogen, hebben bereikt. Voor de belangrijkste embedded opties hebben we enerzijds onze eigen modellen geschat of kunnen we anderzijds bestaande modellen gebruiken. Anderzijds zijn enkele zaken, zoals de correlaties tussen de effecten ietwat onderbelicht gebleven, vooral door een gebrek aan gegevens.