

MANAGING INTEREST RATE RISK: A COMPARISON OF THE EFFECTIVENESS  
OF FORECASTING AND VOLATILITY MODELS

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## ABSTRACT

### MANAGING INTEREST RATE RISK: A COMPARISON OF THE EFFECTIVENESS OF FORECASTING AND VOLATILITY MODELS

Interest rate risk is one of the most important types of risk to which banks are inherently exposed. Interest rates determine a bank's profitability and have an effect on a bank's liquidity and investment portfolio. It is, therefore, extremely important to be able to predict interest rates accurately and manage interest rate risk effectively.

In trying to manage interest rate risk, banks rely on Asset and Liability Committees (ALCOs). They also make use of several strategies, which are described (Gap, Earnings Sensitivity Analysis, Duration Gap and Market Value of Equity sensitivity analysis). The first step for these strategies, on which later steps depend, is to make interest rate forecasts.

Forecasting plays such a crucial role because many significant decisions depend on the anticipated future values of specific variables. Forecasts may be produced in various different ways. The method chosen depends on the reason for and the importance of the forecasts as well as on the costs of alternative forecasting methods.

In an attempt to manage interest rate risk by being able to predict the next rates correctly, several different models are used to try and predict interest rates for two data sets, namely: BA (Bankers' Acceptances, which is money market data) and Esc (Eskom, which is capital market data). They each have their place in the South African financial system, which is described in general.

The chosen simple forecasting models that are used are: naïve, moving average and exponential smoothing models. The aim is to try to predict the direction of the next interest rate (UP, CONSTANT, or DOWN) while supplying a point prediction of the next rate (one-step ahead). The "best" simple forecasting models are determined by specific set criteria (percentage of correct direction predictions, mean squared error and tracking signals).

For the same time series, more advanced models are taken into account where the aim is to try to find an interval wherein the future interest rates (not only in the short-term but in the longer-term as well) are most likely to lie, using models based on the data, as well as first differences. For the long-term forecasts, two types of more advanced models are used, namely: Box-Jenkins models (where, specifically, nonseasonal second-order autoregressive or AR(2) models are examined); and volatility models that are found using a new technique that creates an interval by using different volatility estimates.

The word '**volatility**' used throughout the study refers to models with a fixed volatility function and not dynamic volatility as in models such as the ARCH and GARCH types. In this study, the range from simple to more complex time series models with constant volatility are considered. The former, simple models and AR(2) models are referred to as forecasting models, the latter more advanced models are referred to as volatility estimates.

Short- and long-term predictions are, thus, made for each time series, at different specifically chosen points. A comparison of the effectiveness of the forecasting and volatility models is made.

## Acknowledgements

Thank you! Thank you! Thank you!

Queridos: papá Manuel, mamã Adélia e irmã Manuela  
Sem vocês não seria possível.

Beijinhos!

Da vossa Helena Fernandes

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## CHAPTER 1: INTRODUCTION

### 1.1. Preamble

Banking, especially South African banking, has evolved over the years (Fourie, *et al.*, 1999:3). From specialised institutions that were able to provide few services to specific clients, to institutions that are able to provide many people with diverse services and products, banks have certainly progressed (see Faure, 2003:4 and other references in Chapter 2).

Many types of banks operate in the same financial environment which, inevitably, has also changed and developed over the years (Falkena, *et al.*, 1984:2). The different banks are each supervised, have their own functions, have to adhere to certain regulations and have responsibilities towards different entities and people (see, for example, Fourie, *et al.*, 1999:90 and other references in Chapter 2). The South African Reserve Bank (SARB) is the central bank of South Africa (refer to SARB, 2002a and others). It has its own responsibilities and functions (Fourie, *et al.*, 1999:53).

Indeed, fierce competition amongst banks has forced bank managers to become more competitive. Not only in the services that they provide but also in areas such as interest rates, where ultimately, each bank wants to supply the customer with the best rates on offer and still be able to survive in the markets (Falkena & Kok, 1991:11). Consequently, risk-taking is involved (Cade, 1997:1) and one of the most important risks that banks face and have to manage continually and effectively, is interest rate risk (Chapter 3).

Interest rate risk or "mismatching the book" (Falkena & Kok, 1991:9) as it is sometimes referred to, is one of the biggest concerns that bank managers have. Indeed, the bank's own future depends on predicting interest rates accurately. Thus, in order to manage interest rate risk, many banks rely on an Asset and Liability Committee (ALCO) (Cade, 1997:145). In addition, banks observe and monitor factors like the business cycle (Koch & Macdonald, 2003:256) and apply strategies

such as Gap<sup>1</sup> and Earnings Sensitivity Analysis (which focus on net interest income) as well as Duration Gap<sup>2</sup> and Market Value of Equity (MVE) sensitivity analysis (all of these are described in Chapter 3).

Yet, there is no substitute for the "real thing" that is knowing the next interest rate. This is crucial. In fact, making a forecast of the interest rates is the first step in these strategies (refer, for example, to Koch & Macdonald, 2003:292). It is because of this that many different models have been created in order to try and predict interest rates accurately. Some perform better than others under certain conditions, while others seem to do well with different types of data altogether.

This study looks at the South African financial system in general (Chapter 2), with a specific focus on two interest rates (BA and Esc – refer to Botha, 2003:222 for BA and Van den Berg (2004) and Eskom (2004) for Esc), as well as on a few of the strategies that banks employ to manage interest rate risk (Chapter 3). This is part of the literature study.

In addition, several models are explored in order to determine whether it is possible to predict interest rates accurately, for the short- (Chapters 4 and 5) and long-term (Chapter 6), for the two interest rates mentioned. This is part of the empirical work conducted. From here, several observations and suggestions can be made about the data, the models and the results obtained (done at the end of each of Chapters 4, 5 and 6, as well as in Chapter 7), analyses of which, are extremely important.

## 1.2. Empirical Work

In this study, several simple forecasting models are chosen and used to predict interest rates one-step ahead (Chapter 4). The types of models under consideration are: naïve models, moving average models and exponential smoothing models. Each of these are different and some have variations.

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<sup>1</sup> Also written as GAP.

<sup>2</sup> Also referred to as DGAP.

All the models and their variations are applied to two data sets (explained in Chapter 2). These are of actual interest rates: the first is Bankers' Acceptances (BA rates) and the second, Eskom (Esc rates).

In order to determine which of the models is most accurate in predicting the direction of the next interest rate (UP, CONSTANT or DOWN) and making point predictions one-step ahead, certain criteria is set, namely: Percentage of Correct Direction predictions (PCD), Mean Squared Error (MSE) and Tracking Signals (TS). Each of these is discussed and the results (with regard to the criteria) of applying each model to either of the data sets are obtained (Chapter 4). Thereafter, the models that produce the "best" results are highlighted. Certain conclusions are reached about which models are able to predict interest rates as close to the actual rates as possible and with as little error as possible (end of Chapter 4).

In addition to this, considering the shape of the BA graph, the BA data set is "cut" into nine one-year sections (Chapter 5). Then, the same forecasting models as before are applied to each of the nine sections of data. Once again, outcomes are reached, not only about the models themselves and the results they produce but also about the volume of the results obtained.

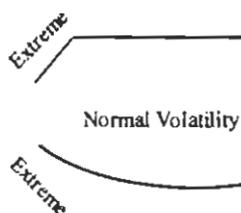
Finally, the effectiveness of forecasting and volatility models for long-term predictions is examined. For making long-term predictions (Chapter 6), two main areas of work are examined, namely: stationary time series is compared to non-stationary time series. The first area of work refers to when there is stationarity in the mean, variance and correlation structure. Here, the Box-Jenkins methodology is looked at, with particular focus on ARIMA(2,0,0) or AR(2) models. The second area of work refers to when there is stationarity in the variance and correlation structure. There are the ARIMA(0,1,0) models, I(1) models or random walk models<sup>3</sup>. The mean is non-stationary and the correlation structure is uncorrelated.

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<sup>3</sup> As Gottman (1981:75) explains, the random walk process  $z_t = z_{t-1} + e_t$  where  $e_t$  is normal white noise, is "the path described by a drunkard who starts at a lamp post at time  $t = 1$ , and is then likely to step in either of two directions on a street in the next time points. These steps form an additive drift".

The goal for these long-term predictions, in both cases, is to find an interval wherein the actual interest rates are likely to lie. However, the latter area of work makes use of a new technique that involves using volatility estimates (maximum absolute value first differences<sup>4</sup>) to get the initial intervals, after which, volatility limits based on a formula are applied to them.

In this section of the study, two types of models are considered. The first is used in anticipation of extreme volatility conditions and the other in anticipation of normal volatility conditions. In other words,



Again, certain conclusions, observations and suggestions are made.

It has to be mentioned here that the word '**volatility**' used throughout the study refers to models with a fixed volatility function and not dynamic volatility as in models such as the ARCH and GARCH types. In this study, the range from simple to more complex time series models with constant volatility are considered. The former, simple models and AR(2) models are referred to as forecasting models, the latter more advanced models are referred to as volatility estimates.

### 1.3. Chapter Outline and Research Aims

Interest rate risk is one of the most important types of risk to which banks are inherently exposed. Therefore, it is important, in particular, to be able to predict interest rates accurately and to be able to manage interest rate risk effectively. Below is a basic outline of the chapters of this study, as well as the main aims that are important and that will be addressed subsequently:

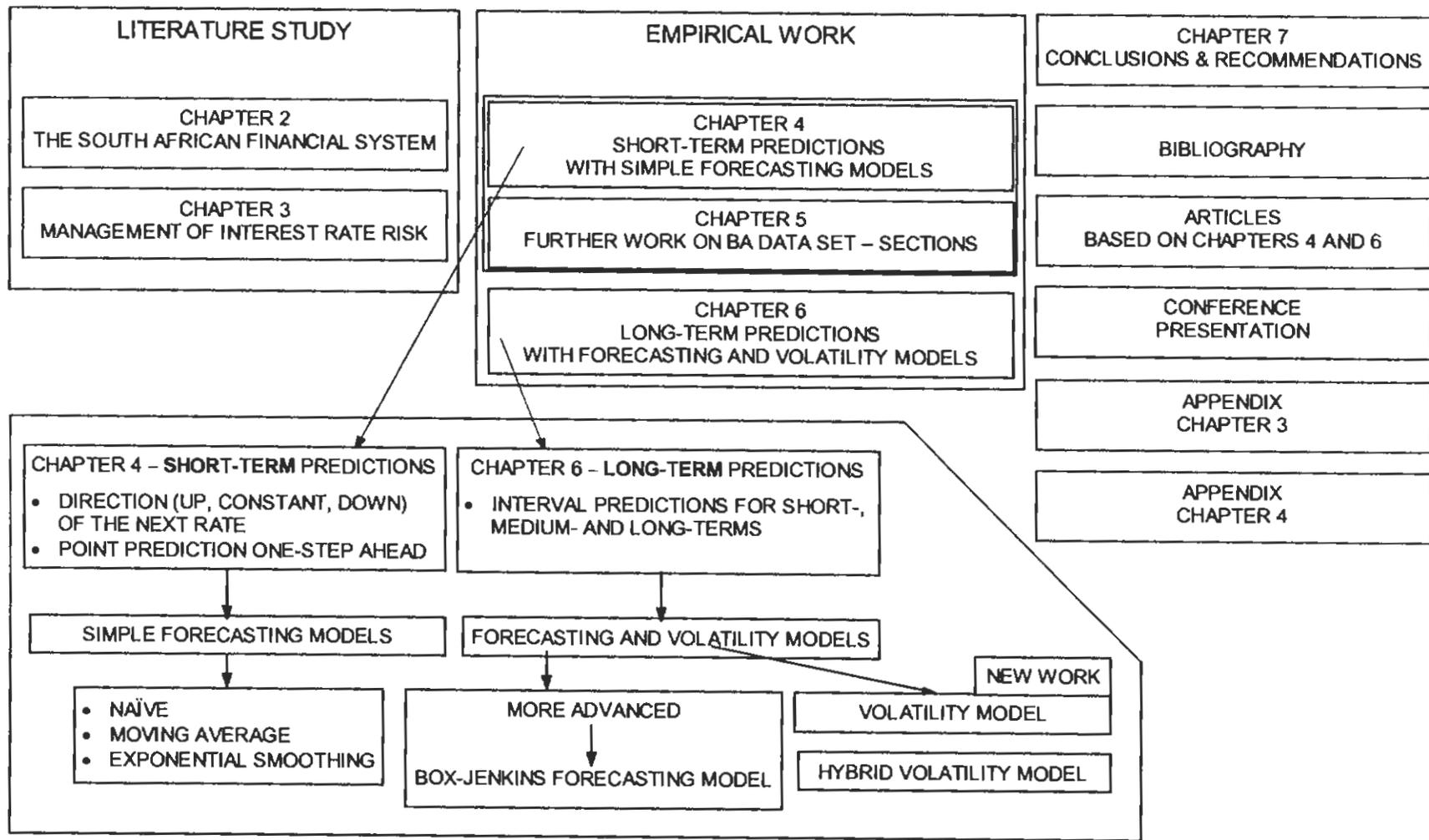
<sup>4</sup> From forecasting with naïve models, the model 1.2

$$Y_t = Y_{t-1} + (Y_{t-1} - Y_{t-2})$$

is a "good" model. This model uses the first differences  $Y_{t-1} - Y_{t-2}$  to predict the next step. This  $\Delta Y_{t-1}$  can be positive, negative or zero. It can also be small or large.

**MANAGING INTEREST RATE RISK: A COMPARISON OF THE EFFECTIVENESS OF FORECASTING AND VOLATILITY MODELS**

**CHAPTER 1  
INTRODUCTION**



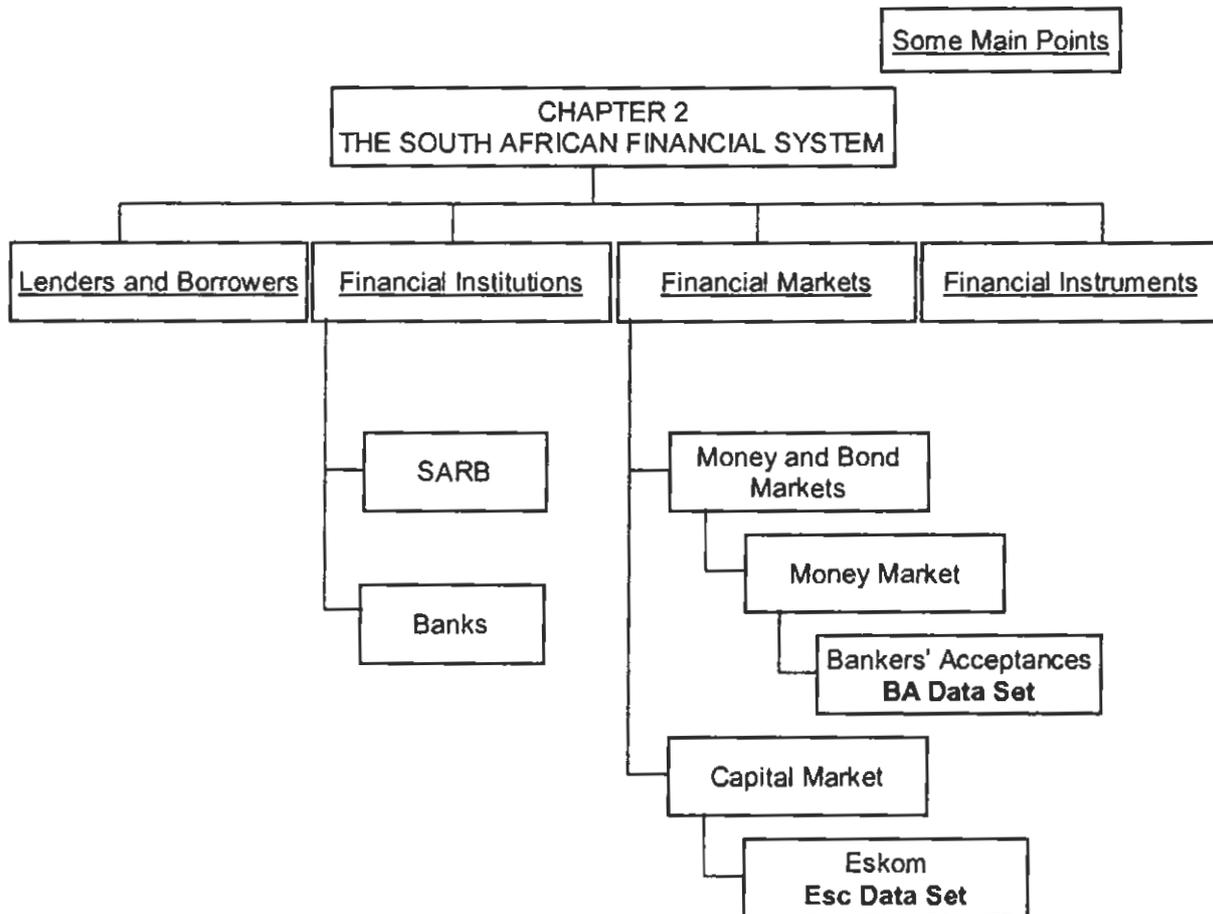
Chapter 1: Introduction

Chapter 1 endeavours to give an introduction to the study. It provides an overview of what is to come and how it all relates to the title of this study – in attempting to manage interest rate risk, how effective are different models and techniques in trying to predict the next interest rate correctly (or at least as close to the actual rate as possible, with as little error as possible) for the short- and long-terms.

A chapter outline and short summary of each chapter is given and the research aims are set down. An overview of the study is shown above.

Chapter 2: Background

In this study, two data sets of actual interest rates are considered. The first is of Bankers' Acceptances (BA rates) and the second, Eskom (Esc rates). Chapter 2 provides the background, which includes information about the South African financial system and its four essential elements. Bankers' Acceptances as well as Eskom rates are described in context.

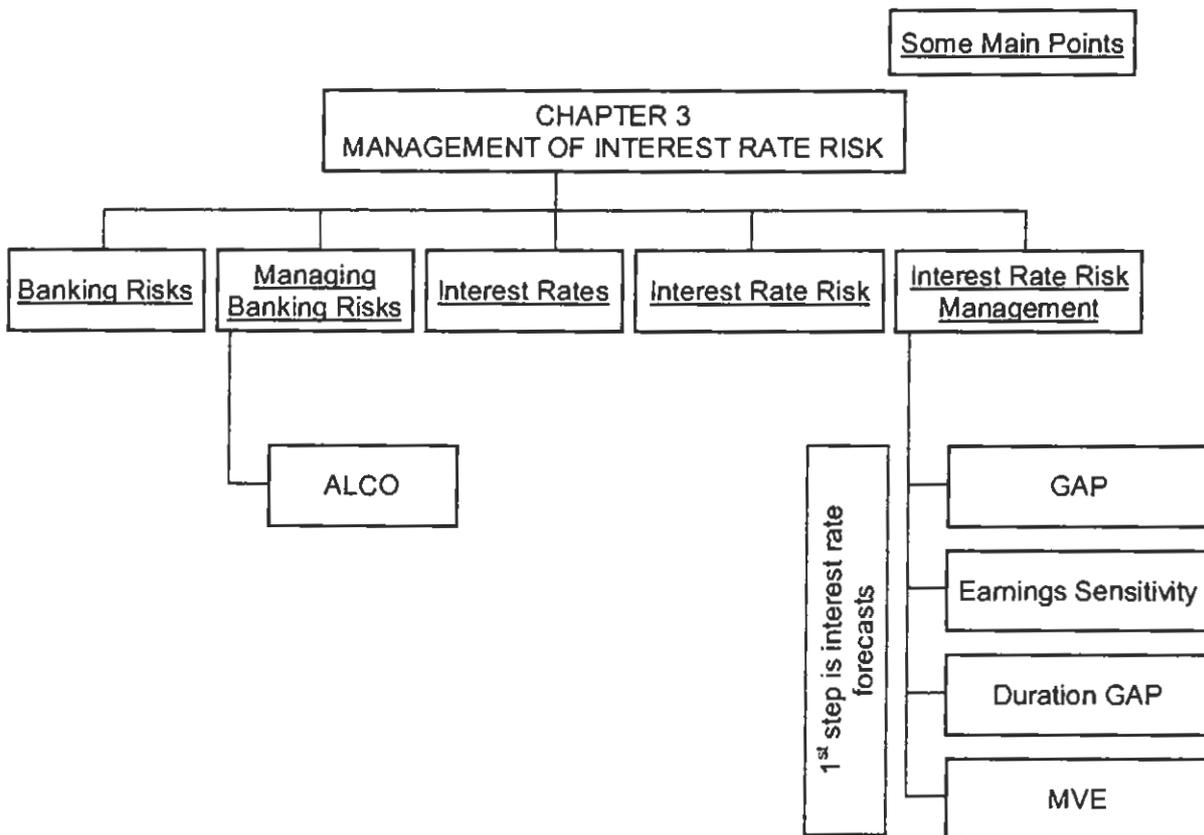


The main aims of Chapter 2 are to:

- Provide background on the South African financial system and its four essential components
- Put in context the two data sets that are to be used in the study

Chapter 3: Management of Interest Rate Risk

Chapter 3 focuses on managing interest rate risk. Certainly, there are many other types of risks faced by banks (which are presented) but the emphasis of the chapter is on how banks manage interest rate risk. Here, the ALCO and its functions are discussed as well as the few strategies mentioned above.

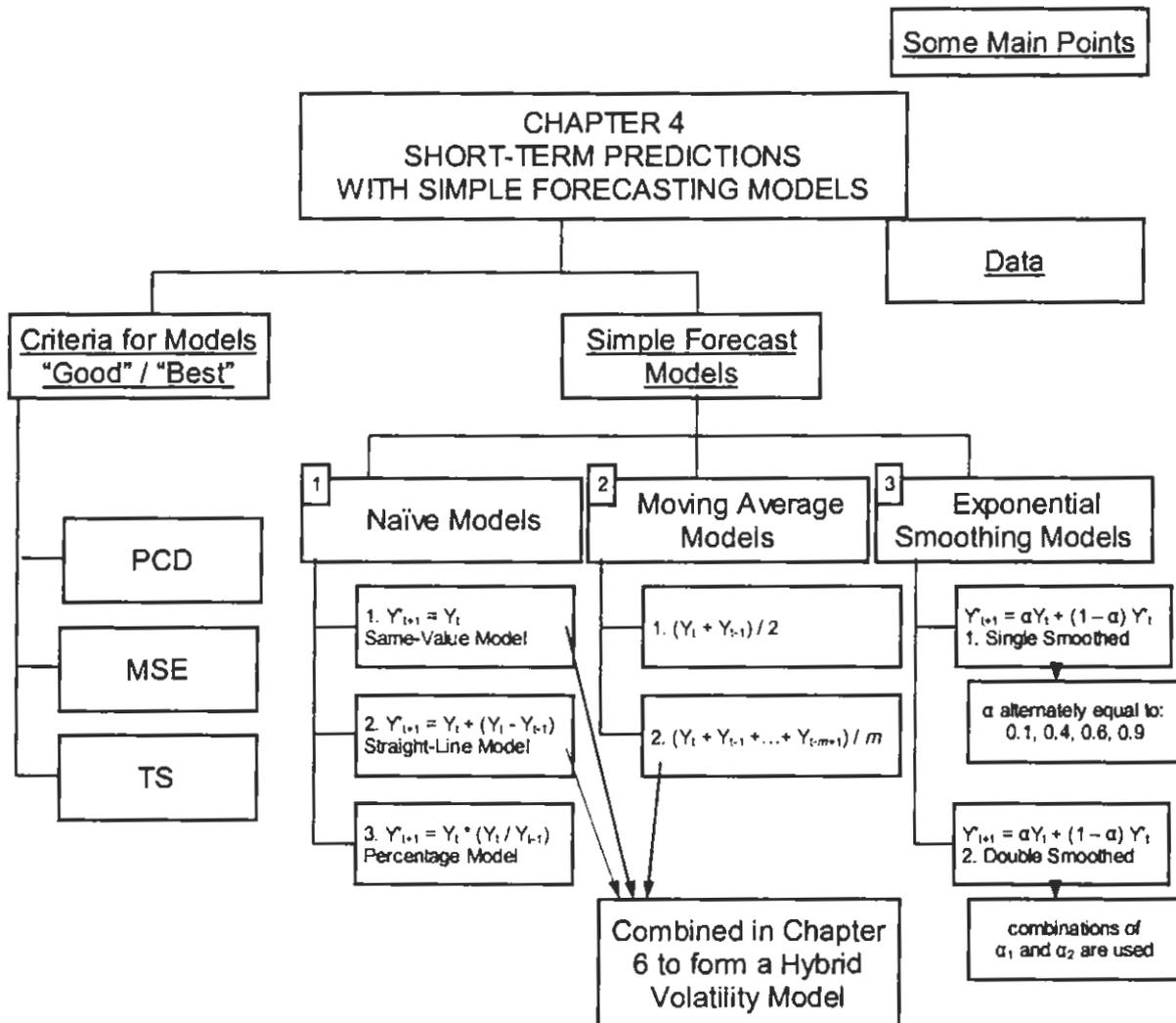


The main aims of Chapter 3 are to:

- Describe what interest rates and risks are, with particular focus on interest rate risk
- Show the importance of predicting and managing interest rates correctly, especially for banks
- Describe the structure and functions of an ALCO
- Identify and discuss some of the strategies used by banks to measure, manage and minimise interest rate risk

## Chapter 4: Short-term Predictions with Simple Forecasting Models

In the interest of predicting the next interest rate correctly, it is in Chapter 4 that the simple forecasting techniques are applied to the two data sets empirically. Having set criteria on how to determine the “best” models, conclusions about the results obtained are presented.



The main aims of Chapter 4 are to:

- Identify simple forecasting models to be used to make short-term predictions
- Set criteria to select the “best” model(s)
- Apply the chosen forecasting models to each of the two data sets
- Obtain results as to the “best” model(s)

## Chapter 5: Further Work On BA Data Set – Sections

Chapter 5 presents extra work done with the BA data set, where the models given in the previous chapter are applied to each of the nine one-year data sections, chosen

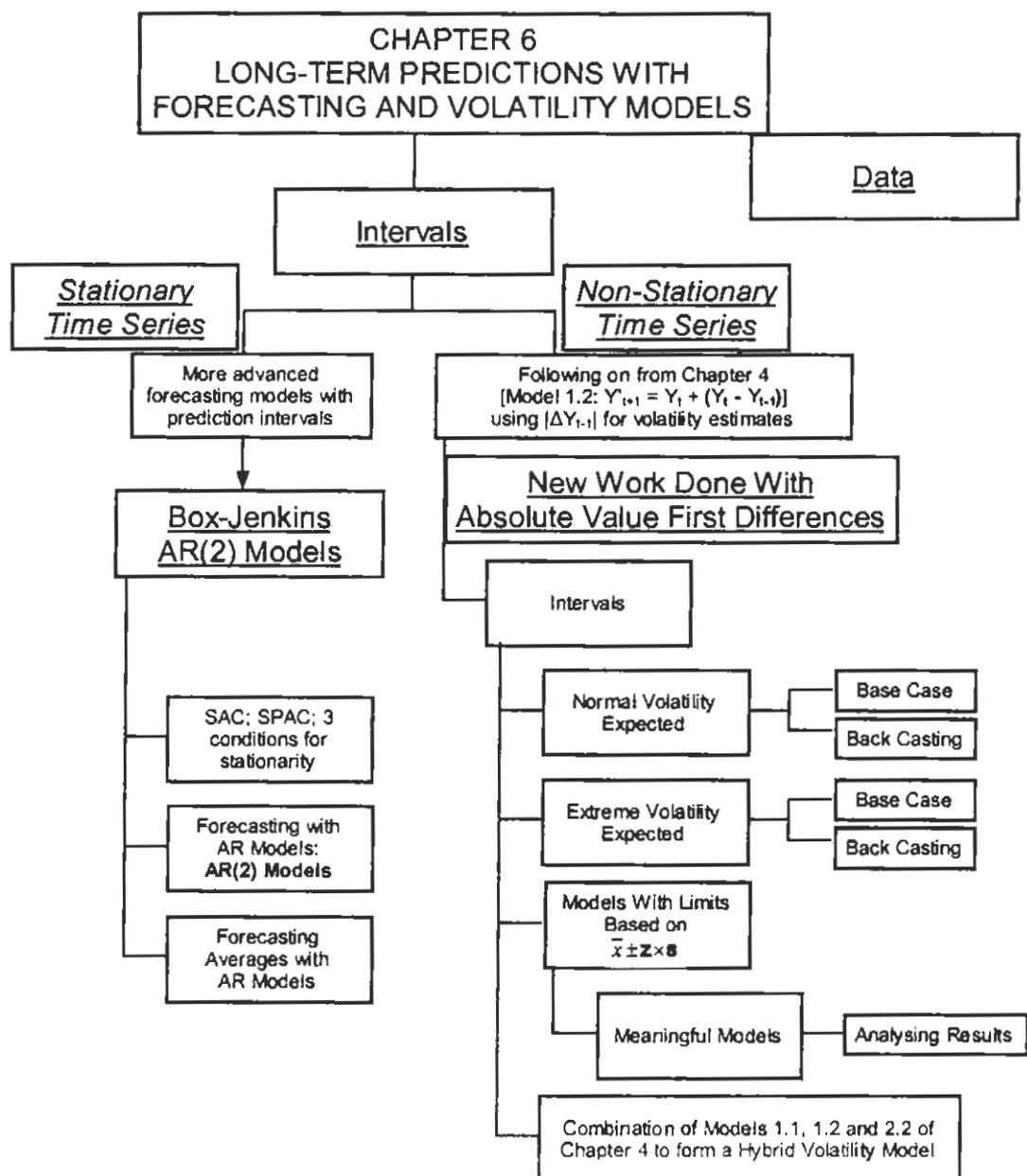
from the shape of the BA graph. Once again, the same criteria is used to choose the “best” models. The main aim of this chapter is essentially:

- To apply the work done in Chapter 4 to sections of the BA data set

### Chapter 6: Long-term Predictions with Forecasting and Volatility Models

Chapter 6 returns to the original BA and Esc time series but this time volatility models are applied to each. Two main areas of work are explored – stationary time series is compared to non-stationary time series. In particular Box-Jenkins AR(2) models are compared to newly developed models (using [first differences] and volatility limits).

Some Main Points



The main aims of Chapter 6 are to:

- Identify and apply an appropriate Box-Jenkins model to the two time series separately
- Apply a volatility formula to the two time series and obtain limits to the intervals found in order to make long-term predictions

### Chapter 7: Conclusions and Avenues for Further Research

The last chapter before the bibliography focuses on certain conclusions, recommendations and avenues for further research. Here, other areas that may be focused on and explored are mentioned and a summary table of what was achieved and the benefits for and contributions to this field of study are presented.

### Appendices

Articles corresponding to Chapters 4 and 6 are given. In addition, a presentation that was based on this study and delivered by the author at a joint SAIE & ORSSA<sup>5</sup> conference in August 2005 is provided. The latter also serves to show how this subject matter is relevant in this field and the contributions that have already been made to it. Two appendices that provide extra information with regard to Chapters 3 and 4 are included as well.

#### 1.4. Chapter Summary

Interest rates are an integral part of the financial system. Many people are aware of them and banks, in particular, need to be able to predict them accurately in order to survive in the competitive environment in which they operate. Managing interest rate risk is essential and in order to do this, bank managers rely on certain committees and strategies.

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<sup>5</sup> Southern African Institute for Industrial Engineering (SAIE) and Operations Research Society of South Africa (ORSSA). The joint 19<sup>th</sup> SAIE & 35<sup>th</sup> ORSSA annual conference was held at the Emerald Casino Resort in Vanderbijlpark from 28-31 August 2005. The theme for this year's conference was: Building towards growth and sustainability in SA. More information about these groups and the conference may be found at: [www.saie.co.za](http://www.saie.co.za) / [www.orssa.org.za](http://www.orssa.org.za) / <http://vaal.puk.ac.za/sdu>

For each of these strategies, the first step is to make a prediction of the interest rate under consideration. Therefore, it is essential to be able to make accurate and valid predictions and it is in this light that this study was undertaken.

Two real time series, based on actual interest rates are used – BA (Bankers' Acceptances from the money market) and Esc (Eskom from the capital market). They are put into context and predictions are made for them.

Specifically, short- and long-term predictions are made using several different models. The short-term predictions involve using simple forecasting models in order to predict the direction (UP, CONSTANT or DOWN) of the next interest rate while making point predictions one-step ahead. Long-term predictions make use of a more advanced forecasting model as well as volatility models to make interval predictions for the short-, medium- and long-terms.

It has to be pointed out that the volatility models used in this study refer to models with fixed volatility and not dynamic volatility as in ARCH and GARCH types. In this section, long-term interval predictions are made by using models that are developed using a new technique that makes use of different volatility estimates. In addition, a hybrid model is developed.

Something else that needs to be made clear is that, in this study, the idea is not to forecast volatility models. In Chapter 6, volatility is used to estimate the interval estimates – obtaining volatility estimates, not models. What is meant by forecasting and volatility models, is that the volatility models are developed from the forecasting models. Given a certain model, what does the variance look like (volatility is variance). Future work might be to work on forecasting volatility models.

Certain conclusions are provided at the end of each of Chapters 4, 5 and 6 (the empirical chapters). Moreover, Chapter 7 undertakes to make a comparison of the effectiveness of some of the different forecasting and volatility models used in the study and also present a few results, conclusions, recommendations and avenues for further research.

Clearly, this study has practical applications. Contributions to this field are also made (the new work with volatility estimates). The results obtained from the models used in this study may surely be used in further studies, in pursuit of managing interest rates and risk.

## CHAPTER 2: THE SOUTH AFRICAN FINANCIAL SYSTEM

### 2.1. Introduction

Banks have become important entities in our lives. Most people have an account at a preferred bank where they deposit their money (and therefore, earn some interest on it) and from which they draw money when they need it. If they need to buy something more expensive like a house or car, they take out a loan from the bank and then pay it off over several years. Indeed, a bank seems like a rather convenient place to keep money and not many people realise that there are different types of banks, that they are able to provide other services and that they must deal with many issues and take precautions in order to survive in the economic market in which they function.

In this chapter, a brief overview of the South African financial system is given. The four main components of this system (lenders and borrowers, financial institutions, markets and instruments) are described. Emphasis is placed on the South African Reserve Bank (the central bank of South Africa), banks in general, the money market (from where the first data set pertaining to Bankers' Acceptances derives) and the capital market (from where the second data set pertaining to Eskom rates originates). The aim is to provide some background and to put in context the importance of these institutions, markets and instruments.

### 2.2. The South African Financial System

A definition for the financial system is given by Fourie, Falkena, and Kok (1999:3) as:

A set of arrangements embracing the lending and borrowing of funds by non-financial economic units and the intermediation of this function by financial institutions to facilitate the transfer of funds, to provide additional money when required, and to create markets in debt instruments so that the price and allocation of funds are determined efficiently.

This definition distinguishes the four<sup>6</sup> essential elements of a financial system:

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<sup>6</sup> Faure (2003:3) identifies a fifth element, namely: the "creation of money when required", which points to the unique money-creating ability of banks.

- ◆ The lenders and borrowers (the non-financial economic units);
- ◆ The financial institutions (which intermediate the lending and borrowing process);
- ◆ The financial markets (the institutional arrangements and conventions that exist to issue and trade or deal the financial instruments);
- ◆ Financial instruments (which are created to fulfil the needs of the participants).

Each one of these elements is important for the correct functioning of a financial system in any country. Indeed, the South African financial system has experienced many changes over the years, due to the monetary authorities and the private financial sector, in the course of the liberalisation of the financial markets. Such changes include the following from Fourie, *et al.* (1999:3) and Faure (2003:4):

- An adjusted attitude towards the implementation of monetary policy
- The emergence of new financial instruments and products
- New financial intermediaries and brokers
- Changes in supervision of markets and institutions
- Substantially higher levels of activity in the financial markets

Indeed, more changes may be observed in the future, since new services and specialist institutions are being designed to accommodate the needs of those who have not enjoyed much exposure to the sector. According to Faure (2003:4), South Africa has a rather sophisticated financial services sector – the products and services are wide-ranging, the technical and technological framework is of the highest quality and most of the markets are well developed and exhibit high levels of liquidity.

The financial institutions are among the most regulated industries. Therefore, any change in monetary policy will, as Falkena, Fourie, and Kok (1984:2) mention, almost immediately alter the financial environment in which financial institutions operate.

Certainly, the financial system in reality is extremely complex and is often simplified in order to be explained. What follows is a brief look at each of the four essential elements of a financial system.

### 2.2.1. Lenders and Borrowers (Surplus and Deficit Economic Units)

There are two types of economic units, namely:

1. **Surplus units** or **ultimate lenders** – whose savings out of income will exceed their planned investment;
2. **Deficit units** or **ultimate borrowers** – whose savings are insufficient to meet desired internal investment.

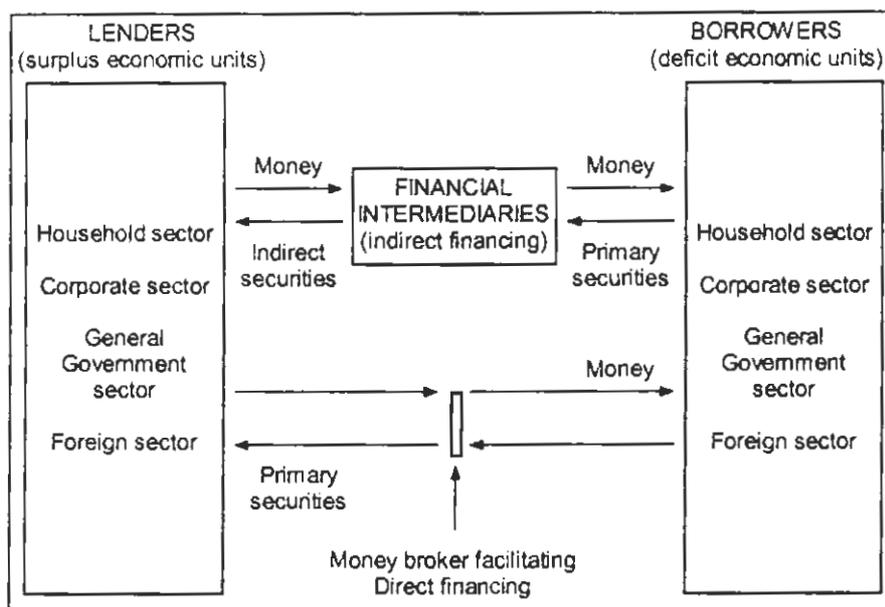
Ultimate lenders can, as Fourie, *et al.* (1999:4) state, further be described as non-financial economic units that generate investible funds (funds that are available for investment). They can be divided into several categories or sectors (as defined by the Reserve Bank), that Fourie, *et al.* (1999:5) list as:

- *Household sector* which consists of individuals and families, private charitable, religious and non-profit bodies serving households. Included here are unincorporated businesses like farmers, retailers and professional partnerships because the transactions of these businesses cannot be separated from the personal transactions of their owners
- *Corporate sector* which comprises all companies not classified as financial institutions and as such, includes business enterprises that are directly or indirectly engaged in the production and distribution of goods and services
- *General government sector* which consists of the central government, provincial governments and local authorities
- *Foreign sector* which covers all organisations, persons and assets resident or situated in the rest of the world

Faure (2003:4/5) points out that the same non-financial economic units also appear on the other side of the financial system as ultimate borrowers (see Figure<sup>7</sup> 2.1.). This is because different members of the four categories, or even the same members at different times, may be either surplus or deficit units.

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<sup>7</sup> Adapted from the diagrams of: Fourie, *et al.* (1999:4), Falkena, *et al.* (1984:200) and Faure (2003:5).



**Figure 2.1. Diagram Illustrating the financial system.**

There are two ways in which excess funds of surplus units are transferred to deficit units:

1. **Direct financing** – which involves the use of a broker who acts as a go-between, distributing the claims on borrowers among the lenders, in return for a commission;
2. **Financial intermediaries** – that perform indirect financing. Fourie, *et al.* (1999:4/5) mention that they assist in resolving the conflict between lenders and borrowers by creating markets in two types of financial instruments (one type for borrowers, another type for lenders). They offer claims against themselves (indirect securities), “tailored to the liquidity and maturity needs of the lenders” (Fourie, *et al.*, 1999:6), in turn acquiring claims on the borrowers (primary securities).

Faure (2003:6) states that they receive a fee, represented by the difference between the cost of their indirect securities issued and the revenue earned from the primary securities purchased (which in the case of banks is called a margin). They also levy other fees.

Essentially, financial intermediaries facilitate the flow of funds from surplus to deficit economic units. One group of financial intermediaries, the banks, is able to perform another special function which, according to Faure (2003:6), is

the creation of new money when required (with the assistance of the central bank). They acquire financial claims first, thereby increasing the financial liabilities in the system (to create money).

A more detailed description of the financial intermediaries continues in the next section (financial institutions).

### 2.2.2. Financial Institutions

Faure (2003:6) notes that financial institutions exist primarily because of the conflict between lenders' and borrowers' requirements in terms of: size, term to maturity, quality and liquidity of financial instruments. They perform the intermediation function<sup>8</sup> and assist in the rapid adjustment of the price of funds (that is, interest rates/ equity prices) in response to changing supply and demand conditions.

Many different types of institutions perform the intermediation function. With respect to the fundamental function of intermediation, Faure (2003:7) states that there is little distinction between banks, finance houses, insurance companies, unit trusts or any other type of intermediary. However, in the nature of the claims (indirect securities) and services offered to lenders and in the nature of the claims on (primary securities) and services offered to borrowers, there are vast differences between intermediaries.

Financial institutions tend to be more specialised on the liability side of their balance sheets. Therefore, they are appropriately classified according to the nature of the indirect securities they issue, as Fourie, *et al.* (1999:7) point out.

#### 2.2.2.1. Classification of Financial Institutions

According to Faure (2003:8), financial institutions may be classified as:

- **Deposit intermediaries** – under which are:
  - South African Reserve Bank (SARB)

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<sup>8</sup> Financial intermediaries facilitate the flow of funds from surplus to deficit economic units by: issuing financial liabilities (indirect securities or claims on themselves) that are acceptable as investments to the ultimate lenders and using the funds obtained in this way to acquire the claims that reflect the requirements of the borrowers (primary securities).

- Corporation for Public Deposits (CPD)
  - Land and Agricultural Bank (LAB)
  - Private banks
  - Mutual banks
  - Postbank
- **Non-deposit intermediaries** – which are divided into:
- *Contractual intermediaries*
    - Long-term insurers
    - Short-term insurers
    - Pension and provident funds
    - Public Investment Commissioners (PIC)
  - *Portfolio intermediaries or collective investment schemes*
    - Unit trusts
    - Property unit trusts
    - Participation mortgage bond schemes
  - *Development finance intermediaries (DFIs)*
    - Development Bank of Southern Africa (DBSA)
    - Industrial Development Corporation (IDC)
    - National Housing Finance Corporation (NHFC)
    - Khula Enterprise Finance (KEF)
    - Infrastructure Finance Corporation (INCA)

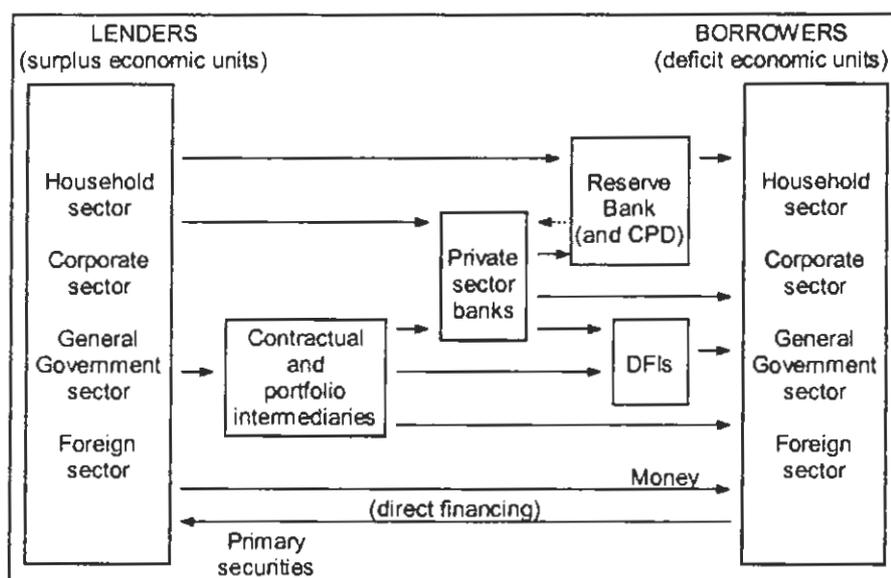
There is no fixed rule that determines the categorisation above and in addition to these financial intermediaries, there are several institutions and funds, called “**quasi-financial intermediaries**” (Faure, 2003:7) (or **QFIs**), that border on financial intermediaries. Their liability and asset financial portfolios tend to be static since they do not borrow and/ or lend to the same extent as those mentioned above, nor are they ongoing lenders and borrowers.

The institutions that fall within this borderline category include the following, from Faure (2003:8):

- Investment trusts
- Friendly societies
- Private equity funds
- Micro lenders

- Finance companies
- Securitisation vehicles
- Savings and credit cooperatives
- Village financial service cooperatives
- Buying associations
- Stokvels

The financial sector is not complete without accountants, attorneys and the brokers (non-principals) who are involved in the different sectors. The main financial institutions and their main intermediation functions and relationships with each other are shown in Figure<sup>9</sup> 2.2.



**Figure 2.2. Diagram illustrating financial intermediaries.**

Both the South African Reserve Bank (SARB) as well as banks are discussed in greater detail in subsequent sections. They constitute an important part of the study, especially in view of the economy and interest rates.

#### 2.2.2.2. Other Financial Bodies

There exist a number of so-called other financial bodies that play an important facilitation or "financial wheel-oiling" (Faure, 2003:12) function in the financial system. They differ from the financial intermediaries in that they do not have a large balance sheet reflecting the lending and borrowing process, which the financial intermediaries have.

<sup>9</sup> Adapted from the diagrams of Fourie, *et al.* (1999:9) and Faure (2003:9).

These other financial bodies (sometimes also referred to as financial institutions) that play a significant role in the financial system, include the following, from Faure (2003:12/13):

- **Financial exchanges** – in South Africa there are two licensed exchanges:
  1. JSE Securities Exchange South Africa, which also includes the South African Futures Exchange (SAFEX);
  2. The Bond Exchange of South Africa (BESA), which has to do with the bond market.
- **Members of the financial exchanges** – the members of BESA and SAFEX may be banks and/ or other financial intermediaries or smaller, individual-owned companies. Members of the JSE are “separately capitalised companies” (Faure, 2003:12), that is, the members are subsidiary companies of banks or smaller individual-owned companies
- **Financial regulators** – in South Africa, the financial regulators are the Bank Supervision Department of the Reserve Bank and the Financial Services Board, which oversees all the other financial intermediaries and exchanges
- **Fund managers** – fund management is a significant business in South Africa. Most pension and provident funds outsource their management to separate fund management companies. These companies are required by the Financial Services Board (their supervisor) to be separately capitalised from other financial intermediaries. Individual-owned fund management companies are also allowed.

From the list of deposit intermediaries above, the financial institutions that are essential elements in this study are the South African Reserve Bank and banks in general. They are examined briefly next.

#### 2.2.2.3. South African Reserve Bank (SARB)

The South African Reserve Bank is the central bank of the Republic of South Africa and is regulated, as Fourie, *et al.* (1999:53) state, in terms of an Act of Parliament. A central bank performs various functions and duties and is charged with certain responsibilities that normal banks or banking institutions do not carry out. The

primary objective of the South African Reserve Bank (SARB) is to protect the value of the currency “in the interest of balanced and sustainable economic growth in the Republic” (Fourie, *et al.*, 1999:53). The central bank is a creator of primary money.

a. SARB: Mission and Vision

The South African Reserve Bank (SARB, 2002a) affirms that the SARB, being the central bank of South Africa, regards its primary goal in the South African economic system as “the achievement and maintenance of financial stability<sup>10</sup>”.

As defined in SARB (2002a), in pursuit of its goal, the Reserve Bank assumes responsibility for:

1. Formulating and implementing monetary policy in such a way that its primary goal is achieved in the interest of the whole community that it serves;
2. Ensuring that the South African money, banking and financial system as a whole is sound, that it meets the requirements of the community and keeps abreast of international developments;
3. Assisting the South African government and other members of the economic community of southern Africa in the formulation and implementation of macroeconomic policy;
4. Informing the South African community and all interested stakeholders abroad about monetary policy and the South African economic situation.

In SARB (2002a), the Reserve Bank maintains that:

South Africa has a growing economy based on the principles of a market system, private and social initiative, effective competition and social fairness. It recognises, in the performance of its duties, the need to pursue balanced economic development and growth.

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<sup>10</sup> According to SARB (2002b), financial stability can be described as: “the absence of the macroeconomic costs of disturbances in the system of financial exchange between households, businesses and financial-service firms”. Stability would be evidenced by:

1. An effective regulatory infrastructure;
2. Effective financial markets;
3. Effective and sound financial institutions.

#### b. SARB: Brief Historical Progress

According to Fourie, *et al.* (1999:61), the establishment of the SARB was a direct result of the disruption caused by the First World War. It formed part of a more comprehensive set of measures that were meant to deal with the unsatisfactory monetary and financial conditions of that time. Some of these conditions were:

- The lack of uniformity in the issue of banknotes
- The possibility of an over-issue of notes under the laws of certain provinces
- A large illegal outflow of gold from South Africa

Thus, an appeal by banks to the government led to the Gold Conference of October 1919. Although this conference did not express the desire for establishing a central bank, it did recommend that a uniform banking Act replace the separate banking laws in force in the four provinces.

This led to the Currency and Banking Act of 10 August 1920, which provided, amongst other things, for the establishment of the Reserve Bank. The Act was promulgated in December 1920 and in the course of the next six months, effect was given to its various provisions. The Reserve Bank “opened its doors for business” (Fourie, *et al.*, 1999:61) for the first time on 30 June 1921. The Bank’s head office has been located in Pretoria from its inception but the Bank has undergone several changes in its powers and abilities over the years, due to changes in the different Acts.

#### c. SARB: Legal Framework

The Currency and Banking Act of 1920 was replaced in 1944 by the South African Reserve Bank Act which, in turn, made way in 1989 for the South African Reserve Bank Act, No 90 of 1989. According to SARB (2004a), the Act of 1989, the regulations framed in terms of this Act and sections 223 to 225 of the Constitution of the Republic of South Africa (Act No 108 of 1996) currently provide the “enabling framework” for the Bank’s operations.

The Act and regulations describe the Bank's framework, the way in which it is managed and the actions it is allowed to take. Besides this, the Constitution prescribes that the aim of the Bank's operations be low inflation and stable financial conditions. This the Bank should endeavour to achieve without fear, favour or prejudice.

The SARB (2004a) affirms that since its establishment, the Reserve Bank has always been privately owned. On 2 May 2002, the delisting of the SARB from the list of the JSE Securities Exchange South Africa took place. Today, the Bank has more than 630 shareholders and its shares are traded on an Over-the-Counter Share Transfer Facility (OTCSTF) market coordinated within the Reserve Bank.

As stated in SARB (2004a), the SA Reserve Bank Act provides for a board of 14 directors. These include the Governor and three Deputy Governors, who are the most senior executives with full-time responsibilities for the workings of the Bank and who are appointed to their positions by the President of the Republic, for a five-year term.

As of 8 August 1999, Mr. TT Mboweni (who is only the eighth Governor since 1921) assumed the responsibility of Governor of the Bank. Three other directors are appointed by the President for a period of three years. The remaining seven directors (one representing agriculture, two industry and four commerce or finance) are elected by shareholders also for a period of three years.

The SARB has fifteen departments which report to either the Governor or a deputy governor, as is explained in SARB (2004c). It also has a college where staff are trained in central banking.

The Bank has been given an important degree of autonomy for the execution of its duties and the independence and autonomy of the Bank are entrenched in the Constitution. However, the Governor of the Reserve Bank holds regular discussions with the Minister of Finance and has periodic discussions with members of the Parliamentary Standing Committee on Finance.

In terms of the Reserve Bank Act, the Governor of the Bank must submit a report relating to the implementation of monetary policy annually to the Minister of Finance. In addition, the Governor must submit a monthly statement of its assets and liabilities and yearly its annual financial statements to the Department of Finance. The annual reports and financial statements are laid upon the Table in Parliament by the Minister of Finance.

d. SARB: Asset and Liability Structure

The Reserve Bank's total assets and liabilities have grown at very uneven rates. The asset and liability structure of the Bank reflects its functions.

According to Fourie, *et al.* (1999:66), the assets of the Bank's balance sheet may be classified as:

- *Gold and foreign assets*
- *Overnight loans*, which reflect the Bank's activity as lender of last resort
- *Other loans and advances*, extended by the Bank
- *Government securities*, consisting of the Bank's portfolio of gilt-edged stock
- *Other securities*, comprising investments in stock of large municipalities and Eskom, as well as in Land Bank debentures
- *Other assets*, consisting of a large number of balances

The liabilities of the Bank may be classified as:

- *Notes and coin in circulation*, which represents the total amount of notes and coin outstanding at any time
- *Deposits of the government*
- *Deposits of banks*, consisting of the balances on the statutory reserve accounts that these institutions are required to maintain at the Reserve Bank, as well as current deposits in excess of the statutory cash reserve requirements
- *Other deposits*, including mainly the accounts of international organisations, foreign banks, foreign governments and the Corporation for Public Deposits

- *Share capital and reserve fund*, which is the sum of the shareholders' stock and the statutory reserve fund
- *Other liabilities*, comprising a wide variety of items

e. SARB: Functions of the Reserve Bank

Issuing of banknotes was one of the initial functions of the Bank. Nowadays, the main functions of the Reserve Bank include the following, from Fourie, *et al.*

(1999:53):

- *The issuing of banknotes and coin* – SARB (2002b) states that it has the sole right to make, issue and destroy banknotes and coin in South Africa. A subsidiary of the Bank, the SA Mint Company, mints all the coins and another subsidiary of the Bank, the SA Bank Note Company, prints all banknotes, on behalf of the Reserve Bank
- *Acting as banker to the government* – in 1927, the accounts of the Government were transferred to the Bank, establishing it as the “Government’s banker” (SARB, 2004a)
- *Acting as a bank to other banks* – since 1921 the Reserve Bank has acted as custodian of the cash balances of other banking institutions. Occasionally, banks may deposit relatively small amounts of so-called “free” reserves (Fourie, *et al.*, 1999:55) as a first line of liquidity, or for the purpose of acquiring banknotes for issuance to the public and effecting settlement of interbank claims arising from the daily exchange of cheques
- *Providing facilities for the clearing and settlement of claims between banks*
- *Acting as custodian of the country’s gold and other foreign reserves*
- *Acting as “bank of rediscount” and “lender of last resort”* – in broad terms, when banks experience a need for cash balances that cannot readily be satisfied in any other way, they are, as Fourie, *et al.* (1999:57) explain, allowed to acquire such balances by making use of credit facilities at the Reserve Bank.

Also, Fourie, *et al.* (1999:58) mention that the Reserve Bank’s lending and discounting activities have the dual purpose of: ensuring the smooth day-to-day operation of the financial markets as well as serving as a channel for the

transmission of monetary policy. Thus, these activities are closely linked with other policy measures like public debt management, open-market operations and the influencing of interest rates by monetary authorities

- *Engaging in public debt management and open-market operations* – the Reserve Bank operates in the money market in the form of open market operations
- *Supervising banks*<sup>11</sup> – the main aim of bank supervision, according to Fourie, *et al.* (1999:60), is to create a legal and regulatory environment that will optimise the quality and effectiveness of risk management in banks. Also, the actions of the supervisory authorities are aimed at enhancing the proper management of risks (like credit, liquidity, interest rate, market and currency risks) to ensure a safer environment for depositors. As SARB (2002b) puts it, the purpose of bank regulation and supervision is “to achieve a sound, efficient banking system in the interest of the depositors of banks and the economy as a whole”.

SARB (2002b) mentions that in South Africa, bank regulation and supervision is performed by issuing banking licences to banking institutions and monitoring their activities in terms of either the Banks Act, 1990 (Act No. 94 of 1990), or the Mutual Banks Act, 1993 (Act No. 124 of 1993). The extent of supervision includes the establishing of certain capital and liquidity requirements as well as the continuous monitoring of the institutions' adherence to these legal requirements and other guidelines

- *Collecting, processing and interpreting economic statistics and other information* – quantitative information on the South African economy (including financial statistics, statistics relating to exchange rate data, a comprehensive set of national accounts, price statistics and indicators of current economic conditions) compiled by the Reserve Bank is collected, processed and interpreted by the Bank, not only for its own policy actions but also for use by the business community and other analysts of economic events.

Fourie, *et al.* (1999:60) point out that a substantial portion of this information

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<sup>11</sup> One of the 15 departments of the SARB is the Bank Supervision Department. The object of this department, according to SARB (2004c), is to “contribute domestically and internationally to the stability and efficiency of the banking system and depositor protection”. The responsibility is delegated by the statutory obligations set out in the Banks Act, 1990. The department's activities are performed by seven divisions.

is published in the Bank's *Quarterly Bulletin*, as well as in the monthly release of certain selected statistics and also on the Internet. In addition, reviews of economic developments are also published in the bulletin and in the Bank's *Annual Economic Report* and prepared for other internal and external purposes. SARB (2002b) mentions that the data that these publications contain are a major source of information for policy-makers, analysts and researchers

- *Formulating and implementing monetary and exchange rate policies* in co-operation with the Ministry of Finance

#### f. SARB: Summary

There are different types of banks and each have their own responsibilities. Anon. (1994a) contends that the principal types of banking in the modern industrial world are commercial and central banking. The South African Reserve Bank (SARB) is the central bank of South Africa. A central bank has many concerns. The first of these, according to Anon. (1994b), should be the maintenance of a soundly based commercial banking structure. A central bank must cooperate closely with the national government and indeed, most governments and central banks have become intimately associated in the formulation of policy. A central bank should also be capable of acting to "offset forces originating outside the economy" (Anon., 1994c), although this is much more difficult.

Fourie, *et al.* (1999:67) state that monetary authorities believe that the creation of financial stability is a prerequisite for longer-term economic development. Sound monetary policy can go a long way towards achieving financial stability that will be conducive to sustainable economic growth.

#### 2.2.2.4. Banks

Fourie, *et al.* (1999:73) reveal that banks are the "custodians" of the general public's money. They accept it in the form of deposits and pay it out on the clients' instructions. A bank is an institution that deals in money and its substitutes. It provides other financial services, accepts deposits, makes loans and derives a profit

from the difference in the interest rates paid and charged, respectively. Also, some banks have the power to create money.

Like any firm, "banks exist for one of two generic reasons" (Fourie, *et al.*, 1999:73):

- they are able to perform services that cannot be provided by other means or types of firms; and/ or
- they have a comparative advantage in the provision of these services.

Some of the major activities that justify the existence of banking firms include the following, from Fourie, *et al.* (1999:73-75):

- *Money creators* – banks create money by way of deposit liabilities. Bank liabilities (cheques) are generally accepted as a means of payment
- *Managers of the payments system* – banks provide a sound and stable mechanism to effect payments. This involves the payment of cheques as well as of credit and debit cards, ATMs, EFTs and others
- *Creators of indirect financial securities* – banks operate as financial intermediaries between ultimate lenders and ultimate borrowers. They transform primary securities (liabilities of firms) into indirect securities (liabilities of financial intermediaries that are desired by investors). Accordingly, Fourie, *et al.* (1999:74) point out that banks hold assets that are subject to specific risks, while issuing claims against them in which these risks are largely eliminated through "diversification". Banks have a competitive advantage over other financial intermediaries performing this function because they enjoy "economies of scale and scope" (Fourie, *et al.*, 1999:74) and they have better information
- *Information agents* – since information is not available to everyone, borrowers choose (frequently for competitive reasons) not to make relevant information publicly available (in the capital market). They are, however, willing to share it with a bank in order to obtain the necessary funding
- *Financial "spectrum fillers"* – banks exist because the capital market is not perfect (there are transaction costs and information is not available to everyone) and it cannot supply the full range of instruments required by

borrowers. Banks fill this gap in the spectrum of financial services and are repeatedly able to supply specific instruments on request

- *Investors for depositors* – Fourie, *et al.* (1999:74) mention that banks accept an investment function for their depositors by assessing investment opportunities and monitoring subsequent investment strategies
- *Dealers in foreign currency* – banks arrange various forms of transfer, handle foreign financing and provide advice on exchange rates and foreign financial market conditions

Yet, banks have not always been as they are now. Indeed, they have evolved over the years into the convenient and complex institutions that they are today.

#### a. Banks: Historical Development

Fourie, *et al.* (1999:79) explain that banking in South Africa was initially focused only on the needs of farmers for long- and later short-term credits. These were supplied by two government banking institutions: the Bank van Leening (established by the Dutch East India Company in 1793) and the Lombard Discount (founded by the British in 1808), respectively.

The era of “free banking” (private banking) started when the Cape of Good Hope Bank was established in 1836. These private, or district, banks were “unit banks” or “one-office banks” – small, local banks, with little financial expertise. During the second half of the 19<sup>th</sup> century the “imperial banks” found a foothold in South Africa and the establishment of these large banks with extensive branch networks resulted in the disappearance of “unit banks”.

In an effort to create a money market in South Africa after World War II, the authorities as well as the private sector took various initiatives. The government established the National Finance Corporation of SA in 1949 for the purpose of providing call-money facilities in South Africa; the first merchant bank, Union Acceptances Ltd, was established in 1955; the first discount house, The Discount

House of SA Ltd, was established in 1957; and the first negotiable certificate of deposit (NCD) appeared in South Africa in 1961.

From mid-1960 to approximately 1980, private banking activities and the development of the securities markets were restricted by the extensive use of direct monetary control instruments. During the 1980s and especially after the implementation of the De Kock Commission recommendations in 1985, South African banks were faced with the increasing adherence to "free-market principles" (Fourie, *et al.*, 1999:80) by the monetary authorities. Deregulation, consolidation and rationalisation took place on a major scale and most of the direct control instruments were no longer used by the end of the 1980s.

By the early 1990s, almost all building societies were transformed from mutual societies to banking institutions and in turn merged into larger banking groups. By the mid-1990s more than 95% of the total assets of banks were held by only four banking groups (ABSA Bank, Standard Bank, First National Bank and Nedbank) with more than 3 000 branches countrywide. The remaining 5% of banks' assets are spread among local banks, foreign-controlled banks, a few branches of foreign banks and some mutual banks.

## b. Banks: Legal Framework

### i. Background

The first Currency and Banking Act of the Union (Act No. 31 of 1920) referred to banks only in general as being a company "receiving or accepting deposits of money, subject to withdrawal by cheque, draft or order" (Falkena, *et al.*, 1984:73). The Banking Act of 1942 defined a people's bank as "an association established for the purpose of promoting thrift among its members and of making loans to its members" (Falkena, *et al.*, 1984:73), while a loan bank meant "a person (other than a people's bank) who carries on the business of accepting deposits of money and of granting small loans" (Falkena, *et al.*, 1984:73).

A deposit-receiving institution was seen simply as a residual, that is, a person accepting deposits but not being a commercial bank, people's bank nor loan bank. The retail banking character of the people's and loan banks was clearly enforced by the Act (Section 20), since it restricted these banks to a maximum of: 100 pounds they could lend to any one person and 4 000 pounds they could owe to any person.

The Banks Act of 1965 subjected all classes of banking institutions (with the exception of discount houses) to the same financial requirements. In addition, new classifications of banking institutions were introduced based on the relative importance of the banking business carried out. These were: commercial, savings, hire purchase and general banks.

However, it became progressively more difficult to classify banking institutions in accordance with the Banks Act because of the rapid development and diversification of banking services offered by any one bank during the 1970s. With the Financial Institutions Amendment Act, No. 103 of 1979, the Registrar reclassified hire purchase, savings and general banks (since the difference between them had become so vague) all as general banks. The Financial Institutions Amendment Act, No. 106 of 1985, repealed the distinction between commercial banks, general banks and merchant banks and all banks, except discount houses, were classified as banks.

Fourie, *et al.* (1999:81) explain, furthermore, that the Deposit-taking Institutions Act, No. 94 of 1990, consolidated and revised its predecessors, the Banks Act, 1965 (Act 24 of 1965) and the Building Societies Act, 1986 (Act 82 of 1986) and finally also repealed the distinction between banks, discount houses and equity building societies. In 1993 the Deposit-taking Institutions Act was renamed the Banks Act, No. 94 of 1990.

## ii. Current Position

Banks are regulated by the Banks Act (Act 94 of 1990). According to Fourie, *et al.* (1999:81). this Act extends to all areas of deposit-taking business, unless such an activity is specifically exempted from the provisions of the Act.

The Banks Act, in conjunction with the regulations promulgated under it, emphasises risk management as the basis for supervision of banks, to a larger extent than before. In exercising their supervisory role under the Registrar of Banks, supervisors review the risk management process of banks and as Fourie, *et al.* (1999:82) point out, ascertain whether risk managers within the banks have the proper procedures and information to determine and manage the various risks to which each bank is exposed. For this, more than 20 different returns have to be completed and submitted to the Registrar. These returns are needed to unbundle the risks; concentrate on individual risks, components of risk and sensitivity to various risks; and encourage the involvement of management and the board of directors of each bank in the process of risk management.

Fourie, *et al.* (1999:82) state that South African regulatory authorities subscribe to and have taken steps, to comply with the minimum standards for the supervision of international banking groups and their “cross-border establishments”. The purpose of these standards is to ensure that no international banking group evades adequate supervision and also to ensure that both host and home-country regulatory authorities are aware of the supervision carried out in the respective countries.

The Banks Act stipulates several requirements with respect to capital, cash reserves and liquid assets<sup>12</sup>. In addition, banks are subject to various reporting requirements concerning large exposures. Also, exchange control limits are imposed on the size of foreign assets and liabilities of banks. Besides specific financial directives, the Act also contains “prescriptions” (Fourie, *et al.*, 1999:83) regarding registration and general stipulations regarding shareholders, auditors, curatorships and liquidation.

Fourie, *et al.* (1999:83/84) note that four other Acts are important to banks:

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<sup>12</sup> Fourie, *et al.* (1999:83) list several liquid assets:

- Any credit balance in a clearing account with the SARB
- Bank notes and coins in a bank's vaults and automated teller machines
- Gold coin and bullion
- Short-term Treasury bills issued
- Securities of the Reserve Bank with a maturity of not more than three years
- Short-term Land Bank bills
- Government stock with a maturity of not more than three years

1. Companies Act, No. 61 of 1973

The disclosure requirements relating to the financial statements of banks have been broadened, with effect from January 1994. Essentially, banks are now required to make full disclosure in terms of the Companies Act and Generally Accepted Accounting Practice (GAAP). In addition, a revised accounting statement – Disclosure in the Financial Statements of Banks (AC120) – became effective from January 1996;

2. Currency and Exchange Act, of 1933

In terms of this Act, the authorities can promulgate regulations that affect banks directly or indirectly. It is used to “impose constraints through exchange control on cross-border financial transactions, including limitations on funds held offshore by banks” (Fourie, *et al.*, 1999:84);

3. Usury Act, 1968

This Act determines the maximum interest rates that financial institutions may impose on lending, credit and leasing transactions;

4. Credit Agreements Act, 1980

This Act stipulates certain constraints on instalment sale and leasing transactions. It affects banking institutions with regard to prescribed minimum deposits, leasing conditions and terms of payments on contracts.

Recently in banking legislation, recognition has been given to the expansion of “informal” banking business that has occurred mostly in the less developed communities. The Banks Act has been amended to include the existence of several savings clubs (“stokvels”) which, Fourie, *et al.* (1999:84) point out, are outside the normal scope of bank regulation and supervision but which also do not have access to accommodation at the discount window of the central bank.

- c. Banks: Changes in Banking

Fourie, *et al.* (1999:75) explain that the traditional role of banks as financial intermediaries is being undermined by certain developments. Although mainly technological improvements have made banks much less distinct, Fourie, *et al.* (1999:76) state that banks are still considered quite different from non-banking institutions.

#### d. Banks: Risk Profile

According to Fourie, *et al.* (1999:77), risks in banking arise because of the nature and asymmetry of contracts on the asset and liability sides of the balance sheet and also because there is no secondary market in bank loans. Moreover, Fourie, *et al.* (1999:78) explain that the risk profile of banks is fundamentally different from that of other financial institutions. Banking is about the management of credit risks, which inevitably form an essential part of banking. To ensure proper credit risk management, banks aim for well-diversified portfolios of exposure.

Undoubtedly, banks face systemic risk. The probability of the failure of a single bank inducing a systemic problem may be low but if such systemic failure were to occur, this would be very serious and the cost would be high. Therefore, regulation to prevent systemic problems may be viewed as an insurance premium against a low-probability occurrence. Fourie, *et al.* (1999:78) point out two essential characteristics of banks that indicate a need for systemic regulation:

- They issue money-certain liabilities on one side of the balance sheet, which are used to fund money-uncertain assets on the other side
- The nature of the liabilities means that they can be withdrawn on demand or at short notice

#### e. Banks: Asset and Liability Structure

Balance sheet structures may differ between several banking institutions to a great extent. However, asset and liability management is, in essence, the same for any banking institution. Banks tend to “enjoy” (Fourie, *et al.*, 1999:89) more short-term flexibility in handling their liabilities, in comparison with their assets (many of which comprise relatively illiquid loans). Net interest income is maximised by funding the assets with:

- Relatively short-term funds if interest rates are in a declining phase of the interest rate cycle
- Longer-term funds if interest rates have entered a phase of rising rates<sup>13</sup>

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<sup>13</sup> Refer to Chapter 3.

Banks fund themselves mostly by accepting deposits (the most important of which are usually those which mature on demand). Examples include the following, from Fourie, *et al.* (1999:89):

- Call deposits
- Current accounts
- Savings and transmission deposits
- Foreign currency deposits
- Negotiable certificates of deposits
- Fixed and notice deposits

An example of the asset and liability structure of a typical bank in South Africa is illustrated in Figure<sup>14</sup> 2.3. below:

Liabilities	Rm	Assets	Rm
Deposits:		Money:	
Cash managed, cheque and transmission	4 181	Notes and coin	392
Other demand	4 258	Deposits with Reserve Bank	91
Savings	4 514	Call loans	2 158
Fixed and notice	30 403	Deposits, discounts, loans and advances:	
Loans received under repurchase agreements	423	Instalment debtors	7 127
Foreign finance on-lent to clients	4 395	Mortgage advances	15 257
Outstanding acceptances and guarantees on behalf of clients	3 312	Bills, notes, acceptances and guarantees	5 300
Capital and reserves	3 153	Overdrafts and other	15 816
Other liabilities	1 308	Investments:	
		Government stock	2 332
		Short-term securities	2 990
		Other assets	4 484
<b>Total</b>	<b>55 947</b>	<b>Total</b>	<b>55 947</b>

***Figure 2.3. Table illustrating the balance sheet of a typical bank.***

Fourie, *et al.* (1999:90) mention that increased competition and deregulation have contributed to structural changes in the financial markets, which in turn have contributed to an active interbank market. Banks deposit considerable volumes of short-term funds with each other and commercial banks, in particular, make use of the money market to bridge short-term liquidity shortages.

f. Banks: Recent Developments and Future Prospects

<sup>14</sup> From Fourie, *et al.* (1999:89).

At the end of 1996, there were more than fifty banks operating in South Africa, according to Fourie, *et al.* (1999:88) and they all operate in just about the same financial markets. It is no surprise then, that it has been said that the South African financial sector is overbanked. Competition is strong, not only between banks themselves but also between banks and other financial institutions. In keeping with these competitive trends, a few South African banks have established foreign outlets. The Council of Southern African Bankers (COSAB) was established in March 1992 with the primary objective of promoting the interests of the banking industry.

Banks are no longer the only suppliers of banking services. Indeed, many activities that were previously performed only by banks can now be done by markets, non-banking financial institutions and non-financial companies. The overall impact of this is that the value of the "banking franchise" (Fourie, *et al.*, 1999:90) is being eroded.

However, this can be positive in the sense that the business of the banking firm may change towards providing a wider range of financial services relative to the traditional "financial intermediation and on-balance-sheet" (Fourie, *et al.*, 1999:90) role. This means that, despite regulatory concerns about diversification, banks may offer the full range of financial services which is, ultimately, in the public interest.

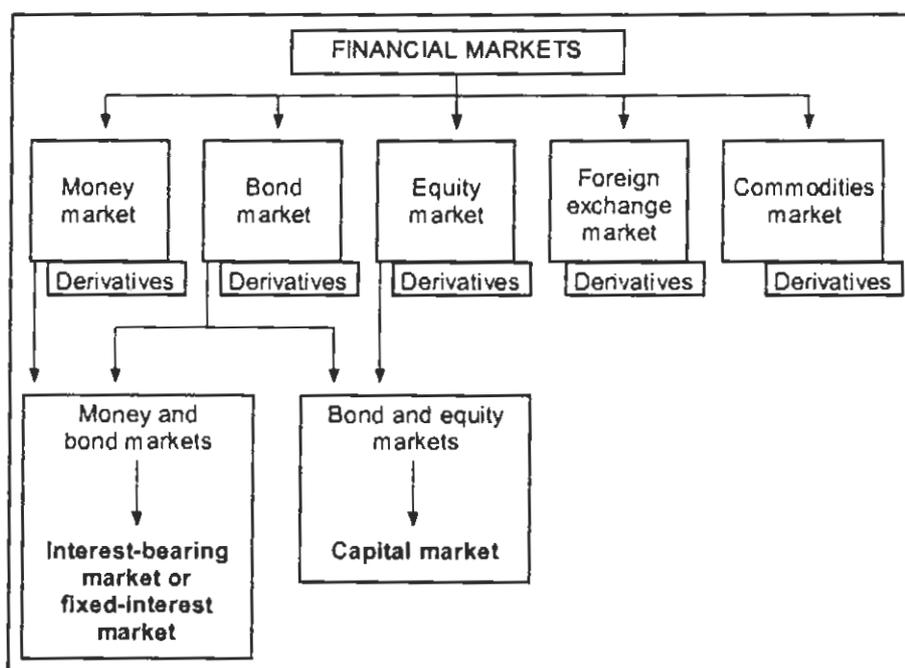
Competition is enhanced. Consumers are offered the choice of one-stop purchases and the chance to exploit potential purchasing economies of scope. More efficient outcomes are produced, since there is the freedom to develop strategies and optimum business portfolios and structures. Also, diversified institutions are less risky than concentrated businesses.

Fourie, *et al.* (1999:90) believe that, in practice, financial conglomerates will not displace specialist institutions. The South African financial system has evolved a dual structure: a few major bank-based financial conglomerates together with a much larger number of more specialist financial institutions. Whether financial conglomerates have a comparative advantage, is up to the market and consumers to decide.

With the introduction of electronic banking, Falkena, *et al.* (1984:75) mention that the size and importance of general banks is expected to grow, since the rationale behind electronic banking is to provide cheaper and more convenient banking to individuals (the market sector of general banks). As a result, competition with the building societies could increase.

### 2.2.3. Financial Markets

Faure (2003:17) points out that the financial markets are simply the “mechanisms and conventions” that exist for transferring funds and their counterparts (the financial instruments) between the various participants. A general picture of the financial markets is shown in Figure<sup>15</sup> 2.4. below:



**Figure 2.4. Figure illustrating the financial markets.**

The economic function of financial markets is, as Fourie, *et al.* (1999:11) put it, to “provide channels for transferring the excess funds of surplus units to deficit units” either directly or through financial intermediaries (indirectly). They also provide other options. Surplus units may purchase primary or indirect securities or reduce their debt by purchasing their own outstanding securities, whereas deficit units may issue securities or dispose of some financial assets previously acquired.

<sup>15</sup> From Faure (2003:24).

According to Falkena, Bamber, Llewellyn, and Store (2001:140), participants in the financial markets are primarily financial institutions. However, large corporates (like Eskom, Transnet and Telkom) are also important participants in the regulated markets. In fact, they even make a market in their own bonds. Faure (2003:18) lists several participants in the financial markets:

- Borrowers (who are issuers of securities)
- Lenders (who are buyers of securities)
- Financial intermediaries (who are buyers and issuers of securities and other debt obligations) and the brokers
- Fund managers
- Speculators
- Exchanges
- Regulators

The participants mentioned above as well as “their dealings in particular financial claims or groups of claims and the manner in which their demands and requirements interact to set a price for such claims (the interest rate)” (Fourie, *et al.*, 1999:12), are what makes up the financial market. Terminology and concepts that are often used in the financial markets include: primary and secondary markets, the spot market, the options and futures markets, financial exchanges, money and capital markets, debt markets and the swap market. Below is a brief look at these.

### 2.2.3.1. Primary and Secondary Markets

#### **i. Primary Market**

The primary market is defined by Fourie, *et al.* (1999:12) as “the market for the issue of new securities to borrow money for consumption or investment purposes”. It includes the issue of both primary and indirect securities.

The markets in non-negotiable instruments (like mortgage loans, savings deposits and life policies) are completely primary markets. Negotiable certificates of deposit and bonds, for example, are issued in the primary market but traded in the secondary market.

## ii. Secondary Market

The markets “in which previously issued financial claims are traded” (Fourie, *et al.*, 1999:12), are referred to as secondary markets. It is important to distinguish between brokers and market-makers when examining the secondary market:

- **Brokers** – usually act on behalf of other financial market participants (principals) in return for a commission. They are not financial intermediaries
- **Market-makers** – are financial intermediaries (mostly banks) that, according to Faure (2003:18), have assumed, or are appointed by the issuers to perform the function of market making. They are prepared to quote buying and selling prices simultaneously for certain securities and are also prepared to “deal in reasonable volumes” (Fourie, *et al.*, 1999:12). Therefore, since these institutions are prepared to hold portfolios of securities for this purpose, they must be capitalised adequately. That is why the market makers are the large domestic and international banks

### 2.2.3.2. Money and Bond Markets

Faure (2003:19) maintains that usually, the financial market, or more specifically, the debt markets<sup>16</sup>, is split into the money and bond markets. These markets embrace the primary (or new issues) market as well as the secondary market. What separates the money and bond markets is the basis of term to maturity of the securities traded. It is arbitrarily determined to be one year.

#### i. Bond Market

The bond market is broadly defined as the market for the issue and trading of long-term securities.

#### ii. Money Market

The money market is broadly defined as the market for the issue and trading of short-term securities (it is characterised by the trading of short-term funds, with maturities of one year or less), or as Falkena, *et al.* (1984:201) describe it, “the arrangement that exists for the lending and borrowing of money in the short term”. It brings short-

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<sup>16</sup> Also referred to as the fixed interest markets, since most instruments carry fixed rates of interest.

term lenders into contact with borrowers who require funding for short-term periods. One of the principal functions of the money market that Koch and Macdonald (2003:260) identify, is to finance the working capital needs of corporations and governments.

According to Falkena, *et al.* (1984:202), the money market embraces both the primary market for short-term securities (the market for new issues of securities) as well as the secondary market (the market for the exchange of previously issued financial securities). It is not a visible market, that is, transactions take place via telephone between parties that know and trust each other.

The money market consists of more than just the issuing and trading of money market instruments. Indeed, it encompasses the all-important "interbank market" (Faure, 2003:19) as well as the various significant operations of the Reserve Bank.

As stated previously<sup>17</sup>, the Reserve Bank operates in the money market in the form of open market operations. The reason for this is to establish a certain desired "money market shortage" (Faure, 2003:19), or level of borrowed reserves, which it provides via the interbank market. These borrowed reserves are provided at the Bank's accommodation rate (previously referred to as the Bank rate, now known as the **repo rate**).

The repo rate as well as the actions of the Reserve Bank are designed to influence short-term interest rates (money market rates), which they certainly do. This is significant since money market interest rates are the foundation of rates and prices in all other markets, including the derivatives markets, as Faure (2003:19) reveals.

According to Falkena, *et al.* (1984:202), money market instruments can be classified in three broad categories: **primary securities**, **indirect securities** and **repurchase agreements**.

**Primary securities** consist of securities representing the obligations of:

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<sup>17</sup> Refer to the portion on the functions of the Reserve Bank in the financial institutions section (2.2.2.).

- Firstly the private sector (*bankers' acceptances*, trade bills and promissory notes)
- Secondly the central government (Treasury bills and government stock)
- Thirdly the semi-public sector bodies (capital project bills, bridging bonds, municipal stock and public corporation stock)

Primary securities are the obligation of the “final borrowers” (Falkena, *et al.*, 1984:203), which can be divided into liabilities of the private and public sectors.

**Indirect securities** consist of:

- Firstly, securities representing the liabilities of private banks and building societies (negotiable certificates of deposit)
- Secondly, securities representing the liabilities of public sector financial institutions (Reserve Bank debentures, Land Bank bills and Land Bank debentures)

The first data set used in this study refers to **Bankers' Acceptances (BA rates)**. Thus, BAs are discussed after Figure<sup>18</sup> 2.5., which shows the debt market securities of the financial system. The table is split into **primary securities** and **indirect securities**.

<b>Issuer</b>	<b>Money market</b>	<b>Bond market</b>
<b><u>Primary securities</u></b>		
Household sector	–	–
Corporate sector	BAs, CP, trade bills	Corporate bonds, debentures
Government sector	TBs, public enterprise bills	Government bonds, municipal bonds
Foreign sector	–	–
<b><u>Indirect securities</u></b>		
<b><u>Deposit intermediaries</u></b>		
SARB	SARB debentures	–
CPD	–	–
LAB	LB bills, PNs, call bonds	Debentures
Private banks	Negotiable certificates of deposit	–
Mutual banks	–	–
Postbank	–	–

<sup>18</sup> Adapted from Faure (2003:20).

Non-deposit intermediaries		
<i>DFIs</i>		
DBSA	DBSA bridging bonds	DBSA bonds
IDC	–	IDC bonds
NHFC	–	–
KEF	–	–
INCA	–	INCA bonds

BAs = bankers' acceptances; CP = commercial paper; TBs = Treasury bills; LB = Land Bank; PNs = promissory notes

***Figure 2.5. Table illustrating the money and bond market securities.***

- *BA data set: Bankers' Acceptances*

A bankers' acceptance (BA) is, as Botha (2003:222) describes, a "discount money market instrument issued by the private sector". It is a primary security and is formally defined as "a **bill of exchange** drawn on and accepted by a bank" (Botha, 2003:222).

The form, content and legal consequences of a bill of exchange are regulated by law, stipulated in South Africa, in the Bills of Exchange Act (No. 34 of 1964). According to Falkena, *et al.* (1984:204), a bill of exchange is defined in this Act as:

An unconditional order in writing, addressed by one person to another, signed by the person giving it, requiring the person to whom it is addressed to pay on demand, or at a fixed or determinable future time, a sum certain in money to a specified person or his order, or to bearer.

Botha (2003:222) regards a bill of exchange as a negotiable security signed and dated by the issuer (the drawer). It contains an "unconditional order or instruction for the debtor (the drawee) to pay a fixed sum of money to a certain person or to that person's order upon maturity" (Botha, 2003:222). If the debtor so agrees, he or she accepts the bill of exchange by signing it.

Bills of exchange hold an important position in the commercial world. They are among the oldest instruments of payment and can be traced back to the fourth century BC. They were created originally, to:

- Enable sellers or exporters of goods to get cash as soon as possible after they had sent off their goods
- Enable the buyers or importers to delay payment until the goods had reached them or until they had sold them

In this respect, a seller would draw a bill on the buyer of the goods (that is, address an order in writing to the buyer), requiring him or her to pay a sum of money (equal to the value of the goods) after a period of time. The seller would get the buyer to “accept” the bill (in other words, to guarantee payment on due date), by signing across the face of the bill. The seller would then be able to negotiate the bill to some “holder of surplus funds” (Botha, 2003:222).

Thus, Bankers’ acceptances are merely “bills of exchange drawn on and accepted by banks” (Botha, 2003:222). They are instruments of high quality and great simplicity and can, as Falkena, *et al.* (1984:204) point out, be negotiated in a sophisticated secondary market that exists for such paper. They were created to avoid the technical problems arising from the physical distances between buyers and sellers, as Botha (2003:222) suggests and also to add to the quality of bills of exchange.

According to Fourie, *et al.* (1999:163), there are three parties to a bankers’ acceptance (hence the term “three-name paper” that is applied). They are:

- The drawer
- The acceptor (the bank)
- The endorser (usually another bank)

BAs are different from ordinary bills of exchange because they can be created by anyone who requires short-term finance. In this sense, the purchaser (a company) or the seller of goods (a company) who requires temporary finance may draw a bill of exchange on his or her banker. Botha (2003:222) explains that this means that the banker undertakes to pay to the company that requires the finance (or to its order), a certain sum of money, after a certain period. By signing across the face of it, the banker then accepts the bill making it a “bankers’ acceptance”. The company requiring finance (the drawer) then endorses the acceptance in blank, thereby

making the bill payable to bearer, which in turn allows the drawer to sell the BA in the market at the “ruling discount rate“(Botha, 2003:223).

It is not unusual for the accepting bank to discount (sell) the BA itself or with another bank on behalf of the drawer. The BA may be sold in the secondary market at the ruling **BA discount rate** many times before maturity. However, whoever holds the BA when it matures receives the full face value from the original accepting bank (the acceptor), as Botha (2003:223) points out. When the BA matures, the drawer must pay the acceptor the full face value of the acceptance.

The accepting bank also charges a **commission** to the borrower. This commission varies from bank to bank and is mainly determined by risk. Also, a **stamp duty** of 5 cents per R100 value of a BA is payable.

Botha (2003:223) states that most BAs are issued for periods of 91 days (three months). A wide range of denominations are available although they are normally created in multiples of R100 000 and R1 million.

In addition, like many other (private sector) money market instruments, “BA business” is managed by the treasury divisions of banks. BAs are **self-liquidating** securities which, according to Botha (2003:223), means that they are created for the purpose of “financing the purchase, manufacture, movement, etc. of goods and are secured by the proceeds arising from the sale of those goods”.

Botha (2003:226) maintains that BAs are extremely safe investments when they are accepted by a large bank. Fourie, *et al.* (1999:166) mention that bankers’ acceptances payable to bearer are transferable by delivery alone. When they are sold, the bills must physically be handed over from one owner to the other. For security reasons scrip is usually held with a bank in safe custody. Acceptances payable to order are transferable “by the endorsement in blank of the holder completed by delivery” (Fourie, *et al.*, 1999:166).

The SARB repealed the liquid asset status of BAs in the early 1990s and because of this, banks became less eager to accept them. As a result, the total amount

outstanding in BAs declined significantly towards the end of the 1990s, as Botha (2003:226) explains. Despite this, however, they are still an important money market security. The BA rate (quoted daily in the financial press) gives a good indication of conditions in the money market – Botha (2003:226) points out that a declining BA rate indicates an expected easing of money market conditions and a rising BA rate indicates the opposite.

a. BA: Primary Market Demand

Fourie, *et al.* (1999:165) state that most BAs are sold to the dealing banks. These, in turn, supply many institutions, which include: mining houses, banks, private and public corporations, pension funds, insurance companies and individuals.

b. BA: Issuing Procedures – Life-cycle of a BA

A Bankers' Acceptance goes through various stages, from creation to expiry. Below is a brief summary of what happens<sup>19</sup>:

1. A company in need of money (to purchase raw materials to be able to complete an order, for example) applies for an acceptance credit facility at a bank. The bank examines the company's creditworthiness. Once satisfied with the "financial standing" (Falkena, *et al.*, 1984:204) of the client applying for an acceptance credit facility, the bank issues a letter of credit (L/C) setting out the terms (including the obligation of the drawer to put the bank in funds on the maturity date of the bankers' acceptance) and conditions under which it is prepared to accept the bill drawn on it.

The acceptor agrees to pay the bill at maturity. The drawer of the bill undertakes to compensate the holder or an endorser should the bill be dishonoured. The endorser undertakes to compensate the holder or a subsequent endorser if the bill is dishonoured. Fourie, *et al.* (1999:164) mention that these days, bills are usually traded as "two-name papers" since most bills are accepted by one of the large commercial banks and are of such quality that they need not be endorsed by a third bank. The documentation is kept in safe custody by the bank;

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<sup>19</sup> Based on the example by Botha (2003:223-226).

2. The company completes the BA form (which looks like a cheque), entering:
  - The current date
  - The maturity (ex: 91 days)
  - The nominal amount
  - The L/C code under which the BA is to be issued (ex: R1 million)

Two company officials sign across the face of the bill and also across the back. If accepted, this will transform the BA into a "bearer instrument" (Botha, 2003:224);

3. The bill is sent to the bank where two of its Treasury Division officials sign it, thereby making it an official bankers' acceptance. The BA is then "discounted (on an all-in basis) by the bank" (Botha, 2003:224), on behalf of its client. The company's account is credited. The calculations are as follows:

c. BA: The Cost of Acceptance Credits

Fourie, *et al.* (1999:164) explain that the cost of acceptance credits is made up of the following:

Acceptance commission charged by the accepting bank	=	0,5 (variable) per cent per annum of nominal value payable in advance
Stamp duty	=	5c for every R100 or part thereof
Discount charges	=	the ruling discount rate for bankers' acceptances

*Example*

Nominal value	=	R1 000 000
Discount rate	=	17,00% p.a.
Tenor of bill	=	90 days
Cost (discount amount)	=	$R1\ 000\ 000 \times [90/365(0,5/100+17,0/100)+0,05/100]$
	=	R43 650,68

This cost in terms of a discount rate per cent per annum would be calculated as:

$$\begin{aligned} \text{Cost} &= 43\ 650,68/1\ 000\ 000 \times 365/90 \times 100 \\ &= 17,703\% \text{ p.a.} \end{aligned}$$

d. BA: Issue Mathematics

Bankers' acceptances are issued on a discount basis only. The proceeds payable to the drawer are calculated with the following formula, used by Fourie, *et al.*

(1999:165):

$$\text{Proceeds} = N - (N \times i/100 \times d/365)$$

Where

N = nominal amount

i = discount rate per cent per annum (i.e. all-in discount rate)

d = tenor in days

*Example*

N = R1 000 000

i = 17,40% p.a.

d = 91

$$\begin{aligned} \text{Proceeds} &= \text{R1 000 000} - (\text{R1 000 000} \times 17,40/100 \times 91/365) \\ &= \text{R956 619,18} \end{aligned}$$

4. The company purchases the raw materials it needs (which are paid for with the proceeds from the BA) and manufactures the products;
5. The finished products are despatched to the business that ordered them, who pay the company in cash;
6. The bank's Treasury Division sells the BA in the secondary market at the ruling discount rate only (since stamp duty and commission have already been "paid" by the drawer as Botha (2003:225) points out):

e. BA: Dealing Mathematics

According to Falkena, *et al.* (1984:207), BAs are traded in the secondary market also on a discount basis. The consideration is calculated in terms of the same formula:

$$\text{Consideration} = N - [ N \times (i/100) \times (d/365) ]$$

Where

N = nominal amount

i = discount rate per cent per annum

d = remaining tenor in days

*Example*

N = R1 000 000

i = 17,15

Due date = 3 October 1985

Settlement date = 14 July 1985

d = 81

$$\begin{aligned} \text{Consideration} &= \text{R1 000 000} - [ \text{R1 000 000} \times (17,15/100) \times (81/365) ] \\ &= \text{R961 941,10} \end{aligned}$$

Botha (2003:225) mentions that the BA may be traded several times before the expiry date;

7. Whoever holds the BA on the maturity date, presents it to the bank and receives the full face value of R1 million from the bank<sup>20</sup>;
8. The company repays the bank the nominal value (R1 million) of the BA.

As stated before, the value of bankers' acceptances created has declined to some extent over recent years, mostly due to the liquid asset status and eligibility (for Reserve Bank advances) of the instrument being withdrawn, as Fourie, *et al.* (1999:165) reveals. Nevertheless, bankers' acceptances are considered attractive for the following reasons, from Fourie, *et al.* (1999:165):

- They are "prime" money-market instruments, the drawers and acceptors being of strong financial standing
- They are available across the full maturity spectrum up to three months (and in some cases longer)
- They are instruments of great simplicity
- A ready market exists for them

Falkena, *et al.* (1984:206) note that:

- Liquid bankers' acceptances may be held by banks to meet their liquid asset requirements but only up to a certain limit
- Some non-liquid bankers' acceptances (those drawn by certain public bodies) are considered approved investments for pension funds and insurance companies
- A large quantity of bankers' acceptances are sold to the discount houses in terms of a "quota system" established between the accepting banks and the houses

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<sup>20</sup> On maturity, bankers' acceptances are payable by the accepting banks and have to be presented to them by the holder on due date, either directly or indirectly and in the case of encoded acceptances, by deposit to his or her current account at any bank, as Fourie, *et al.* (1999:166) state.

f. BA: The Secondary Market

According to Fourie, *et al.* (1999:165), a developed secondary market exists for bankers' acceptances. The dealing banks are involved as market-makers, at the centre of the market. Secondary market activity varies substantially from month to month and is usually higher, as Fourie, *et al.* (1999:166) point out, during periods when interest rates are declining.

2.2.3.3. Spot, Forward and Derivatives Markets

i. Spot Transaction

Fourie, *et al.* (1999:13) contend that when a financial instrument is traded and settled on the same, or on the following day<sup>21</sup>, it is termed a spot transaction.

ii. Forward Transaction

When a financial instrument is traded on one day for settlement in two weeks (for example), it is termed a forward transaction. The price of the forward transaction is the spot price plus the price of money for a two-week term. Forward markets are traded over-the-counter (OTC). A forward is derived from the spot market.

iii. Derivatives Market

There are many other products (instruments) that are derived from the spot market activity. These derivatives can be categorised as in Faure (2003:22), shown below:

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<sup>21</sup> Or even three days later, according to Faure (2003:22).

<b>Equity Market</b>	<b>Bond Market</b>
Futures	Futures
Options	Options
Options on futures	Options on futures
Warrants (which are essentially options)	
	<b>Commodities Market</b>
<b>Money Market</b>	Futures
Repurchase agreements <sup>22</sup>	Options on futures
Interest rate swaps <sup>23</sup> (swaps)	
Forward rate agreements (FRAs) <sup>24</sup>	<b>Foreign Exchange Market</b>
Caps and floors <sup>25</sup>	Forwards
	Swaps

**Figure 2.6. Table illustrating the South African derivatives markets.**

Derivatives market is a term used for the options and futures markets. The options market is divided into options on spot instruments and options on futures. They are both linked to the forward market because their prices are largely determined by the forward price. Options and futures are termed derivatives because they are *derived* “from specified underlying assets or notional assets” (Fourie, *et al.*, 1999:14):

- An **option** grants the holder the right (but not the obligation) to buy or sell the underlying asset at a predetermined price during a specified period. The holders’ potential profit is not fixed, while their potential loss is limited to the

<sup>22</sup> A **repurchase agreement** is defined by Falkena, *et al.* (1984:203) as the “sale of existing financial securities with the undertaking by the seller to repurchase the same securities on a stipulated date and at a price determined at the time of the sale”. Simply put, it is “the loan of a previously issued security at an agreed rate of interest for a specified period of time” (Faure, 2003:22).

<sup>23</sup> Fourie, *et al.* (1999:13) state that an **interest rate swap** entails the swapping of interest obligations between two parties via a facilitator. It is an agreement between two parties to exchange a fixed rate of interest for a floating rate of interest to a mutually agreed notional amount (which is not exchanged between the parties). The term of the agreement determines whether it is a money market or bond market transaction.

<sup>24</sup> A **forward rate agreement (FRA)** is an agreement between two parties that want to protect themselves against a future movement in interest rates. As Fourie, *et al.* (1999:351) explain, the two parties agree on an interest rate, for a specified period, from a specified future settlement date, based on an agreed principal amount. In other words, or as Faure (2003:23) puts it, they fix a rate on a deposit or a notional loan, that starts some time in the future. Their exposure is only the “interest difference between the agreed and actual rates at settlement” (Fourie, *et al.*, 1999:351).

<sup>25</sup> **Caps and floors** are similar to options:

- The purchase of a **cap** makes it possible for a company with a borrowing requirement to hedge itself against rising interest rates, as Faure (2003:23) maintains. The contract establishes a ceiling but the company retains the right to benefit from falling interest rates
- A **floor** contract allows a company with surplus funds to shield itself against declining interest rates, as Faure (2003:23) mentions, by determining a specified floor up front, while retaining the right to profit from rising interest rates

amount of the premium paid. Naturally, the holders will exercise their options only if it is profitable to do so

- A **futures contract** is an agreement to buy or sell a standard quantity and quality of an asset (that is, a financial asset, commodity or notional asset) on a specific date and at a price to be determined at the time of negotiation of the contract, from or to an exchange established for such a purpose

#### 2.2.3.4. Financial Exchanges

Fourie, *et al.* (1999:14) indicate a distinction between an over-the-counter market and a formalised market:

##### **i. Over-the-counter (OTC)**

OTC refers to the meeting of buyers and sellers “over the counter” in a retail outlet, for example, or in a flower market, over the telephone or via a communications system. OTC markets may be subject to regulation, or may be free of supervision by the authorities point out. Most markets start in this way and then progress to become formal markets.

##### **ii. Formal Markets (or Exchanges)**

These are normally governed by statute and the rules and regulations of such an exchange. In South Africa, the money market, the foreign exchange markets (and their derivatives) and the spot commodities markets are OTC markets, according to Faure (2003:23). The equity, bond and futures (and options on futures) markets are formalised.

#### 2.2.3.5. Allied/ Other Related Markets

Fourie, *et al.* (1999:14/15) mention that the term “financial markets” refers to:

- All lending and borrowing,
- the intermediation of this process
- and the exchange of financial obligations.

Thus, strictly speaking, the equity market, although closely linked to it, is not a financial market. According to Faure (2003:19), other markets that are closely related to the equity and debt markets (or interest-bearing or fixed-interest markets) include the foreign exchange and the commodities markets.

**i. Foreign-exchange Market**

In South Africa, the foreign-exchange market is an OTC market and is closely monitored and controlled by the monetary authorities. Although it is not a financial market, it can be seen as one because it has a domestic and foreign lending and borrowing dimension.

**ii. Commodities Market**

This is the market for the exchange of commodities (big volume items, like maize). It is an OTC market, where the commodities are exchanged for money. The commodities market has a significant derivatives market allied to it – agricultural futures and options on these futures. The Agricultural Derivatives Division of SAFEX regulates this market, in which the derivative instruments are traded.

**iii. Equity Market**

The equity market does not involve borrowing and lending and in South Africa, is formalised in the form of the Johannesburg Stock Exchange. Fourie, *et al.* (1999:15) point out that the primary equity market involves the issuing of equity in a corporate entity (the extension of ownership), while the secondary equity market involves the exchange of ownership in a corporate body.

The equity and bond markets are together referred to as the "capital market". This is due to the fact that these markets are used to acquire capital for long-term investments, as Faure (2003:21) explains.

**2.2.3.6. Capital Market**

The capital market is, as Van den Berg (2004) notes, the market for the issue and trading of long-term securities. The term is measured as the term to maturity of the

security and to be able to be classified as a capital market instrument, this term must be longer than three years. In the capital market, the securities traded are informally classified into short-term capital market instruments (where the term to maturity of the instrument is up to five years), medium-term (five to ten years) and long-term (more than 10 years).

The capital market can be seen as “the complex of institutions and mechanisms through which funds with a term of more than three years are pooled and made available to the private and the public sectors” (Fourie, *et al.*, 1999:183). In addition to the term structure, the capital market can be analysed from several other perspectives such as the following, from Fourie, *et al.* (1999:183/184):

1. A distinction can be made between public sector borrowers who issue stocks (also known as bonds) and private sector borrowers who issue debentures;
2. Another distinction can be made between the primary capital market (where first issues are sold or placed) and the secondary market (where issued securities are subsequently traded);
3. A classification can be made according to the way primary issues are placed – through a public issue (where securities are offered to the public at large), or by way of a private placement (where securities are offered only to a select number of investors);
4. Another distinction is between fixed-rate securities (like Eskom loan E168 11% fixed coupon stock) and variable-rate securities (like Cape Town loan L357 variable coupon stock linked to Eskom rates);
5. Shares (equities), which pay dividends, are distinguished from interest-bearing securities, which pay interest on a regular basis;
6. Securities which are listed on an exchange are in a different category than unlisted securities;
7. Yet another distinction is between negotiable securities (like RSA stock) and non-negotiable securities (for example, five-year mortgage participation bonds);
8. A last distinction is between bearer securities (for example, national defence bonds) and securities which are registered in the owner's name (like Eskom stock).

Fourie, *et al.* (1999:183) contend that there is no market for capital as such (that is, for the capital goods themselves). There are markets only for the financial instruments that represent either title or claims to financial capital.

a. Capital Market: Primary Market

The primary market is "the market for the first issue of securities" (Van den Berg, 2004). In South Africa, the main institutions involved in the primary capital market as issuers of securities are, according to Fourie, *et al.* (1999:184):

- The Treasury
- Public corporations (like Eskom and the Rand Water Board)
- Public utilities (for example, Telkom and Transnet)
- Local authorities and companies

Fourie, *et al.* (1999:184) mention that the main participants, as buyers, in this market are:

- The Public Investment Commissioners
- Insurance companies
- Building societies
- Pension funds and trust companies

b. Capital Market: Secondary Market

The secondary market is "the market for trading securities once they have been issued" (Van den Berg, 2004). It has a big influence on the issues in the primary market because the market rate is determined in the secondary market. The same institutions listed above are also operative in the secondary capital market where, Fourie, *et al.* (1999:184) state, they are supplemented by the banks, stockbrokers, the SARB (through its open-market operations) and money brokers.

### c. Capital Market: Instruments

When lenders make capital funds available to borrowers, the borrowers deliver a contract, or an instrument, representing their relationship with the investors. These capital market contracts include the following, from Fourie, *et al.* (1999:195):

- Variable-interest securities (for example, mortgages)
- Shares (such as ordinary company shares)
- Negotiable documents (for example, options such as a letter of allocation)
- Fixed-interest securities (like gilts)

### d. Capital Market: The Variable-interest Securities Market

Most long-term loans are subject to variable-interest rates because the inflation rate (and therefore, the real return for the investor) can fluctuate sharply. Fourie, *et al.* (1999:188) point out that the market for variable-interest securities in South Africa is still somewhat undeveloped and the public sector has embarked on issuing securities with variable interest rates only in relatively limited numbers.

Fourie, *et al.* (1999:188/189) explain that securities of this kind are linked to:

- The overdraft rate – when market conditions are difficult (when available cash is limited and uncertainty could discourage traditional investors to take up stock), the banks may be tapped as a further source for funds. This is achieved by getting the banks to take up public sector stock with a variable rate linked to the prime overdraft rate. This is normally a capital market instrument with relative short-term maturities of between three to five years
- The rate on long-term marketable Eskom stock (the Eskom rate) – In this case, it is important that the Eskom stock used as a basis be marketable. This is because a price for the linked stock has to be calculated whenever transactions take place.

This type of stock is usually issued when investors are uncertain about future interest rate developments. Also, since its maturities are longer (generally ten years), a long-term marketable Eskom stock offers a better basis than the

prime overdraft rate

- The 90-day bankers' acceptance rate – in order to improve flexibility, certain public institutions also make use of a facility by which their short-term securities linked to the 90-day bankers' acceptance rate are sold by merchant banks in the money market

Notably, these variable interest securities to the public sector are practically unmarketable in the secondary capital market, according to Fourie, *et al.* (1999:189). This is due mostly to their variable pattern of income, which implies that their future earnings cannot be discounted easily to a present value.

e. Capital Market: The Fixed-interest Securities Market

The second of the data sets used in this study (**Esc data set**) pertains to **Eskom rates** which fall under the category of fixed-interest securities. Briefly, a fixed-interest security may be defined as "a contract to pay interest at a prescribed rate on given dates and to repay the principal on a fixed date" (Eskom, 2004).

According to Fourie, *et al.* (1999:184), both the public and private sectors finance a large part of their expenditure by means of long-term loans with fixed interest rates. The fixed yield implies that the price of the security will fluctuate inversely with changes in the interest rate of the market.

Public sector fixed-interest securities are known as:

- "gilt-edged" securities (or "gilts") when they refer to government stock
- "semi-gilts" when they refer to the stock of lower-ranking public bodies (like municipalities or public enterprises)

Fixed-interest securities can be issued:

- In the name of the holder (like government stock)
- In a bearer's name (like defence bonds)

Fixed-interest securities are sold in various ways, depending mainly on whether they are gilts, semi-gilts, debentures or annuities. Fourie, *et al.* (1999:184/185) explain that in South Africa government stock used to be sold through “public issues offering fixed amounts of stock at fixed yields for different maturities”. Currently, a tap or tender basis is being employed. A “tap” is the main method that is used by the Reserve Bank to issue bonds. The Reserve Bank makes its intention to issue bonds known to the major market participants and invites bids. Then, it reserves the right to accept or reject bids, as Fourie, *et al.* (1999:171) point out.

Investors have certain requirements such as the following, from Fourie, *et al.* (1999:186/187):

- Marketability of stock – investors are more interested in stock that can be traded since this allows them to realise capital profits in times of decreasing interest rates and also offers them flexibility in the management of their portfolios
- Large issues of stock – preferably of at least R billion. Over the past few years, issuers (like the government and Eskom) have consolidated some of their less marketable stock issues into a single loan in order to improve the marketability of their stock
- The ability to hedge their portfolios against adverse movements in interest rates – all the large issuers now also make a market (that is, quoting buying and selling prices continuously) in options on their stocks so as to improve marketability

The close interaction between the money and capital markets is evident when it comes to fixed-interest securities. Despite the difference in maturities, Fourie, *et al.* (1999:187) maintain that there is no difference in the way fixed-interest securities are dealt with in the money and capital markets. The maturity of the fixed-interest securities does not influence the character of the instrument. Characteristics such as the issue and dealing mathematics and the splitting and transferability of fixed-interest securities are the same as for the money market.

In South Africa, government stock with less than three years to run to maturity is classified as a liquid asset, according to the Banks Act. Due to this distinction, capital market transactions in all stock are defined as “those pertaining to stock with an outstanding maturity of more than three years” (Fourie, *et al.*, 1999:187).

The most important aspect as far as the secondary market for public stock is concerned, has been, according to Fourie, *et al.* (1999:187), the enormous growth in the value of stock traded since the mid-1970s and the role played by stockbrokers and trading banks in this respect. Growth in the secondary market for semi-gilts was spurred by institutions like the South African Reserve Bank, Eskom, Transnet and Telkom. Fourie, *et al.* (1999:187) add that these institutions make a market in their own securities and are prepared to quote a two-way price (that is, buying and selling prices) on any of their issued securities.

The promulgation of the Financial Markets Control Act (Act No. 55 of 1989) has, as Fourie, *et al.* (1999:187) state, lead to the formalisation of the market for fixed-interest securities. This Act requires all listed stocks to be traded on a formal exchange within a set of rules approved by the Registrar of Financial Markets. The Bond Market Exchange became operational in May 1996.

#### f. Capital Market: Government Bonds

Government bonds are fixed-interest-bearing securities which means that “a fixed rate of interest (the coupon rate of interest) based on the nominal (face or par) value is payable six-monthly in arrears” (Fourie, *et al.*, 1999:172). Bonds that have been issued on tap or by tender, may be issued:

- At a discount to par value – the coupon interest is lower than the yield to maturity or redemption
- At par – the coupon interest is equal to the yield to redemption
- At a premium – the coupon rate is higher than the yield to maturity

Government bonds are redeemed at par (at face value). This amount, along with the final interest payment may be collected from the Treasury upon presentation of the certificate, as Fourie, *et al.* (1999:175) note.

g. Capital Market: Eskom Data Set

According to Eskom (2004), Eskom bonds are fixed-interest securities, the majority of which have fixed interest payments biannually, fixed maturity dates and fixed maturity values. Eskom sells bonds to raise money for capital projects (like building power stations and transmission lines). Every new batch of Eskom bonds that is issued is given an issue number. One of the well-known issues is the E168.

Each issue has a maturity date on which Eskom will redeem the bond. Short-dated or long-dated bonds may be bought. Each batch pays interest. Van den Berg (2004) explains that the interest paid on the nominal amount of capital market securities (called the coupon rate) appears on the certificate received by the holder (the investor) of such a security. This coupon rate is one of the parameters used to determine the consideration paid for the security when it is traded in the secondary market.

Most securities are issued at a fixed coupon rate<sup>26</sup>. The Eskom 168 (E168) security, for example, is issued at a coupon rate of 11%. This means that the registered holder of an Eskom E168 certificate will receive 11% interest per year on the nominal amount of the instrument. Van den Berg (2004) mentions that the nominal amounts are in multiples of R1 million<sup>27</sup> and the interest on the E168 is paid biannually on 1 June and 1 December<sup>28</sup>.

Eskom bonds can be sold at any time at current market rates. Van den Berg (2004) points out that capital market securities are physical certificates and the issuer of the

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<sup>26</sup> Van den Berg (2004) states that there are certain securities that are issued at a variable coupon rate, where the coupon rate is then linked to a well-known interest rate like the prime overdraft rate or the 90-day BA rate, as explained in the section on variable-interest securities.

<sup>27</sup> Eskom (2004) maintains that investments of less than R500 000 nominal value are not allowed due to the costs involved in servicing the account.

<sup>28</sup> Van den Berg (2004) provide an example: the holder of an E168 with a nominal value of R1 million will receive R55 000 on 1 June and R55 000 on 1 December.

security keeps a register of owners. This register is used by the borrower (issuer) to pay interest to the lender (owner of the security) on the interest payment dates indicated on the certificate.

When an instrument is sold to a new owner in the secondary market, the buyer is registered as the new owner on the settlement date of the transaction, as Van den Berg (2004) explains. The issuer's register (for registration of new owners) closes usually one month prior to the interest payment date. The date when the register closes is known as the last day to register (LDR). Consequently:

- The person or company who is registered as the owner one month before the interest payment date (that is, on LDR), will receive the interest on the payment date. In other words, the buyer buys the instrument "cum interest" (including interest)
- If a bond is sold and settled after the LDR but before the interest payment date, the seller will receive the interest payment. The buyer is then known to buy the instrument "ex interest" (without interest)

Since Eskom bonds are negotiable instruments, they can be bought and sold freely. This means that they are subject to the "economic laws of supply and demand" (Eskom, 2004), which means that:

- When demand is high (or supply is low), it costs more to buy – the effective rate of return is lower
- When demand is low (or supply is high), it costs less to buy – the effective rate of return is higher

Eskom conducts an active market in its bonds to ensure ready marketability. Eskom (2004) explains that Eskom bonds are denominated in South African Rands. This means that all interest and capital payments are in Rands and that the regulations apply to the movement of funds and their conversion into other currencies. Subject to these regulations, interest and capital payments are made to the holders of the bonds at any bank of their choice, anywhere.

i. Issue Mathematics

As an example<sup>29</sup>, consider the following, from Fourie, *et al.* (1999:172/173):

Date of issue = 1 July 1997  
Maturity date = 15 August 2022  
Coupon rate = 14% p.a.  
Interest dates = 15 February and 15 August

In the case of a tender, bids are submitted at a "rand price per cent in multiples of one cent" (Fourie, *et al.*, 1999:172).

- If tenders are assumed to be accepted at par (R100.00%), R100 is paid for every R100 of nominal or face value of the bond.

The first interest payment will be calculated in terms of the following formula:

$$\text{Interest payment} = c/100 \times d/365 \times N$$

Where

c = coupon rate of interest  
d = number of days from issue date to first interest date  
N = nominal value

Thereafter interest is payable six-monthly at R7 per R100 invested<sup>30</sup>.

- If tenders are assumed to be accepted at a discount price of R98,81%, the investors who tendered at that price would pay R98.81 for every R100 of nominal value of the bond. They would also receive R7 every six months for every R100 of nominal value. The investors would calculate their so-called **running yield** as follows:

$$\text{Coupon/price} \times 100$$

Where

Coupon = coupon rate<sup>31</sup> x principal<sup>32</sup>  
= 14/100 x 100  
= 14  
Price = buying price

Thus, running yield = 14/98,81 x 100 = 14,1686% p.a.

<sup>29</sup> The calculations shown here have been simplified.

<sup>30</sup> That is,  $R100 \times 0.14 = R14 \rightarrow R14 / 2 = R7$

<sup>31</sup> The coupon rate (or nominal yield) is, according to Van Zyl (2003:248), the interest that the issuer promises to pay to the bondholder during the life span of the bond. It is usually expressed as a percentage per annum. It may be a fixed or a variable interest rate.

<sup>32</sup> Van Zyl (2003:248) defines the principal as "the amount that the issuer will repay to the bondholder when the bond expires". It is also called the face value, par value or nominal value of a bond.

ii. Dealing Mathematics

Government bonds are dealt in on the basis of yield to maturity<sup>33</sup> expressed as interest rates. This yield is agreed between the purchaser and the seller. The all-in price<sup>34</sup> (which is quoted per R100 nominal) is calculated in two parts: the so-called clean price and the accrued interest.

As an example, consider the following from Fourie, *et al.* (1999:174/175):

$$\text{Accrued interest} = c \times d/365$$

Where

c = coupon rate per cent per annum

d = number of days from last interest date to settlement date

$$\text{Clean price} = \text{all-in price} - \text{accrued interest}$$

*Example*

Bond:	13% R153	Yield to maturity:	14,50%
Interest dates:	28 February and 31 August	Contract date:	2 October 1997
Maturity date:	31 August 2010	Settlement date:	16 October 1997
Nominal amount:	R1 000 000		

The clean price would be calculated to be R91,33

$$\begin{aligned} \text{Accrued interest} &= 13 \times 46/365 \\ &= R1,64\% \end{aligned}$$

The consideration would be found using:

$$\begin{aligned} \text{Consideration} &= \text{nominal amount} \times (\text{clean price} + \text{accrued interest})/100 \\ &= R1\,000\,000 \times (91,33 + 1,64)/100 \\ &= R929\,700 \end{aligned}$$

<sup>33</sup> Fourie, *et al.* (1999:173) state that the **yield to maturity** (or redemption) is commonly used to assess the relative attractiveness of a particular price. It is defined in Fourie, *et al.* (1999:173) as "the interest rate at which the present value of the interest receipts plus the present value of the redemption proceeds equal the price". Special calculators are available to perform these calculations quickly.

<sup>34</sup> The present value of the future interest receipts plus the present value of the redemption.

If a bond is transacted **ex-interest**, the interest is paid to the registered holder of the bond (that is, the seller) and the all-in price must take account of this. If the above bond was transacted for settlement on 14 August 1997, for example, then the clean price would be R91,35 and the accrued interest would be calculated as follows:

$$\text{Accrued interest} = c \times d/365$$

Where

c = coupon rate per cent per annum

d = number of days from settlement date to *next* interest date

$$\text{All-in price} = \text{clean price} - \text{accrued interest}$$

Therefore,

$$\begin{aligned} \text{Accrued interest} &= 13 \times 17/365 \\ &= R0,61\% \end{aligned}$$

which is then deducted from the clean price to determine the all-in price and

$$\begin{aligned} \text{Consideration} &= R1\,000\,000 \times (91,35 - 0,61)/100 \\ &= R907\,400 \end{aligned}$$

According to Eskom (2004), the longer the life of the bond, the greater the price movement (volatility) and thus, capital gain or loss for the same change in market yield. Also, the higher the coupon rate, the lower the fluctuation in the clean price.

#### h. Capital Market: Regulation of the Market

In 1989 the Financial Markets Control Act was promulgated. It regulated the initiation and existence of financial markets. The Bond Market Association was formed to establish an exchange and from this, the Bond Exchange of South Africa (BESA).

Van den Berg (2004) explains that BESA was established as a formal financial exchange licensed under the Act on 15 May 1996 and is responsible for: the listing/delisting of instruments, its members and the surveillance of trading activities. Members of BESA include: resident banking groups, large issuers, stockbrokers and many major resident financial institutions and intermediaries that meet specific requirements. They may act as agent and principal (dual trading capacity), or as principal only. A Guaranty Fund has been established for the protection of the investing public against the consequences of the insolvency of members.

#### 2.2.4. Financial Instruments (Products)

Faure (2003:14) identifies two broad categories of financial instruments:

- ◆ Equities (or shares);
- ◆ Debt instruments.

##### 2.2.4.1. Equities (or Shares)

There are different types of shares (or equities). Faure (2003:14) name the following:

- **Ordinary shares** – which impart to the holder the right to vote on issues that affect the company. The shareholder does not, however, have a right to the profits, until the board of directors declares a dividend
- **Preference shares** – which impart to the holder the prior right, over ordinary shareholders, to the distribution of dividends and capital in the event of the company “winding up”. They are closer to debt instruments than to ordinary shares. Types of preference shares mentioned by Faure (2003:14) are:
  - Participating preference shares
  - Convertible preference shares
  - Redeemable preference shares
  - Combinations of the above

##### 2.2.4.2. Debt Instruments

Fourie, *et al.* (1999:9) indicate that, due to the processes of borrowing and financial intermediation, there are a wide range of financial instruments and products in the South African financial system. A financial instrument or claim is “a claim against a person or institution for the payment of a future sum of money and/ or a periodic payment of money” (Fourie, *et al.*, 1999:10).

There may be:

- No periodic payment of money (as with Treasury bills)
- A periodic payment of money (as with long-dated bonds, on which interest is payable six-monthly in arrears, as Faure (2003:15) mentions)

- No promise of a sum of money in the future but a periodic payment only (as with an undated bond)

Faure (2003:15) points out that the more common instrument compels the issuer to pay periodic interest and to redeem the claim on the due date.

Reversibility or marketability (which refers to the ease with which the holders of claims can recover their investments) is one of the most important characteristics of financial claims. It can be achieved in two ways, namely:

1. By recourse to the issuer;
2. By recourse to a secondary market, in which the holder can sell the claim.

According to Fourie, *et al.* (1999:10), there are many examples of non-reversible claims, which usually involve the retail sector (the household sector). Examples of non-reversible claims are shown in Figure<sup>35</sup> 2.7. below:

<b>Primary securities</b>	
Household sector	IOU, hire purchase contract
Corporate sector	Loan to, leasing contract
Government sector	-
Foreign sector	-
<b>Indirect securities</b>	
<b>Deposit intermediaries</b>	
SARB	-
CPD	-
LAB	-
Private banks	Fixed deposit
Mutual banks	Savings account
Postbank	Postbank maxi save certificate
<b>Non-deposit intermediaries</b>	
<i>Contractual intermediaries</i>	
Short-term insurers	Policy
Long-term insurers	Retirement annuity
Pension and provident funds	Members' interest in pension fund
PIC	-
<i>Portfolio intermediaries</i>	
Unit trusts	Units (marketable to issuer)
Participation mortgage bond schemes	Share in participation mortgage bond

**Figure 2.7. Table with examples of non-reversible claims.**

<sup>35</sup> Adapted from Faure (2003:15).

Fourie, *et al.* (1999:11) state that reversible securities are securities that can be traded in the secondary market existing for such paper. These securities are usually issued in large denominations and are, therefore, referred to as the wholesale markets. The household sector is seldom involved. Examples of reversible (marketable) claims (securities) are shown in Figure<sup>36</sup> 2.8. below:

<b>Primary securities</b>	
Household sector	–
Corporate sector	Bankers' acceptances, commercial paper, bonds
Government sector	Treasury bills, bonds, public enterprise bills and bonds
Foreign sector	–
<b>Indirect securities</b>	
<b>Deposit intermediaries</b>	
SARB	SARB debentures, bank notes, coin
CPD	–
LAB	Land Bank bills, promissory notes, debentures
Private banks	Negotiable certificates of deposit
Mutual banks	–
Postbank	–
<b>Non-deposit intermediaries</b>	
<i>Contractual intermediaries</i>	
Short-term insurers	–
Long-term insurers	–
Pension and provident funds	–
PIC	–
<i>Portfolio intermediaries</i>	
Unit trusts	Units (marketable only to issuer)
Participation mortgage bond schemes	–
<i>Development finance intermediaries (DFIs)</i>	
DBSA	DBSA bonds and bridging bonds
IDC	IDC bonds
NHFC	–
KEF	–
INCA	INCA bonds

***Figure 2.8. Table containing examples of reversible claims.***

Some of these have already been described.

#### 2.2.4.3. Derivative Instruments

In addition to the debt market and equity market instruments, there are many other related financial instruments called **derivatives**. As Faure (2003:17) points out, the

<sup>36</sup> Adapted from Faure (2003:16).

name pertains to the fact that these instruments are **derived** from the debt and equity instruments and therefore, cannot exist on their own.

As already seen above and as Faure (2003:17) reveals, the derivative instruments may be categorised according to the markets and instruments from which they are derived, namely:

- Money market
- Bond market
- Equity market
- Foreign exchange market
- Commodities market

### 2.3. Conclusion

The focus of this chapter was on the South African financial system. The aim was to provide some background and to put in context the two data sets that are used in this study.

The four components of the financial system were described briefly. The central bank and its influences on the interest rates were mentioned. Also, the banks (as the financial institutions that deal with interest rates) and the markets in which they function were explored. Several financial instruments were pointed out.

The BA data set pertains to Bankers' Acceptances (from the money market) and the Esc data set pertains to Eskom rates (from the capital market). When these interest rates fluctuate, they can be the cause of banks "gaining" or "losing" money, depending on how equipped they are to deal with and manage interest rates and risk. This is the topic of the next chapter.

## CHAPTER 3: MANAGEMENT OF INTEREST RATE RISK

### 3.1. Introduction

Banks are able to perform certain functions and provide varied services to their customers. Yet, as explained in Chapter 2, they function in the financial system and thus, face many challenges. Bankers must manage several interconnected financial businesses profitably, while still considering the changing needs and preferences of clients and society in general. Additionally, banks compete with each other as well as with other institutions for funds and loans in the financial markets. Such is the business of banking.

When operating in deposit and loan markets, bankers must manage many types of risks, bearing near-term profitability, longer-run growth and capital adequacy in mind, as Falkena and Kok (1991:3) point out. As tempting as it may be to borrow more funds when prudent lending or investing can increase the returns to shareholders, leveraging bank capital more heavily could become a concern for equity analysts and shareholders if earnings appear likely to become more volatile.

Supervisors of the Reserve Bank and the Registrar of Financial Institutions are able to assess how effectively banks are able to manage risks. The central bank has to monitor bank behaviour continually, as it pursues its own objectives for money and credit growth.

Evidently, risk is an important concern for banks. Indeed, there are many different types of risks. One of the major types is interest rate risk. Since both the data sets used in this study rely on the market and its interest rates, the aims of this chapter are to describe:

- What risks are, in banking terms
- The types of risks that banks face
- What interest rates are
- What interest rate risk involves
- The asset-liability committee involved in managing interest rate risk
- How banks perceive interest rates and risk

- The importance for banks of predicting and managing interest rates correctly, in light of the damage their incorrect handling can cause to the bank
- The various methods banks have at their disposal to measure, manage and minimise interest rate risk

### 3.2. Banking Risks

Inevitably, banks encounter and have to deal with many types of risks. They are “highly geared financial risk-takers” (Cade, 1997:1) and when things go wrong, the results can be disastrous. There have been many examples of people and corporations who have lost a small fortune just because their prediction of interest rate movements was incorrect. Thus, risk management and in particular, interest rate risk management, is extremely important. Yet, in order to deal with risk management, a definition of risk must be given first.

Indeed, there are many definitions for “risk” amongst the various areas of study and no single definition serves all purposes. However, a suitable definition of risk in banking, according to Cade (1997:2), is: “exposure to uncertainty of outcome”, where:

- *Exposure* denotes a position or a stake in the outcome
- An *outcome* is the consequence of a particular course of action
- *Uncertainty* can be reflected in the volatility or variability of potential outcomes plotted on a probability distribution curve, where, Cade (1997:3) explains, the normal measure of dispersion is either the *variance* or the *standard deviation*. The wider the standard deviation, the greater the volatility and therefore, in theory, the uncertainty and the risk

Cade (1997:5) points out that if risk is seen as an outcome that deviates from the expected, then in some instances it may be a gain and not necessarily a loss:

- “pure” (or “static”) risk extends only downside from the expected outcome – it represents a possible loss. One-way risk
- “speculative” (or “dynamic”) risk can produce either a better or a worse (than expected) result – a profit or a loss. Two-way risk

Cade (1997:6) states that “no enterprise can achieve anything without engaging in risk”. Therefore, several courses of action are available to a banker that is faced with a particular source of risk. Taking the type of risk and the particular circumstances into account, an appropriate solution, like the ones below suggested by Cade (1997:5), is chosen:

- Avoid it, if in prospect
- Accept and retain it on an economically justifiable basis
- Increase, reduce or eliminate it by executive actions
- Reduce it by diversification within a portfolio of risks
- Hedge it artificially – counterbalance and neutralise it by using derivative instruments
- Liquidate it by transfer without recourse to another party

### 3.2.1. Types of Banking Risks

Classifying the many types of risk that banks are subjected to can be difficult. However, the following six types, from Cade (1997:16), fall into a framework that is generally accepted and recognised by bankers:

- **Solvency risk** – risk of ultimate financial failure of the bank through chronic inability to meet obligations. It is considered one-way (downside) risk, since solvency is the standard and insolvency is a disaster
- **Liquidity risk** – risk of the bank being unable to meet repayments, withdrawals and other commitments on time. Banks have certain recourses at their disposal to ensure adequate liquidity, that they are able to meet unexpected demands for cash and money transfers or term loans without hesitation or delay. These including the following from Falkena and Kok (1991:4):
  - Holding excess statutory liquid assets which can be sold for cash
  - Borrowing through the money market to meet cash drains
  - Depending on the Reserve Bank’s discount window

Liquidity risk is considered one-way risk, since liquidity is necessary and not a bonus

- **Credit risk** – risk of loss to the bank through default by an obligor, for example, the risk of a borrower not being able to repay his loans. Inevitably, banks cannot avoid all losses but they can try to minimise this type of risk by evaluating the type of people and organisations to which they lend money. Credit risk is considered one-way risk if the obligor does not pay more than face value or what is legally due and instead, pays less. However, it may be classified as two-way risk in the sense that expected loss may not materialise in which case the bank “wins”
  
- **Interest rate risk** sometimes referred to as “mismatching the book” – briefly, this refers to the vulnerability of net interest income, or of portfolio present values, to changes in interest rates. As Falkena and Kok (1991:4) explain, managing the book entails weighing the running gain from “borrowing short and lending long” against the risk of short-term rates rising so rapidly that the interest rate spread disappears or becomes negative. It is considered two-way risk. Managing interest rates and risk is the main focus of this chapter. Thus, interest rate risk will be examined more thoroughly in subsequent sections
  
- **Price risks** – risk of loss/ gain in value of assets, liabilities, or derivative contracts due to changes in market price; notably movements in exchange rates or share prices. Especially those banks that are involved in international finance, face currency risk. It involves the risk of the relative values of currencies changing with detriment to the bank. These type of banks should pay close attention to exchange and interest rate movements. Two-way risk
  
- **Operating risks** – risks arising from failures in operating processes, or the systems that support them, due to human error or omission, design fault, business interruption, fraud, sabotage and natural disaster, to name a few. It is seen mostly as one-way risk but it can be classified as two-way when expected loss does not materialise (similar to the situation with credit risk)

To this list, other types of risk can be added. Examples from Cade (1997:17) include: legal, regulatory, event, portfolio concentration and behavioural risks. However, most of these tend to fall under the heading of those already mentioned. There is also the

systemic risk that every bank faces. Bascom (1997:147) lists other risks such as: settlement and transfer risks and adds that the effective management of these risks assists in stabilising the banks' overall cash flow and also in ensuring their profitability and viability.

As Cade (1997:23) suggests, the aims in risk management should be to optimise the risk/ reward relationship, avoid shocks and provide prudent cover for expected and unexpected loss. This is an ongoing process which banks have to deal with if they want continued and consistent success. Regrettably, there are no guarantees.

### 3.3. Managing Banking Risks

According to the Federal Reserve Center for Online Learning (FRCOL, 2004), banks make money by taking risks. Some of these risks are fairly easy to assess and are specific to particular assets or liabilities. Others are not – they are more complex and can be assessed only by considering a bank's balance sheet as a whole. Therefore, as Falkena and Kok (1991:5) state, banks organise internal committees to oversee the management of the various risks.

Managing interest rate risk (in particular) is fundamental to the business of banking and so, dynamic asset and liability management has become increasingly important. Interest rate risk has become of more concern to the majority of banks because of sharply fluctuating interest rates. In fact, Cade (1997:145) points out that in most banks, it is the prime focus of attention for the asset and liability management process (ALM) and its supervisory committee (ALCO).

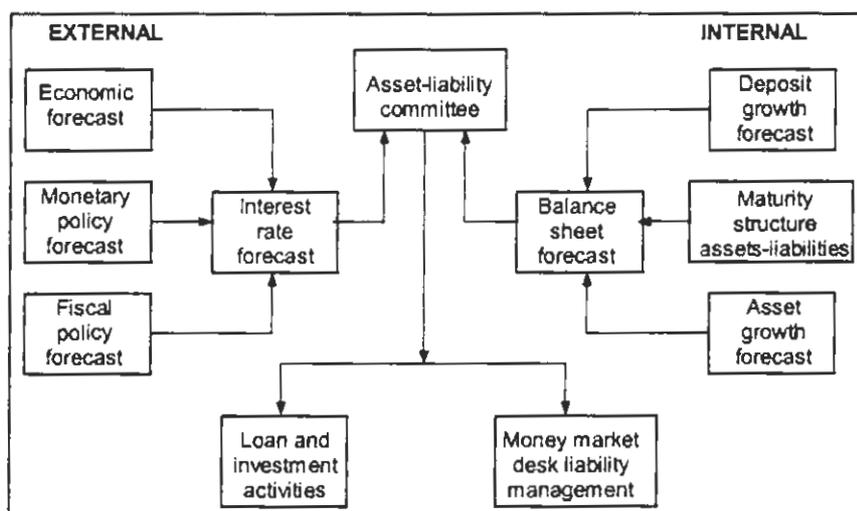
#### 3.3.1. ALCO – Organisation and Function

In order to manage interest rate risk, some of the major banks depend on an asset-liability committee (ALCO)<sup>37</sup> where, Falkena and Kok (1991:5) state, lending,

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<sup>37</sup> In FRCOL (2004), it is pointed out that this committee may also be known as the Asset and Liability Management Committee, or ALM committee.

investing, borrowing and staff functions like the economics department are represented. Figure<sup>38</sup> 3.1. below illustrates the asset-liability management of a bank.



**Figure 3.1. Diagram illustrating the asset-liability management of a bank.**

Asset-liability management attempts to use “an explicit and coordinated approach” (Bascom, 1997:148) to the management of both sides of a bank’s balance sheet. The goal is to ensure that there are asset-liability managers and an asset-liability committee (ALCO) that manage the bank’s balance sheet in such a way that the exposure of its earnings, liquidity and equity to changes in market conditions, is minimised.

Specifically, as stated in FRCOL (2004), the ALCOs:

- Assess the probability that various liquidity shocks and interest-rate scenarios<sup>39</sup> will occur
- Position the bank to handle the most likely of these scenarios at minimum cost (impact on earnings and capital) while still achieving a reasonable level of profitability
- Allocate the bank’s remaining assets and liabilities to meet risk and profitability objectives

<sup>38</sup> From Falkena and Kok (1991:6).

<sup>39</sup> Different scenarios like the following should be considered:

- The bank experiences an unexpectedly large volume of deposit withdrawals
- Loan repayments occur faster than anticipated
- Interest rates suddenly rise by 100 basis points (or one percent)

The results of achieving the goal may be seen as: stable net interest margins, optimum earnings, adequate liquidity and effective control of financial risks. Bascom (1997:148) mentions that, in order to attain these results, the ALCO must be guided by policies that address the bank's overall asset-liability management goals and risk limits specifically, as well as by information that relates directly to its asset-liability positions.

Other functions and responsibilities of an ALCO include the following, from Falkena and Kok (1991:5) and Cade (1997:74):

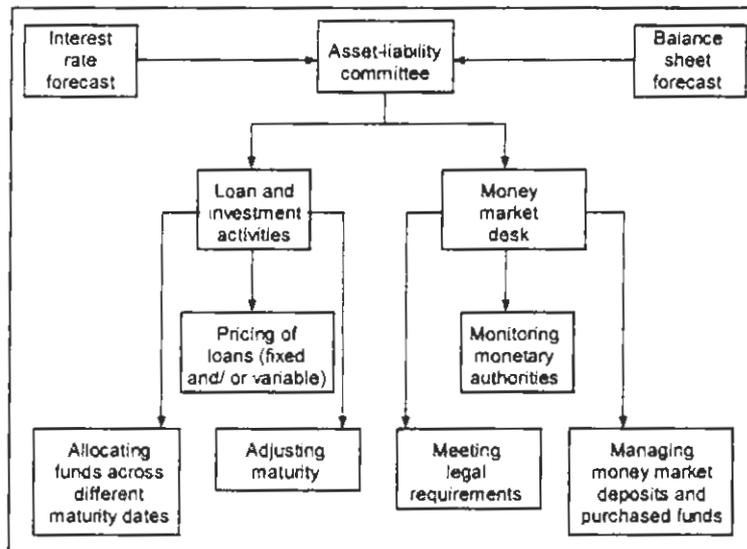
- Coordinating changes in the maturities and types of bank assets and liabilities in order to sustain profitability in a changing economic environment
- Watching the liquidity and the bank's ability to meet demands made on it, by selling assets or borrowing money
- Shaping a basic borrowing and lending strategy
- Ensuring the execution and adjustment of this strategy to changing circumstances
- Managing funding mismatches and attaining desired levels of liquidity
- Managing rate-sensitive assets and liabilities and the effects of rate, volume and mix changes in order to preserve and optimise the interest turn
- Managing various portfolio price sensitivities
- Liaising with other parties with regard to:
  - Financial plans and budgets
  - Business development and new products
  - Portfolio management
  - Capital adequacy and sustainable growth

Bascom (1997:26) states that an important objective of asset-liability management is to minimise the exposure of a bank's net operating cash flow and its equity, to changes in interest rates. This objective is achieved more readily if bank management:

- Understands the nature of interest rate competition
- Understands the relationship between yields, prices and maturities of investment securities
- Has the ability to forecast interest rate changes

- Can adjust the bank's portfolios appropriately, to these interest rate changes

According to Falkena and Kok (1991:9), the ALCO forms the focal point for the continuing adjustment of the maturity and terms of the bank's loans, investments and borrowing. Figure<sup>40</sup> 3.2. below illustrates this.



**Figure 3.2. Diagram illustrating ALCO decision making.**

Falkena and Kok (1991:9) explain that members of an ALCO committee usually include the following:

- The general manager (who may chair the committee), oversees the money and capital market departments (the areas where there is the greatest flexibility for changing the asset-liability mix of the bank)
- The chief financial manager of the bank (who may also chair)
- The managing director
- The member in charge of domestic and international lending
- The senior loan manager (who chairs the credit committee, which establishes loan terms and policies)
- The bank's chief economist
- A manager closely involved in the money market operations of the bank

<sup>40</sup> From Falkena and Kok (1991:8).

Through experience, banks have learned that an ALCO should not be too sizeable. On average, the ALCO of a large bank should consist of more or less seven people and a smaller bank needs only four.

There are differences in the times that ALCOs meet (in some banks the ALCO meets only weekly, while in others, once or twice a month) and there are also differences in the ways the ALCO operates in different banks:

- In some banks it plays essentially a monitoring and co-ordinating role. As Falkena and Kok (1991:9) mention, it serves as a forum where senior managers review:
  - The bank's balance sheet
  - The economic and interest rate outlook
  - The state of loan demand
  - Avenues for adjustment

In this type of bank, individual general managers are responsible for decision making and are responsible to the managing director for their departments' performance

- In other banks, Falkena and Kok (1991:9) point out, ALCO meetings have detailed agendas, take up specific proposals for action and hand down binding guidelines for asset and liability operations. These committees may even have their own secretary and a small staff

Cade (1997:74/75) suggests that, meeting monthly, the ALCO receives and debates about reports from treasury on: the liquidity profile; the interest rate turn; interest/ exchange rate/ equity price sensitivities; balance sheet structure; regulatory considerations; and market and economic intelligence.

According to Falkena and Kok (1991:9), in its regular meetings, the ALCO also:

- Examines the possibilities for maintaining (or improving) the positive rate spread between interest income and interest costs
- Reviews a bank's foreign currency exposure
- Sets limits to how far the international department and branches abroad can be out of balance for the major currencies

The committee usually focuses on a simplified balance sheet with roughly 15 to 20 asset categories and 15 to 20 liability groups.

Bascom (1997:148) identifies two major difficulties inherent in the asset-liability management process:

1. The failure to adopt meaningful policies;
2. The failure to implement the policies once they are adopted.

For effective risk management results, Bascom (1997:149) points out that a massive effort has to be made to improve the information available to and the competence of, ALCO members. Also, to ensure effective asset-liability management, Bascom (1997:149) lists two basic policy areas that should be clear:

1. ALCO authority, purpose, membership and functions;
2. Performance targets (like net interest margins, return on average assets and equity) that must be achieved.

In a volatile interest rate environment, Falkena and Kok (1991:9) explain that an ALCO will seek to lock in an interest rate spread and take calculated risks in "mismatching the book". Assets and liabilities are broken down by type and by maturity and they are grouped with regard to their sensitivity to interest rate changes. The pricing structure of assets and liabilities is particularly important.

The manner in which a bank structures its assets and liabilities, will determine its interest rate risk position. As Bascom (1997:36) points out, even though the management of a particular bank may not be able to control the changes in market interest rates, it may implement certain measures to minimise the negative impact of these changes on the bank's financial condition and operating results.

#### 3.3.1.1. The Profit Plan

Falkena and Kok (1991:6) state that the ALCO regularly works within the framework provided by the bank's annual profit planning process. Profit planning involves a concerted effort by the managing director and general management, to plot the course of the bank's planned growth over the next year, as Falkena and Kok (1991:7)

suggest. Every year each general manager makes a detailed projection of how the assets and liabilities under his/ her supervision are expected to evolve during the coming year and provides estimates of the expense and manpower that will be needed in order to achieve this.

The common input to planning at this stage is a forecast of the economy (which is prepared by the economics department). In addition, there is a projection (made with advice from the fund-raising, lending and investment departments of the bank) of one or more key interest rates, which is a basic input to the plan.

The bank adopts a formal profit plan (which provides merely a framework for making decisions) for the year after three passes of the planning material. The managing director then tracks the performance of each department in relation to its own plan, as Falkena and Kok (1991:8) mention. Deviations in interest rates and volumes, for example, are to be expected.

#### 3.3.1.2. Shaping a Profitable Strategy

A typical ALCO meeting entails a review of a bank's position, pointing out recent changes in the balance sheet. According to Falkena and Kok (1991:10), the following is roughly what takes place:

- The economist presents the latest projections of domestic economic activity as well as a similar review of the main industrial countries
- The economist gives the ALCO his/ her current view on interest rates, observing the extent to which rates are expected to deviate from that in the annual profit plan
- Interest rates are discussed and on occasion, a probability is attached to forecasts of key interest rates three to 12 months forward
- The ALCO takes up the outlook for loan demand, starting with the projections prepared by the economics department
- The lending functions report major imminent transactions and comment on whether these projections are likely to materialise. It is important to determine

whether a bank's prime lending rate for domestic business loans should be changed

The ALCO tries to keep the bank's book reasonably balanced if it expects interest rates to be volatile:

- A falling rate outlook may lead to shorter funding:
  - On the asset side, a bank can: increase bankers' acceptances in its portfolio, take on more fixed-rate term loans or acquire additional fixed-interest securities in the market. In addition, a bank can enter into options contracts to acquire long-term stock
  - On the liability side, a bank can: rely more on money market funds to finance the rollover of maturities and its asset build-up. By allowing the average maturity of its liabilities to shorten, it can increase the expected favourable effect from falling interest rates. The bank can reduce or, if competitive conditions permit, even stop offering longer-term savings deposits
- A rising interest rate outlook may lead to a lengthening of liabilities:
  - Reduce fixed-rate assets
  - Expand the share of variable-rate assets in a bank's portfolio
  - Lengthen the maturities of liabilities

The objective, according to Falkena and Kok (1991:11), is to reduce the volatility of bank earnings, while continuing to make interest rate judgements at the margin, that will enhance earnings.

The theory is understandable but actually forecasting business loan growth and interest rates can be risky. At times, major banks have been disappointed by loan demand, either because some of the larger companies fund through the intercompany or "grey" market, or because the economy is not as strong as expected. Other times, loan demand is intense.

Also, Falkena and Kok (1991:11/12) explain that interest rates can behave unexpectedly for prolonged periods. For example, when the Reserve Bank wants to

moderate overly rapid money supply growth, short-term rates may rise sharply, only to fall later when money growth slows down. Since competitors are likely to expect the same, banks have to be agile in order to perform better. Market yields reflect when interest rates are generally expected to rise. Long-term government stock acquired previously for a portfolio will already be selling at below book cost. The ALCO may modify a bank's asset-liability mix because it believes interest rates are going to rise higher or faster than expected by the market as a whole. Yet, there could equally well be a surge in loan demand peculiar to a particular bank.

ALCO members know that it is not easy to implement decisions quickly in large banks, especially with regard to changes in loan terms. Bankers keep a close watch on their share of the market so that they will have a good idea of the size of operations that can readily be tolerated by the market and customers. Falkena and Kok (1991:13) point out that ALCO's moves (like those of the monetary authorities) usually involve a series of moderate adjustments to a well-plotted strategy instead of dramatic changes of direction.

Increasing interest rate volatility has made ALCOs more cautious about assuming the interest rate risks involved in banking. To cope with volatile interest rates, major banks have started to rely more on market-based pricing. Falkena and Kok (1991:10) explain that from the ALCO's standpoint, market-based pricing can help a bank to protect its earnings from variations in interest rates. In order to do so, the bank matches its loans with liabilities whose maturities correspond to the dates for repricing the loan. Then the ALCO can focus on whether the bank should mismatch its book in view of the interest rate outlook. However, this shifts a major part of these risks to the borrower. Banks have to ensure that their borrowers are able to absorb interest rate risks, otherwise they may find the credit risk of loans to be higher than they assumed.

Being aggressive at times may strengthen a bank's reputation for astuteness. However, members of the ALCO aim to avoid a course that could cause a bank's "good name" (Falkena & Kok, 1991:12) to be questioned.

An ALCO has to shape present strategy with regard to how it sees the economic state, with all the uncertainties and differing opinions involved. This strategy must profit from a bank's organisational strengths but must also be flexible enough to change promptly when its forecasts of loan demand and deposit growth deviate from reality. The ALCO monitors the situation closely.

Other major concerns of the ALCO include:

- The cyclical patterns of the economy (discussed next)
- Credit demands
- Monetary policy
- The opportunities and risk presented for the bank, by these concerns

#### **i. Interest Rates and the Business Cycle**<sup>41</sup>

It is believed that the level of interest rates and economic growth vary inadvertently over time. Koch and Macdonald (2003:256) note how, when total spending increases, interest rates tend to increase (as borrowers compete for loans to finance this spending) and when total spending falls, interest rates tend to fall. Trends in total economic activity are evaluated usually in terms of the percentage change in real gross domestic product<sup>42</sup> (GDP). Historically, a cyclical pattern has been observed.

Figure<sup>43</sup> 3.3. below, serves to illustrate the business cycle and the reaction of interest rates to this cycle.

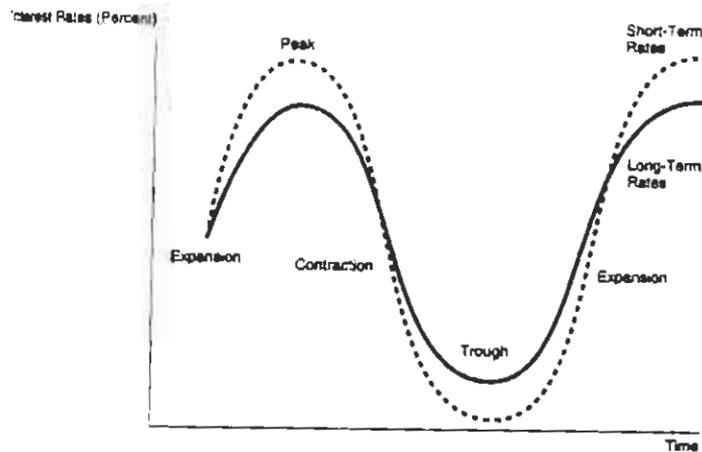
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<sup>41</sup> This section is a simplified version of what really happens, given the complex relationships that exist in the macroeconomy.

<sup>42</sup> GDP equals the Rand sum of "consumption expenditures, government spending, investment expenditures, and net exports" (Koch & Macdonald, 2003:256).

Real GDP equals gross domestic product in current rands divided by the GDP deflator.

<sup>43</sup> From Koch and Macdonald (2003:257).



***Figure 3.3. Diagram illustrating how interest rates react over the business cycle. The vertical axis represents the market interest rate; the horizontal axis, time.***

From the figure above<sup>44</sup>, four phases can be identified, as in Koch and Macdonald (2003:257/258):

1. **Expansion** – where typically, increasing consumer spending, inventory accumulation and rising loan demand is evidenced.  
During the expansion, consumers spend more and businesses borrow in order to accumulate inventory and finance capital expenditures. This puts upward pressure on prices, since the production of goods and services often lags behind the demand for them. Interest rates increase because the demand for loanable funds increases more than the supply of loanable funds. The Reserve Bank begins to slow money growth;
  
2. **Peak** – this phase is characterised by monetary restraint, high loan demand and little liquidity.  
At peak growth in real GDP, loan demand is still high since spending is high. However, consumers slow their spending and business investment follows. In an effort to slow inflation, the Reserve Bank restricts credit availability by slowing the growth in the banking system's reserves. This puts upward pressure on interest rates because the supply of loanable funds shrinks, while the demand for loanable funds remains relatively strong. This leads to the next phase;

<sup>44</sup> The pattern represented in Figure 3.3. is "a simplistic representation of reality" (Koch & Macdonald, 2003:258). For example, the length of an expansion is shown as being equal to the length of a contraction. In reality, this might not be so.

3. **Contraction** – characterised by falling consumer spending, inventory contraction and falling loan demand.

During the contraction, consumer spending declines, businesses reduce their inventories and postpone capital expenditures. Consequently, loan demand drops. Usually inflation slows. Towards the end of the contraction, the Reserve Bank accelerates money growth (the growth in monetary reserves) in an effort to stimulate spending and reduce unemployment. Interest rates then decline;

4. **Trough** – in this phase, there is monetary ease, limited loan demand and excess liquidity.

The percentage change in real GDP “bottoms out” at the trough, along with the level of interest rates.

The cycle then repeats itself.

The sustained growth in earnings is the final objective of bank management. Falkena and Kok (1991:6) point out that positioning the bank to take advantage of changes in credit demand and interest rates is critical to this objective. Banks are less confident of their ability to forecast interest rates and mismatch their book due to the volatility of interest rates. Therefore, they have put greater emphasis on pricing loans on a “variable rate basis” (Falkena & Kok, 1991:6) in order to lock in a profitable interest spread between interest income and interest expenditure regardless of what happens to interest rate levels.

### 3.4. Interest Rates

#### 3.4.1. What are Interest Rates?

According to The South African Reserve Bank (SARB, 2004b), interest rates are “prices for loanable funds – prices of funds invested, lent out or borrowed for various periods of time”. The supplier or lender of funds usually wants to earn an income. The user or borrower will generally be prepared to pay for the right to use the accumulated funds.

The prices of funds (also referred to as the general level of interest rates or the nominal or market interest rate) is determined by the supply of and the demand for funds. As is pointed out in SARB (2004b):

- The supply of funds depends on society's preference for current versus future consumption. Societies that prefer to accumulate wealth now and postpone consumption to a later date, will set aside a higher portion of their current income for wealth accumulation than societies that have a stronger preference to spend now
- The demand for funds depends on the opportunities available for using borrowed funds efficiently and profitably – the more profitable the usage of funds, the greater the demand for funds

As explained in SARB (2004b), if the demand for funds increases and/ or the supply declines, the price of funds will rise (interest rates will move higher). If the demand for funds declines and/ or the supply increases, the price of funds will fall (interest rates will move lower). However, at the same time, the interest rate level and expected changes in that level will also affect the supply of and the demand for funds.

An interest rate relates to a period in the future, since funds are provided to borrowers for future repayment. Lenders and borrowers of funds can foresee the future only imperfectly. Thus, uncertainty about the future plays a prominent part in the process of interest rate determination.

Other uncertainties that are most likely to have an impact on the level of interest rates include the following, from SARB (2004b):

- The term of the period over which funds are made available – the longer the term of the loan, the greater the uncertainty that circumstances may change and therefore, the higher the compensation demanded by the lender of funds
- The ability of the borrower to repay the loan – the higher the risk of default by the user or the lower his/ her credit rating, the higher the interest rate asked by the lender

- Expected inflation – if inflation is expected to be high, the buying power of borrowed funds declines rapidly. The lender will seek protection against the “erosive power of inflation” (SARB, 2004b) by demanding a higher interest rate. Therefore, higher inflation will bring about higher interest rates

Thus, the interest rate can be seen as the price which “equates the supply of funds with the demand for funds” (SARB, 2004b). If the supply is inadequate relative to demand, the interest rate has to rise to encourage a larger supply of funds to match the demand for funds. The South African Reserve Bank (SARB) plays an important role in determining the level of short-term interest rates. This is because these rates are strongly connected to the rates at which the Bank lends money to private-sector banks (mentioned in Chapter 2).

There are many interest rates established in the various financial markets of the economy. The different interest rates reflect the total demand for and supply of funds in the different markets. As stated in SARB (2004b), in a market-orientated economy like the one in South Africa, interest rates have to be flexible and also sensitive to changes in underlying market forces. Government interference in the financial markets (which prevents the efficient functioning of market forces), reduces the effectiveness of the price mechanism and can easily lead to permanent undesired distortions in the flow of funds.

#### 3.4.2. How Does the Reserve Bank Influence Interest Rates?

In pursuit of its objective of protecting the value of the Rand, the Reserve Bank conducts monetary policy under the “inflation-targeting framework” (SARB, 2004b). Inflation targeting is a monetary policy framework that involves announcing a numerical target point or range for the inflation rate that is planned to be achieved over a specific future period of time. When setting monetary policy, the Reserve Bank decides on the level of short-term interest rates necessary to meet the inflation target.

The repurchase transactions system (or repo system for short) is a formal system that is in place to guide the process through which banks borrow from the Reserve

Bank. This repo system of borrowing and lending involves the temporary sale of a financial asset by the borrower (bank) in exchange for the needed cash from the lender (Reserve Bank). There is an explicit agreement that the borrower must repurchase the financial assets at an agreed future date – currently after one week. The repurchase or repo rate is the interest rate at which the Reserve Bank lends money to private banks. This repo rate is determined by the Reserve Bank at each meeting of its Monetary Policy Committee and is expressed as a rate per annum.

According to SARB (2004b), the repo rate serves as a benchmark for the level of short-term interest rates. If the repo rate increases, banks have to pay more for repo funds. To maintain their existing profit margins, banks raise the interest rates at which they lend money to their customers. This causes a general rise in interest rates and this eventually helps to control inflation. Actions like these, taken by the Bank, are known as the “formulation and implementation of monetary policy” (SARB, 2004b). It takes approximately two years for the full effects of changes in interest rates to work through the economy and impact on inflation.

The Bank plays an active part in promoting the development of relatively free and efficient money and capital markets. Having these is necessary for the effective application of monetary policy measures because they allow the repo rate changes to be transmitted efficiently to the economy.

### 3.4.3. South African Interest Rates

South Africa has a very low saving ratio which requires relatively high interest rates. The high inflation in the country also contributes to high interest rates. As pointed out in SARB (2004b), this is because interest rates have to be at least higher than current and expected inflation in order to encourage domestic saving.

Despite this, the level of interest rates in South Africa is not exceptionally high in comparison with most of the other emerging economies. Prospects for lower interest rates in South Africa depend on the following, from SARB (2004b):

- The maintenance or tightening of discipline in public-sector finances

- Slower growth in bank credit extension and the money supply
- A stronger national saving effort
- An improvement in the current account of the balance of payments and the level of foreign reserves
- Relative strength of the currency in relation to other currencies
- Declines in the rate of inflation
- The level of interest rates and inflation in other parts of the world

### 3.5. Interest Rate Risk

Interest rate risk is the classical two-way (or “speculative”) risk, generally defined as “exposure to loss (or gain) caused by changes in interest rates” (Cade, 1997:145). These losses or gains may be incurred either in net interest income or in present values of financial instruments in which the bank has a position.

Any financial institution is exposed to interest rate risk. This is because assets and liabilities mature (or are repriced) at different times. Consider the following examples from Falkena and Kok (1991:37):

1. If liabilities mature before assets do, there is a rollover of those liabilities until a sufficient quantity of assets mature to repay the liabilities. There is a risk that interest rates may rise and that these expensive funds have to be used to fund assets that are yielding lower returns;
2. If assets mature before liabilities do, they have to be reinvested until they are needed to repay the liabilities. Should interest rates fall, the reinvestment may be accomplished at rates below those being paid on the liabilities waiting to be retired.

Theoretically, a bank could avoid any interest rate risks<sup>45</sup> although, in practice, no bank is able to do this. In fact, for competitive reasons, banks often have to accept funds from clients with maturities they do not really want because refusing client funds too often could be detrimental to their client base. This, in turn, could affect the

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<sup>45</sup> A bank could achieve this by “restricting its profit source to an interest spread of perfectly matched liabilities and assets in terms of maturity” (Falkena & Kok, 1991:37). However, having a fully matched book does not necessarily mean a no-risk position.

banks' leverage on equity capital. Also, in trying to avoid any interest rate risk, Falkena and Kok (1991:38) point out that having a fully matched book denies a bank any long-term interest rate strategy and could force the bank out of the marketplace by other banks or financial institutions that are willing to take such risks.

### 3.5.1. Historical Development

Prior to the early seventies, interest rates were relatively stable (often under deposit rate control) and monetary policy was based largely on "interest rate targeting" (Falkena & Kok, 1991:38). As a result, the banks' funding costs were also reasonably stable. Thus, banks spent most of their time and skills on the asset side of their balance sheets and considered the liability side as "given".

Yet, even in those days, bank managements tried to "play" (Falkena & Kok, 1991:38) the interest rate cycle to some extent. This was done mostly according to experience:

- By "shortening" a bank's book when interest rates were expected to be in a cyclical downswing. This meant increasing the amount of maturing liabilities relative to maturing assets
- By "lengthening" the book when interest rates were in a cyclical upswing. This meant increasing the amount of maturing assets relative to maturing liabilities

According to Falkena and Kok (1991:38), an exact analysis of the interest rate risks and rewards of mismatching assets and liabilities (with consideration for expected short-term interest rate movements) was, however, never fully undertaken. Then, in the early seventies the economic environment was changed radically by factors that included:

- The oil crisis
- Large international capital flows
- Significant inflation differentials between countries
- An unstable exchange rate system
- Large increases in the debt of the public sector

As a result, interest rates started to fluctuate sharply, forcing bank managements to adjust to this new environment. Greater trust was placed in free market forces to regulate the economy. The traditional bank cartel arrangement was dissolved in 1982 and soon banks started to compete more vigorously against one another.

Falkena and Kok (1991:38) mention that in 1983 banks began to pay interest on certain current accounts for the first time in their history. Factors that had a great impact on the interest rate volatility of that time include: the transition from a variable liquid asset system to a cash reserve system and a more effective use of open market operations and discount policy.

The new interest rate environment, together with the technological possibilities of mass data processing, led to the creation of many new financial instruments (all commanding market-determined interest rates). Investors, Falkena and Kok (1991:39) suggest, wanted a positive real return on their money, implying that the inflation factor was being explicitly taken into account in any investment decision.

Therefore, Falkena and Kok (1991:39) state, since the mid-seventies, a huge switch of funds has been taking place from no-interest (or low-interest) accounts to higher-yielding, rate-sensitive accounts. Thus, as in the case of their assets, the banks' liabilities have had to start being managed with increasing effectiveness.

As a consequence to investors and borrowers trying to avoid the new uncertainty surrounding sharply fluctuating interest rates, more and more loans and deposits became based on variable interest rates. For the banks, this implied an increased credit risk because part of the interest risk was now shifted to borrowers.

Also, banks' funding costs were reflected in the cost of credit much sooner. For the monetary authorities, this meant that a restrictive monetary policy would initially result only in a rise in the cost of credit and no longer cause an immediate and rapid decline in the supply of bank credit, as had been the case in the past.

### 3.5.2. Relationship With Other Financial Risks

According to Falkena and Kok (1991:39), interest rate risk management is particularly linked with credit and liquidity risk management:

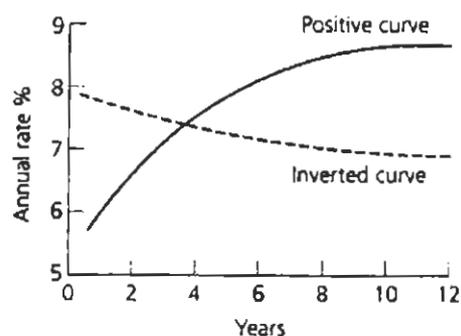
- **Credit risk management** – selecting bank clients is extremely important. If a bank becomes involved in a hedging operation with a company that ultimately cannot fulfil its financial obligations, for example, the bank does not reduce interest risk exposure. Instead, it increases its credit risk. In addition, the more lending a bank does at a variable rate, the more credit risk it accepts because effectively, the interest rate risk is shifted to the borrower, who may not be able to fulfil his/ her commitments later on.
  
- **Liquidity risk management** – Falkena and Kok (1991:40) suggest that the close interaction between liquidity risk and interest rate risk management becomes clear when considering the impact of the yield curve on bank risk management:

#### i. Yield Curves and Associated Risks

According to Cade (1997:149), interest is said to consist of two components:

1. A “risk-free” rate, representing compensation for sacrifice of liquidity by the lender;
2. A premium, tailored to the credit risk of the borrower.

These elements drive the **yield curve** – a line “joining the current rates of interest for like instruments or quotes with different maturities” (Cade, 1997:149). It displays the term structure of interest rates. Figure<sup>46</sup> 3.4. below is an illustration of yield curves.



**Figure 3.4. Diagram illustrating yield curves.**

<sup>46</sup> From Cade (1997:149).

There are separate yield curves for different kinds of instruments on either side of the balance sheet. Mostly, however, the yield curve ascends positively from left to right explaining the attraction to banks of “borrowing short and lending long” (Cade, 1997:150) in the hopes of better interest turn. This is one of many reasons why the interest repricing tendencies of a bank’s assets and liabilities may be mismatched and subsequently, why net interest income is at risk from changes in interest rate levels.

Occasionally, the pattern may flatten or become inverted (which, as Cade (1997:150) mentions, reflects short term “hiccups” in liquidity, or market expectations of a reduction in rates). More specifically, three different yield curves may be evidenced:

1. A **normal (or positively sloped) yield curve** – the yield curve is said to be normal or positively sloped if the interest rate on long-term investments is higher than the interest rate on short-term investments, as Falkena and Kok (1991:40) explain, meaning that the longer the term of the investments, the greater the return on those investments. To increase profits, the bank will borrow funds short term and lend these funds long term. However, interest rate exposure (and profitability) is increased at the expense of decreased bank liquidity;
2. An **inverse (or negatively sloped) yield curve** – the yield curve is said to be inverse or negatively sloped if “at a specific moment the return on short-term investments is higher than the return on long-term investments” (Falkena & Kok, 1991:40). To maximise profits, the bank has to borrow funds long term and lend these funds short term, raising its own liquidity in the process (which the market is paying for in the form of high interest rates on short-term assets).

Borrowing long and lending short, however, may cause serious interest rate risks for the bank because an inverse yield curve almost always indicates that interest rates are likely to fall in the near term and move to a normal yield curve in the longer term. The bank’s positive interest margin (or spread) may suddenly become negative because the bank risks keeping long-term funds at a relatively high rate (which can only be invested short term at a lower yield).

Although the bank is still liquid, it is no longer at the market's cost. Thus, Falkena and Kok (1991:40) emphasise that increasing short-term profits by using a steep inverse yield curve is extremely risky and may easily get the bank into "long-term trouble";

3. A **flat yield curve** – a flat yield curve represents a time where no profit can be obtained from mismatching assets and liabilities. It is a relatively short period of waiting which bank managements can do almost nothing about. Times like these could endanger the profitability and creditability of a bank in the long run, if members of its ALCO come up with elaborate ideas to boost earnings.

Cade (1997:150) suggests that the yield curve is the best way to illustrate the varieties of interest rate movement (the principal types of rate shift) that financial intermediaries face:

1. "**Open position risk**" refers to the consequences of a simultaneous and parallel shift in interest rates (and thus, yield curves) across the board – for example, a 1% rise or fall in all rates. The bank may find that its prospective net interest income is suddenly changed for better or for worse;
2. In reality, however, it is unlikely for there to be a uniform change in all rates. Instead, the rates for different maturities move by different percentages and the slope of the yield curve changes accordingly, making the effects of repricing mismatches that already exist, worse. This threat that a yield curve will not retain its shape, is commonly known as "**yield curve risk**";
3. "**Basis risk**" denotes the possibility that yield curves for different instruments or products may not move in parallel with one another. Koch and Macdonald (2003:299) point out that changes in net interest income associated with changes in the difference between different interest rates are a reflection of basis risk.

### 3.6. Assessment of Interest Rate Risk

In order to assess the interest rate profile of a bank, Falkena and Kok (1991:42) identify five broad analyses that have to be made, namely those in respect of the:

- ◆ Maturity structure;
- ◆ Balance sheet projection;
- ◆ Gap exposure;
- ◆ Net interest income projection;
- ◆ Risk-return exposure.

a. Assessment of Interest Rate Risk: Maturity structure analysis

To obtain insight into the interest rate exposure of a bank's balances, a maturity analysis of the variable and fixed-rate items<sup>47</sup> on the balance sheet is made. The first step in a maturity analysis is "the completion of runoff schedules of the bank's actual maturing balances" (Falkena & Kok, 1991:42).

These schedules may change considerably over time. This may be because maturing balances<sup>48</sup> may be reinvested at different maturities and at different interest rates than they were previously (the so-called rollover activity of the bank), while the bank may attract new funds or do new business<sup>49</sup>. Any change in the runoff schedule, as a result of rollover activity or new business, will "affect the dynamic average monthly balances and the weighted interest rate for a particular time interval" (Falkena & Kok, 1991:48).

b. Assessment of Interest Rate Risk: Balance sheet projection

Apart from rollovers (at uncertain interest rates in the future), projections include the expected new bank business. Balances differ from static runoff schedules in that they are dynamic evolving averages. A 24-month projection is required to do balance sheet projections for the 12 months to follow.

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<sup>47</sup> Falkena and Kok (1991:42) clarify the following terms:

- Variable-rate items – the funds and assets of the bank that can be repriced virtually immediately
- Fixed-rate items – the funds and assets that can be repriced only on maturity
- Non-rate items – on which no interest is paid or received, like current account balances or equity

<sup>48</sup> These are the so-called *nostro* accounts, over which the bank has control.

<sup>49</sup> Where the bank has no direct initiative to change the value of the balance – the so-called *loro* accounts.

c. Assessment of Interest Rate Risk: Gap exposure analysis

A “gap” is an imbalance and may be defined, as in Falkena and Kok (1991:48), as: “the difference, in rand terms, between rate-sensitive assets and rate-sensitive liabilities over a particular time interval”.

- A **positive gap** – indicates that more assets are maturing and/ or being repriced than liabilities
- A **negative gap** – shows that more liabilities are maturing and/ or being repriced than assets

The selection of the appropriate cumulative gap that is to be used for strategic planning may differ from bank to bank. Nonetheless, most banks and building societies in South Africa seem to use the “call to 3-month cumulative gap and try to keep a matched book for the longer-than-two-years period” (Falkena & Kok, 1991:49). This gap is particularly attractive since 3-month money market instruments (like bankers’ acceptances, NCDs, Treasury bills, and promissory notes) are amongst those most traded in the market, allowing relatively simple adjustments to this gap.

Falkena and Kok (1991:49) explain how the size and timing of interest-sensitive gaps are essential in the analysis of interest rate risk exposure.

- A bank may have a “**liability-sensitive**” book – for example, a negative call to 3-month cumulative gap during the next 12 months. The mismatching of interest sensitivity “exposes the net interest income of the bank to rising interest rates” (Falkena & Kok, 1991:49). In other words, if interest rates do indeed, rise, more liabilities than assets are repriced at higher rates during the next 12 months. A strategy such as this is often called “short-funding” because long-term assets are funded with short-term money. If interest rates fall, then the opposite happens.
- In contrast, a bank with an “**asset-sensitive**” book is exposed to the risk of falling interest rates. If rates decline, then a positive cumulative call to 3-month gap during the next 12 months will imply that more assets are being repriced at lower rates over the projected period than liabilities. Thus, the bank’s net interest

income will be reduced. A positive gap strategy like this is often called "long-funding" because "short-term assets are generally being funded by longer-term liabilities" (Falkena & Kok, 1991:50). A strategy such as this would be profitable if interest rates increased.

The bank may decide to manage its interest rate risk in many ways. Depending on what the ALCO wishes to achieve, the bank must respond in an appropriate way. Not every financial institution can have a gap exposure that it likes – some institutions are always long or short funded due to the nature of their business or because it is forced by government regulations.

According to Falkena and Kok (1991:50), whether the size of a particular gap exposure is acceptable to the bank's management depends on:

1. The expected course of interest rates;
2. The bank's "appetite" for risk;
3. The bank's ability to reposition its balance sheet in a short space of time.

The trade-off between risks and rewards has to be in line with the broad objectives of the bank where prudence and profitability are concerned. No interest rate bet should be so great that the banker is "betting the bank" (Falkena & Kok, 1991:50).

d. Assessment of Interest Rate Risk: Net interest income projection

The difference between total interest income and total interest expenditure, is net interest income. Here, account is taken of: the runoff of the existing book, rollovers and expected new business. Falkena and Kok (1991:55) state that changes in the bank's projected net interest income may be triggered by changes in:

1. Market interest rates – the rate effect on net interest income;
2. Asset and liability growth – the volume effect;
3. Maturity and repricing characteristics of new and non-maturity accounts – the mix effect.

e. Assessment of Interest Rate Risk: Risk-return analysis

A risk-return analysis<sup>50</sup> is based on simulation exercises where different gap exposures are introduced into different interest rate scenarios "to establish their impact on the bank's net interest income" (Falkena & Kok, 1991:56). These relationships may be presented in graphic or tabular form.

In graphic form, a "base case" forecast (the most likely scenario) is represented on the graph. Then, by changing just the interest rate forecast and keeping all other variables constant, different levels of net interest income can be calculated. Lines of "low rate" and "high rate" forecasts (which represent the broadest band of interest rate figures realistically imaginable) are drawn and certain conclusions can then be taken from the graph.

The triangular area (known as the "zone of indifference") formed by the three lines crossing each other, indicates a gap exposure with net interest income unaffected by either a drop or a rise in interest rates. A gap exposure within the triangle will give a predictable and stable net interest income in spite of interest rate volatility. Outside the triangle, there may be greater income potential but at greater risk. Usually, the greater the expected interest rate instability (and as a result, uncertainty), the closer the ALCO will work to the "zone of indifference".

Once management has decided on the appropriate size of the gap, the money market desk attempts to implement this decision, taking into consideration the day-to-day market developments. The ALCO, being a strategic decision-making body, does not normally interfere with this.

### 3.7. Interest Rate Risk Management: Strategies

One of the strategies that management may use to cope with the changes in the interest cycle is to try to anticipate all significant interest rate movements correctly. Many people are tempted to use this strategy from time to time. It has its own

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<sup>50</sup> Risk-return analysis is also referred to as an interest-sensitivity analysis.

guidelines, from Cade (1997:147) shown below and used to be the conventional wisdom:

Approaching peak	Approaching trough
<ul style="list-style-type: none"> <li>• shorten funding maturities</li> <li>• begin to lengthen investment maturities</li> <li>• acquire investments</li> <li>• expand fixed rate loans</li> </ul>	<ul style="list-style-type: none"> <li>• lengthen funding maturities</li> <li>• begin to shorten investment maturities</li> <li>• sell investments</li> <li>• restrict fixed rate loans</li> </ul>

However, it is an extremely risky strategy and in addition to its public relations downside, neither regulators nor bank shareholders are in favour of using it. On the other extreme is a strategy with a policy of choosing to do nothing to hedge structural exposures. This can be extremely hazardous in that, while gains and losses may even out in the long run, the bank may be forced to close in the shorter run.

Thus, management has had to rely on other approaches in an attempt to manage interest rate risk. Two of these approaches involve the bank seeking to stabilise either its net interest income or its share price (but not both at the same time). Cade (1997:146) puts it more formally – management may aim to:

- Adopt interest repricing positions which hedge (lock in) the bank’s net interest income so as to meet a constant revenue or rate of return target, irrespective of changes in interest rates, or
- Adopt interest repricing positions which hedge the bank’s present value, and hence tend to stabilise its share price

Net interest income falls under the heading of structural exposure, which is the topic of the next section. Here, GAP and earnings sensitivity analysis are described. Thereafter, duration GAP and market value of equity sensitivity analysis are mentioned as alternative methods of analysing interest rate risk.

### 3.8. Interest Rate Risk: Structural Exposure

Structural exposure revolves around the sensitivity of net interest income to changes in the level of interest rates.

#### 3.8.1. Managing Interest Rate Risk: GAP and Earnings Sensitivity

Speculating on interest rate movements is not a fixed science and every so often banks can get into a lot of trouble because of this. Nevertheless, in order to survive in the market, banks keep trying to find the edge over each other. In an attempt to maximise profits, minimise risks, honour responsibilities towards clients and still satisfy customers, banks resort to certain management techniques.

To manage interest rate risk, specifically, some banks rely on GAP and earnings sensitivity analysis. In this context, Koch and Macdonald (2003:290) point out that interest rate risk refers to the volatility in net interest income due to changes in the level of interest rates and shifts in the composition and volume of bank assets and liabilities. A bank that takes considerable risk will see its net interest margin vary widely when rates increase or decrease, while a bank that assumes little risk will observe little change in its performance due to rate changes.

There are traditional measures of interest rate risk associated with **static GAP** models. As Koch and Macdonald (2003:290) suggest, these models focus on:

- GAP as a static measure of risk
- Net interest income as the target measure of bank performance

GAP analysis can be modified to focus on the sensitivity of bank earnings across different interest rate environments. This net interest income simulation (also known as “what if” forecasting) provides information with regard to how much net interest income changes, when rates are assumed to rise and fall by certain amounts. It takes embedded options in a bank’s assets and liabilities and off-balance sheet

activity into consideration. This also provides a better understanding of potential changes in earnings<sup>51</sup> and is thus, aptly termed **earnings sensitivity analysis**.

When dealing with GAP and earnings sensitivity, efforts to manage interest rate risk force a bank's ALCO to:

- Establish specific targets for net interest income
- Measure overall risk exposure
- Formulate strategies (that reflect management's view of actions that will lead to maximising the value of the bank) to attain the targets

Before describing GAP and earnings sensitivity, however, some of the factors that affect net interest income are looked at briefly.

#### **i. Factors Affecting Net Interest Income**

Many factors affect net interest income – some are (at least partially) controllable, others are not. Koch and Macdonald (2003:295) mention a few:

- Changes in the *level* of interest rates
- Changes in the *composition* of assets and liabilities
- Changes in the *volume* of assets and liabilities outstanding
- Changes in the *relationship* between the yields on earning assets and rates paid on interest-bearing liabilities

Koch and Macdonald (2003:295) point out that asset and liability management examines the impact of all factors on net interest income. Changes in the magnitudes of non-earning assets and non-paying liabilities also influence net interest income and net interest margin. Also, if a bank is able to reduce its non-earning assets, then net interest income increases automatically, as Koch and Macdonald (2003:300) explain. The magnitude is determined by how the funds are invested. A rate-sensitivity report is a framework that is commonly used to evaluate a bank's interest rate risk position and monitor potential changes in net interest income. It provides a point estimate of a bank's interest rate risk profile implied by the basic concept of a static GAP.

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<sup>51</sup> Changes in interest rates as well as changes in other factors affect potential earnings.

A brief look at GAP analysis is needed before the following factors that affect net interest income: changes in the level of interest rates; changes in the relationship between short-term asset yields and liability costs; changes in volume; changes in portfolio composition; and rate, volume and mix analysis, can be mentioned in more detail. Thus, an introduction to GAP analysis is given first.

#### 3.8.1.1. Traditional Static GAP Analysis

The most basic approach to measuring structural exposure<sup>52</sup>, as stated in Cade (1997:151), is to "maintain an interest sensitivity ladder dividing assets and liabilities into time bands (or "buckets"), according to when their respective interest rates are contractually due for review (i.e. "repricing)". By comparing the rate sensitivity of assets with the rate sensitivity of liabilities, traditional static GAP models endeavour to measure how much interest rate risk a bank witnesses at a fixed point in time.

Within each time band there will be a net "gap" or "mismatch" position, consisting of one of the following, from Cade (1997:151):

- **Positive gap** – occurs when the volume of assets repricing exceeds the volume of liabilities repricing.

A positive gap in the early time bands indicates an asset-sensitive situation where predominantly assets will reprice and react first to a change in interest rates. Net interest income should show an early increase when interest rates rise and a decrease when interest rates fall. The bigger the gap, the bigger the risk. The change in earnings is only until the liabilities catch up with rate repricing

- **Negative gap** – occurs when the volume of liabilities repricing exceeds the volume of assets repricing.

A negative gap in the early time bands indicates a liability-sensitive position where net interest income temporarily stands to shrink when interest rates rise and to expand when interest rates fall. Generally, this type of gapping lies outside the "prudent range of conduct" (Cade, 1997:152) but can be justified if there is strong reason to expect a reduction in interest rates soon

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<sup>52</sup> Recall that structural exposure is the risk relating to net interest income.

- **Zero gap** – equilibrium.

Zero or neutral gapping in the early time bands suggests that the bank's net interest income is not sensitive to general changes in interest rates in either direction. This is consistent with a risk-averse policy focused on stabilising net interest income.

Koch and Macdonald (2003:292) explain static GAP analysis more specifically – there are several basic steps in the analysis:

1. Management develops an interest rate forecast;
2. Management selects a series of sequential time intervals for determining what amount of assets and liabilities are rate sensitive<sup>53</sup> within each time interval;
3. Assets and liabilities are grouped into these time intervals (or “buckets”), according to the time until the first repricing. The principal portion of the asset or liability that management expects to reprice is classified as rate sensitive. The effects of any off-balance sheet positions (like those associated with interest rate swaps and futures) are also added to the balance sheet position according to whether the item effectively represents a rate-sensitive asset (RSA) or rate-sensitive liability (RSL). A bank's static GAP for each time interval<sup>54</sup> is then:  $GAP = RSAs - RSLs$ ;
4. Management forecasts net interest income, given the interest rate environment and assumed repricing characteristics of the underlying instruments.

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<sup>53</sup> Koch and Macdonald (2003:295) summarise that, generally, an asset or liability is classified as rate sensitive within a time interval if:

1. It matures;
2. It represents an interim, or partial, principal payment;
3. The interest rate applied to outstanding principal, changes contractually during the interval;
4. The outstanding principal can be repriced when a base rate or index changes and management expects this base rate/ index to change during the interval.

<sup>54</sup> There is a periodic GAP and a cumulative GAP for each time interval (or bucket):

- The **periodic GAP** compares RSAs with RSLs across each of the different time buckets – as Koch and Macdonald (2003:302) suggest, each periodic GAP figure indicates whether more assets or liabilities can be repriced within a specific time interval. However, it ignores whether assets and liabilities in other periods can be repriced and because of this, is not that meaningful
- The more important **cumulative GAP** compares RSAs with RSLs over all time intervals, from the present through the last day in each successive time interval – cumulative GAP figures are the most important because as Koch and Macdonald (2003:302) point out, they measure a bank's net interest sensitivity through the last day of the time bucket by comparing how many assets and liabilities reprice through that last day. The cumulative gap measures the sum of the periodic GAPs through the longest time frame considered. Koch and Macdonald (2003:293) provide an example: the cumulative GAP through 90 days (0-90 days) equals the sum of the periodic GAPs for the two time buckets, 0-30 days and 31-90 days.

The information gathered is used to identify the bank's interest rate risk and to develop strategies to manage this risk. Management may change the size of the GAP to:

- Hedge net interest income against changing interest rates<sup>55</sup>
- Speculatively try to increase net interest income

The bank may amend its gapping profile through some of the following ways suggested by Cade (1997:153):

- Changing its funding strategy
- Changing repricing characteristics on the lending side
- Switching out of some types of investments and into others
- Adopting other policy revisions
- Entering into a variety of derivative contracts to hedge its positions

Koch and Macdonald (2003:304) mention how many community banks have policy statements that limit interest rate risk by specifying that selected GAPs, as a fraction of earning assets, cannot fall outside of a certain percent.

#### **i. Another Look at Factors Affecting Net Interest Income**

- *Changes in the Level of Interest Rates*

According to Koch and Macdonald (2003:296), fluctuating interest rates can increase, decrease, or not affect a bank's net interest income, depending on the portfolio mix, rate sensitivity and GAP value<sup>56</sup>. Furthermore, the sign of a bank's GAP indicates whether interest income or interest expense is likely to change more when interest rates change. Figure<sup>57</sup> 3.5. below, illustrates the effects of changes in the level of interest rates:

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<sup>55</sup> Hedging involves reducing the volatility of net interest income either by directly adjusting the Rand amounts of RSAs and RSLs, or by taking an off-balance sheet position (like with forwards, futures, option contracts and interest rate swaps).

<sup>56</sup> The GAP measure compares the Rand value of a bank's assets that reprice within a certain interval, to the Rand value of liabilities that reprice within the same timeframe.

<sup>57</sup> From Koch and Macdonald (2003:297).

GAP Summary						
Line	GAP	Change in Interest Rates	Change in Interest Income		Change in Interest Expense	Change in Net Interest Income
1	Positive	Increase	Increase	>	Increase	Increase
2	Positive	Decrease	Decrease	>	Decrease	Decrease
3	Negative	Increase	Increase	<	Increase	Decrease
4	Negative	Decrease	Decrease	<	Decrease	Increase
5	Zero	Increase	Increase	=	Increase	None
6	Zero	Decrease	Decrease	=	Decrease	None

**Figure 3.5. Table illustrating the effects that changes in the level of interest rates have on net interest income.**

The relationships summarised in the table above can be explained in greater detail:

1. A positive GAP indicates that a bank has more RSAs than RSLs across a time interval. If rates rise, interest income increases more than interest expense because more assets are repriced. Thus, net interest income increases;
2. If the GAP is positive and the rates decrease, the effect is the opposite of that in Line 1. Interest income falls more than interest expense, therefore, net interest income falls. A bank like this is said to be *asset sensitive*;
3. A negative GAP indicates that a bank has more RSLs than RSAs across a time interval. If all rates rise by equal amounts at the same time, both interest income and interest expense rise but interest expense rises more because more liabilities are repriced. Thus, net interest income declines, as does the bank's net interest margin;
4. If the GAP is negative and interest rates fall during the interval, more liabilities than assets are repriced at the lower rates such that interest expense falls more than interest income falls. In this case, both net interest income and net interest margin increase. A bank such as this is said to be *liability sensitive*;
5. A zero GAP indicates that a bank's RSAs equal its RSLs. Equal interest rate changes do not alter net interest income because changes in interest income equal changes in interest expense;
6. Same as Line 5. When the GAP is zero, interest income changes by the same amount as interest expense.

Whether net interest income (NII) rises or falls depends on whether the GAP is positive or negative and how the level of interest rates changes. Koch and Macdonald (2003:297) summarise this framework as the following relationship:

$$\Delta NII_{exp} = GAP \times \Delta i_{exp} \quad (\text{Eq. 1})$$

Where

$\Delta NII_{exp}$  = the expected change in net interest income over a period of time from

some base amount

GAP = cumulative GAP over the interval through the end of the period of time

$\Delta i_{exp}$  = the expected permanent change in the level of interest rates

However, the relationship shown in Equation 1 applies only in the case of a parallel shift in the yield curve. This rarely occurs.

According to Koch and Macdonald (2003:298), the sign and size of GAP provide information regarding a bank's interest rate risk position:

- The sign indicates the bank's interest rate bet
  - If GAP is positive, the bank "wins" (that is, its net interest income should rise) when rates rise and "loses" when rates fall
  - If GAP is negative, the bank "wins" when rates fall and "loses" when rates rise
- The size of GAP indicates how much risk a bank assumes – the further GAP is from zero (lowest risk), the greater the potential variation in net interest income and therefore, the greater the assumed risk

Some ALM programs focus on the GAP or GAP ratio when evaluating interest rate risk. Koch and Macdonald (2003:305) suggest:  $GAP \text{ Ratio} = \text{RSAs} / \text{RSLs}$

- When the GAP is positive, the GAP ratio is greater than one
- When the GAP is negative, the GAP ratio is less than one

Neither the GAP nor the GAP ratio provide direct information on the "potential variability" (Koch & Macdonald, 2003:305) in earnings when rates change. The GAP ratio is further lacking in that it ignores size.

- Changes in the Relationship Between Short-term Asset Yields and Liability Costs

As Koch and Macdonald (2003:299) explain, net interest income may differ from that expected if the spread between earning asset yields and the interest cost of interest-bearing liabilities, changes. This can happen because of an unexpected shift in the yield curve<sup>58</sup>, an increase or decrease in risk premiums and also “nonsynchronous changes” (Koch & Macdonald, 2003:299) in indexes on floating-rate assets or liabilities. For example, if liabilities are short-term and assets are long-term, then the spread will narrow when the yield curve inverts and widen when the yield curve increases in slope.

- Changes in Volume

As Koch and Macdonald (2003:300) mention, net interest income varies directly with changes in the volume of earning assets and interest-bearing liabilities, regardless of the level of interest rates. Consider, for example, a bank that doubles in size. The portfolio composition and interest rates are unchanged. Net interest income doubles because the bank earns the same interest spread on twice the volume of earning assets “such that NIM is unchanged” (Koch & Macdonald, 2003:300). GAP doubles but is the same fraction of total assets. The net effect is that growth (or, alternatively, contracting) leads to an increase (or, if the bank contracts in size, to a decrease) in the Rand amount of earnings but does not change profitability measures nor the relative size of GAP to assets.

- Changes in Portfolio Composition

Any variation in portfolio mix may change net interest income. A manager who wants to reduce risk for a bank, for example, might try different transactions which can change both the GAP and the bank's interest rate risk position. These transactions can also alter the bank's expected net interest income.

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<sup>58</sup> Unequal changes in the level of different maturity interest rates are labelled a “nonparallel shift in the yield curve” (Koch & Macdonald, 2003:299).

There is no fixed relationship between changes in portfolio mix and net interest income. The impact varies with the relationships between "interest rates on rate-sensitive and fixed-rate instruments and with the magnitude of funds shifts" (Koch & Macdonald, 2003:300). Banks often change mix as part of initiatives to offset anticipated adverse changes in net interest margin.

- Rate, Volume and Mix Analysis

Many banks publish a summary in their annual report about how net interest income has changed over time. Changes attributable to shifts in asset and liability composition and volume are separated from changes associated with movements in interest rates.

This view of GAP and net interest income is simplistic, since asset yields and interest costs do not change coincidentally or by equal amounts. Managers should rather calculate GAP over relatively short periods and allow for a wide range of interest rates and repricings.

## ii. Static GAP Analysis: Strengths and Weaknesses

- Strengths

Koch and Macdonald (2003:304) suggest that the main strength of static GAP analysis is that it is easy to understand. Other strengths include the following:

- Periodic GAPs indicate the interest rate risk over distinct maturities and suggest magnitudes of portfolio changes to alter risk
- They also show the specific balance sheet items that are responsible for the risk
- GAP measures can be calculated rather easily once the cash flow characteristics of each instrument have been identified
- Static gap management may be sufficient as a "guidance system" (Cade, 1997:159) for simple banking operations with mainly short term asset and liability maturities

- Weaknesses

Traditional mismatch/ gap analysis embraces several valid insights and allows for a natural feel for the macro risks being run. Despite these attractions, however, static

GAP contains a number of weaknesses, which include the following from Koch and Macdonald (2003:304/305):

1. There are serious *ex post* measurement errors – because management does not know the frequency with which market interest rates will change, it is difficult to forecast accurately when considering for example, loans whose rates are tied to base rates or indexes;
2. GAP analysis ignores the time value of money – the selection of maturity buckets does not allow for the distinction between cash flows that arise at the beginning of the period versus those that arise at the end. A bank's gains from rising or falling interest rates depend on the actual timing of repricings within each interval. The chosen time bands for each particular type of bank may be insensitive to hidden internal mismatches;
3. The cumulative impact of interest rate changes on a bank's risk position are ignored. GAP measures, which should be calculated over the entire range of repricings, often focus only on near-term changes in net interest income. As a result, many banks evaluate GAP measures and variation in net interest income through the upcoming year only. Interest rate changes, which also affect the value of fixed-rate assets and liabilities and total risk beyond one year, are ignored;
4. Liabilities that pay no interest are often ignored in rate-sensitivity comparisons. This is because many banks allocate demand deposits as non-rate-sensitive liabilities. Thus, GAP analysis does not recognise any rate risk associated with demand deposit flows, even though a bank normally loses deposits when interest rates rise;
5. Static GAP does not capture risk associated with options embedded in the loans, securities and deposits that banks deal with. Options have different values and a different probability of being exercised when interest rates are at different levels.

In addition to the above, there are a few weaknesses in the basic mismatch ladder that cause it to be unsuitable to be used by itself in a large or complex banking operation. Examples of these weaknesses include the following from Cade (1997:154/155):

- The large number of items that don't allow for easy classification within the grid – which includes products with uncertain repricing characteristics such as savings accounts, consumer loans and overdrafts
- The gap report addresses only open position risk – it assumes that all interest rates will move together in the same direction by the same amount
- The gap report does not address yield curve risk nor basis risk
- It takes a "gone concern" instead of a "going concern" view of the bank – it features only existing assets and liabilities and does not model future business development, which is why it is often referred to as the "static gap report"

### iii. **GAP: Managing Interest Rate Risk Exposure**

After assessing its interest risk profile, the bank may want to reduce or enlarge its risk exposure. According to Falkena and Kok (1991:59), in principle, the repositioning of the gap may be done in three different ways, namely by:

- a. Engaging in a new pricing strategy;
- b. Purchasing or selling the required quantity of funds in the market;
- c. Selling the risk to a party that is willing to absorb it.

#### a. Pricing strategy

Falkena and Kok (1991:59) state that if the bank wishes to move to a shorter-funded book, it may:

- Make interest rates on short-term deposits more attractive
- Increase the rates on its long-term loan

Whether the bank is able to achieve this, depends on:

- The bank's interest spread and the interest rate elasticity of demand for loans
- The time horizon available to reposition the balance sheet

#### b. Volume strategy

The second (and quicker) alternative that may be used to reduce an unfavourable risk exposure, is to reposition the mix of assets and liabilities. Falkena and Kok

(1991:60) mention how this is done by purchasing or selling the required amount of funds in the market (the volume effect). Whether it is possible depends on factors like the equity base of the bank being sufficient to carry an enlarged balance sheet or market constraints.

However, a bank management cannot always maximise short-term profits by means of price and/ or volume strategies because:

1. It takes time to reposition a balance sheet in this way;
2. The main type of business it conducts always involves a short- or a long-funded book.

Furthermore, Falkena and Kok (1991:60) suggest that if a country has no sophisticated futures or swap markets (as in South Africa), management must resort to making a definite trade-off between short-term and long-term profits or at least trying to minimise the risk premium during difficult business conditions.

c. Hedging strategy

The third alternative is selling the quantified interest risk exposure (the premium risk) to a party that is willing to absorb it. This is an example of “off-balance sheet correction” (Falkena & Kok, 1991:60), which can be done by means of hedging instruments<sup>59</sup> (like forward<sup>60</sup>, futures, swap or option agreements).

Falkena and Kok (1991:61) provide a short description of the following:

- **Futures contracts** – these are highly standardised contracts that are available in small amounts. They are very liquid, so that interest rate risk exposures can be hedged for as short a time space as a few hours

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<sup>59</sup> The aim of all hedging instruments in the context of interest rate risk management is, as Falkena and Kok (1991:61) put it, to “change the interest rate sensitivity of the book for a specific and defined period of time without affecting the balance sheet directly”.

<sup>60</sup> For a long time the traditional hedging instrument was the **forward contract**. However, it had two major shortcomings:

1. It was available only for relatively large amounts in professional business;
2. Its maximum maturity was only two years.

Since the seventies, new hedging instruments (including futures, swap and option contracts) have been developed to complement the forward contract.

- **Swap contracts** – are locked-in agreements for a specific period of time. They make it possible to hedge interest rate risk from one year to around 10 years
- Flexible **option contracts** – give the holder a right but no obligation, to buy or sell certain financial instruments. In this way, they allow hedging against an unfavourable interest rate movement only, without affecting the potential gain of a favourable interest rate movement for the portfolio

In addition, given certain basic information (like the structure of monthly gap exposures and the size of the gaps to be repositioned), the optimal trade-off between (long-term) swap contracts and (short-term) futures contracts can be determined with linear optimisation techniques. Falkena and Kok (1991:66/67) explain that option contracts are more expensive hedging instruments than futures contracts because they limit possible losses only and leave potential profits unlimited (they are a type of insurance contract). They are appealing if management is confident that interest rates will move in a particular direction but still wants to guard against the impact of adverse interest rate developments.

In the eighties, the financial markets started to combine the newly developed hedging instruments and refine existing hedging contracts. This resulted in new hedging instruments like options on futures contracts and forward rate agreements.

Excessive mismatching can be extremely dangerous and therefore, as Cade (1997:154) states, it is not uncommon for a bank to prescribe:

- Mismatch limits for each time band
- A ceiling on the percentage of expected net income put at risk for every percentage point increase or decrease in interest rates

These controls are even more necessary if the ALCO takes a more liberal approach to risk management. However, if the ALCO adopts the “prudent range of conduct” (Cade, 1997:154), then the bank will look for near-term gapping positions which are neutral to positive in line with the chosen policy, thereby avoiding the creation of distortions that could be problematic in the future.

### 3.8.1.2. Earnings Sensitivity Analysis

Recently, bank managers have used an earnings sensitivity framework to measure and monitor interest rate risk. According to Koch and Macdonald (2003:306), this framework extends static GAP analysis by making it dynamic through model simulation or “what if” analysis of all the factors that affect net interest income across a wide range of potential interest rate environments.

In essence, earnings sensitivity analysis repeats static GAP analysis, assuming different interest rate environments. It then compares expected net interest income between the different environments. The steps include the following, from Koch and Macdonald (2003:306):

1. Forecast interest rates;  
Under the different assumed interest rate environments:
2. Identify changes in asset and liability volume and composition;
3. Forecast when embedded options in assets and liabilities will be in the money and exercised;
4. Identify which and by how much, assets and liabilities will reprice over different time horizons. Identify off-balance sheet items that have cash flow implications;
5. Calculate (estimated) net interest income;
6. Compare the forecasts of net interest income.

Koch and Macdonald (2003:306) mention that the primary value of this framework is that it allows managers to assess how volatile net interest income might be across a wide range of interest rates. Koch and Macdonald (2003:297) suggest that earnings sensitivity analysis recognises that the amount of RSAs and RSLs changes when interest rates change and also that different interest rates change by different amounts at different times<sup>61</sup>.

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<sup>61</sup> The rate sensitivity of different instruments might be nominally the same. The impact, however, is different because of different timing of rate changes and different magnitudes of rate changes. When conducting the “what if” analysis, managers are able to examine the impact of nonparallel shifts in interest rates and the “differing degrees or effective rate sensitivity” (Koch & Macdonald, 2003:308). Thus, the impact of interest rate changes is not as straightforward as is suggested by Equation 1 nor by simple GAP.

### i. Simulation analysis

Simulation analysis is a dynamic approach, used to test what could happen to balance sheet structure, net interest income, present values and other financial targets up to three years ahead, under reasonable and unreasonable conditions. It consists of "modelling the characteristics of all the bank's asset and liability products, and subjecting them to a perpetual series of forward scenarios" (Cade, 1997:157).

Simulation analysis uses gap and duration<sup>62</sup> analysis as a starting point. Thereafter, as Cade (1997:157) mentions, it allows for manipulation of:

- Future business mix and volumes
- Forecast and hypothetical interest rates
- Yield curve risk and basis risk
- Exercise of options and embedded options

It permits the greatest examination of a bank's interest rate sensitivities and strategies with its "what if" forecasting. Extensive simulation gives the bank the benefit of a greater awareness.

Many software packages are available to assist banks in carrying out simulation. It requires a lot of information and here the user must decide on the level of detail that is needed. For example, it is not practical for a large bank to track every asset and liability. In this case, assets and liabilities must be grouped by class. However, in grouping too many assets or liabilities, some of the power, flexibility and sensitivity (which are the chief attractions of simulation) are lost. Top management influences the level of detail and range of scenarios.

Simulation analysis is the most comprehensive tool available for the management of structural exposure. If used properly, it can provide an information base for developing policy and testing the bank's strategic and financial plans that no other method can. On the other hand, if it is not given the attention and support it needs, simulation analysis (like other modern banking techniques) can be a waste of time and money.

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<sup>62</sup> Discussed later in this chapter.

Typically, seven different interest rate environments are compared. The first one is a base case, or most likely scenario. According to Koch and Macdonald (2003:306), it may be based on:

- Current rates
- Forward rates implied by the yield curve
- Management's specific forecast of rates

Each of the other scenarios then assumes that rates move systematically higher or systematically lower.

An important part of these forecast environments is that they recognise that different customer options are exercised at different times. Also, management is able to specify different interest rate changes for different instruments. In each environment, management determines different amounts of assets, liabilities and off-balance sheet positions that are effectively rate sensitive. In this way, a different effective GAP for each scenario is calculated.

The output is the change in net interest income or change in NIM from the base case. Policy or risk limits are usually set relative to allowable changes in net interest income and NIM from the base case. A more extensive framework is one where managers forecast the change in non-interest income and non-interest expense across different rate environments. The final output is then the change in net income versus the base case. The assumed rate may be "immediate (shocks)" or "incurred over time (gradual)" (Koch & Macdonald, 2003:307).

## **ii. Exercise of Embedded Options in Assets and Liabilities**

To understand the risk inherent in a bank's operations, it is necessary to understand the different types of options that bank customers have. A customer may have several options, such as: the option to refinance a loan early, or repay a loan early, or a depositor's option to withdraw funds prior to final maturity (which is an option embedded in bank liabilities). In any of the cases, the action of the customer (exercising his/ her options) can "upset" the bank's plans. For example, in the last case mentioned, an early withdrawal might surprise a bank by forcing it to pay the depositor back far in advance of final maturity.

Whenever options are embedded in bank assets and liabilities, Koch and Macdonald (2003:307) believe that managers should address three issues:

1. Whether the bank is the buyer or seller of the option. The buyer is the party that controls when the option is exercised, while the seller receives some compensation for selling (or writing) the option;
2. How and by what amount, is the bank being compensated for selling the option, or how much it must pay if it is buying the option;
3. The bank should forecast when the option will be exercised. These forecasts will depend on the assumed rate environment<sup>63</sup>.

Market participants can, generally, not forecast interest rates accurately for long periods of time. Nevertheless, the focus on embedded options is important because it forces management to recognise the risks inherent in their portfolios. These risks exist even if rates do not change because the possibility remains that rates might change. Furthermore, Koch and Macdonald (2003:307) state that it allows management to identify a “worst case scenario” and have a better sense of maximum loss potential.

When doing earnings sensitivity analysis, Koch and Macdonald (2003:308) mention that it is important to recognise that banks often enter into off-balance sheet contracts with explicit options. These also affect interest flows. Caps and floors on interest rates and puts and calls on interest rate futures are used to manage interest rate risk. Each type of contract may have different cash flow effects in different rate environments that can alter a bank’s interest income and/ or interest expense. The effects of these must also be included in any forecast of net interest income volatility, as Koch and Macdonald (2003:308) mention.

### 3.8.1.3. Managing the GAP and Earnings Sensitivity Risk

Koch and Macdonald (2003:315) point out how the general interest rate risk faced by a bank is indicated by effective GAP measures and the potential variation in net

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<sup>63</sup> According to Koch and Macdonald (2003:307), loan refinancing (prepayments) usually rise sharply when interest rates fall; bonds are normally called when interest rates fall; and typically, deposits are withdrawn early when deposit rates rise sufficiently.

interest income. Equation 1 applies in the income statement GAP framework but not the general earnings sensitivity framework. Generally, it suggests that:

- If interest rates are expected to increase during the GAP period, a positive cumulative GAP will lead to an increase in net interest income. Thus, if management expects rates to increase, it should become more asset sensitive
- If rates are expected to fall, a negative GAP will lead to an increase in net interest income. Thus, if management expects rates to decrease, it should become more liability sensitive

Koch and Macdonald (2003:315) explain that the actual change in net interest income will meet expectations only if interest rates change in the direction and amount expected and if RSAs and RSLs are forecast accurately. Significantly, the size of the effective GAP or the range of variation in net interest income denote how much risk a bank is taking:

- The larger the absolute value of GAP, the greater the change in net interest income for a given change in rates
- The greater the potential variation in net interest income from the base case, the greater the risk

The GAP model suggests that a bank that chooses not to speculate on future interest rates can reduce interest rate risk by obtaining a "zero effective GAP or no variability in net interest income" (Koch & Macdonald, 2003:315). The bank is fully hedged because its interest rate risk is negligible. However, in addition to this zero-risk position seldom being achieved, it is seldom desired.

A bank may choose to speculate on future interest rates and actively manage the GAP. Koch and Macdonald (2003:315) mention that Equation 1 suggests that a bank can systematically increase net interest income if it can accurately forecast rates and vary its effective GAP accordingly.

Certain steps that banks can take to reduce risk in the context of effective GAP management are listed in Koch and Macdonald (2003:315):

1. Calculate periodic GAPs over short time intervals;

2. Match fund reprisable assets with similar reprisable liabilities so that periodic GAPs approach zero;
3. Match fund long-term assets with non-interest-bearing liabilities;
4. Use off-balance sheet transactions (like interest rate swaps and financial futures) to hedge.

Alternatively, management may choose to alter the effective rate sensitivity of a bank's assets and liabilities on-balance sheet, by doing the following, from Koch and Macdonald (2003:316):

<b>Objective</b>	<b>Approaches</b>
Reduce asset sensitivity	Buy longer-term securities Lengthen the maturities of loans Move from floating-rate loans to term loans
Increase asset sensitivity	Buy short-term securities Shorten loan maturities Make more loans on a floating-rate basis
Reduce liability sensitivity	Pay premiums to attract longer-term deposit instruments Issue long-term subordinated debt
Increase liability sensitivity	Pay premiums to attract short-term deposit instruments Borrow more via non-core purchased liabilities

### 3.8.2. Managing Interest Rate Risk: Duration GAP and Market Value of Equity

One of the biggest drawbacks of funding GAP and earnings sensitivity analysis is that they emphasise a bank's risk profile over the short run and mostly ignore cash flows beyond one or two years. The disadvantage lies in that a bank's assets and liabilities may be substantially mismatched beyond two years and hence, exhibit considerable risk which goes undetected.

Duration gap and market value of equity sensitivity analysis are alternative methods of analysing interest rate risk and managing the interest rate risk position of a bank. These methods emphasise "the price sensitivity of assets and liabilities to changes in interest rates and the corresponding impact on stockholders' equity" (Koch & Macdonald, 2003:323). In this framework, interest rate risk refers to "the volatility in the market value of stockholders' equity attributable to changes in the level of interest

rates" (Koch & Macdonald, 2003:323). The value of equity of a bank that assumes considerable risk, will rise or fall sharply when interest rates change unexpectedly.

The two methods incorporate estimates of the duration of assets and duration of liabilities which, as Koch and Macdonald (2003:323) point out, reflect the value of promised cash flows through final maturity. Thus, they provide a comprehensive measure of the interest rate risk for the whole balance sheet of a bank.

Generally, the implications of when banks "win" and "lose" can be compared to those of GAP and earnings sensitivity analysis. However, the magnitude of the estimated effects may differ sharply.

#### 3.8.2.1. Measuring Interest Rate Risk with Duration Gap

**Duration gap analysis** compares the price sensitivity of a bank's total assets with the price sensitivity of its total liabilities to determine whether the market value of assets or liabilities changes more when rates change. Any "differential impact" (Koch & Macdonald, 2003:324) will reveal how the bank's market value of equity will change.

Duration is most easily understood as an elasticity measure – it provides information about how much a security's price will alter when market interest rates change. The longer the duration, the greater the price sensitivity.

##### i. Duration, Modified Duration and Effective Duration

Conceptually, duration measures the average life of an instrument. Frequently, market participants use three different duration measures (Macaulay's duration, modified duration and effective duration) that differ in terms of how they are calculated and how they should be used but whose interpretations are similar.

**Macaulay's duration** (D) is measured and quoted in units of time. It is computed "as a weighted average of the time until cash flows are received" (Koch & Macdonald, 2003:324). The weights equal the present value of each cash flow as a fraction of the security's current price. Time refers to the length of time in the future until

payment or receipt. Investors know that interest rate risk can be minimised by matching duration with the preferred holding period. This is because “price risk is balanced with reinvestment risk” (Koch & Macdonald, 2003:324).

The duration formula below, from Koch and Macdonald (2003:324), is for a security with  $n$  cash flows discounted at the market interest rate  $i$ , with an initial price  $P^*$  and  $t$  is the time until the cash payment is made.

$$D = \sum_t \frac{[\text{cash flow}_t / (1 + i)^t] \times t}{P^*} \quad (\text{Eq. 2})$$

This measure of price sensitivity is used in the approximate price elasticity relationship:

$$\frac{\Delta P}{P} \approx - \frac{D}{(1 + i)} \times \Delta i \quad (\text{Eq. 3})$$

With **modified duration** =  $D / (1 + i)$  (Eq. 4)

Koch and Macdonald (2003:325) mention that modified duration has the useful feature of indicating how much the price of a security will change in percentage terms for a given change in interest rates. Securities can then easily be ranked by modified duration to determine which ones are most price volatile.

Both the above measures calculate duration on the assumption that all promised cash flows will be realised. This holds true for option-free securities. The concept of **effective duration** is used to estimate how price sensitive a security is when the security contains embedded options.

According to Koch and Macdonald (2003:325), effective duration (Eff Dur) “compares a security’s estimated price in a falling rate environment with an estimated price in a rising rate environment relative to the initial price times the assumed rate differential”. The equation is:

$$\text{Eff Dur} = \frac{P_{i-} - P_{i+}}{P_0(i+ - i-)} \quad (\text{Eq. 5})$$

Where

$P_{i-}$  = price if rates fall;       $P_{i+}$  = price if rates rise;       $P_0$  = initial (current) price;

$i^+$  = initial market rate plus the increase in rate;

$i^-$  = initial market rate minus the decrease in rate.

Koch and Macdonald (2003:326) point out that the use of effective duration allows the cash flows of the underlying instrument to change when interest rates change. Although it is just an approximation, effective duration is useful because it recognises that an embedded option may be exercised and therefore, may modify the expected cash flows and value of a security, dramatically.

Effective duration also demonstrates how some securities may exhibit negative duration (an effective duration calculation that is negative). This happens when the price of a security in a declining rate environment falls below the price in a rising rate environment, such that the numerator in Equation 5 is negative.

## ii. Duration Gap Model

Duration gap (DGAP) models focus on “managing net interest income or the market value of stockholders’ equity, recognizing the timing of all cash flows for every security on a bank’s balance sheet” (Koch & Macdonald, 2003:326). Duration has a use as an elasticity measure. In contrast to static GAP analysis (which focuses on rate sensitivity or the frequency of repricing), duration gap analysis focuses on price sensitivity<sup>64</sup>.

There are four steps in duration gap analysis, according to Koch and Macdonald (2003:326/327):

1. Management develops an interest rate forecast;
2. Management estimates the market value of bank assets, liabilities and stockholders’ equity. The market value of equity (MVE) equals the amount

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<sup>64</sup> GAP and duration gap are two ways of looking at interest rates and two alternate but consistent ways of interpreting a security’s features. To understand the differences between them, it is important to understand the differences between rate sensitivity and price sensitivity. As Koch and Macdonald (2003:327) explain:

- **Rate sensitivity** refers to the ability to reprice the principal on an asset or liability. GAP and earnings sensitivity analysis focus on how frequently the principal amount of an asset or liability will reprice
- **Price sensitivity** refers to how much the price of an asset or liability will change when interest rates change

Usually, if an instrument is very rate sensitive, it is not very price sensitive and vice versa.

that makes the market value of assets equal to the market value of liabilities plus MVE;

3. Management estimates the weighted average duration of: assets<sup>65</sup> and liabilities respectively. The effects of both on- and off-balance sheet items are incorporated. These estimates are used to calculate duration gap;
4. Management forecasts changes in the market value of stockholders' equity across different interest rate environments.

Duration is an appealing measure because it is additive across securities in a portfolio. Koch and Macdonald (2003:326) mention that a bank's interest rate risk is indicated by comparing the weighted average duration of assets with the weighted average duration of liabilities. Like with GAP and earnings sensitivity analysis, the analysis produces different outcomes in different interest rate environments.

Like with GAP analysis, the sign and magnitude of DGAP provide information concerning when a bank is likely to "win" and "lose" and also the magnitude of the interest rate bet. By speculating on future interest rate changes, management may adjust DGAP to hedge or accept interest rate risk.

Koch and Macdonald (2003:327) state that with the focus on the market value of stockholders' equity (MVE) and the general level of interest rates (characterised by  $y$ ):

<sup>65</sup> The weighted average duration of bank assets (DA) is calculated using the following formula, from Koch and Macdonald (2003:327):

$$DA = \sum_{i=1}^n w_i Da_i \quad (\text{Eq. 6})$$

Where

- $A_i$  = market value of asset  $i$  ( $i$  equals  $1, 2, \dots, n$ )
- $w_i$  =  $A_i$  divided by the market value of all bank assets (MVA) ( $MVA = A_1 + A_2 + \dots + A_n$ )
- $Da_i$  = Macaulay's duration of asset  $i$
- $n$  = number of different bank assets

Similarly, the weighted duration of bank liabilities (DL) is calculated using:

$$DL = \sum_{j=1}^m z_j Dl_j \quad (\text{Eq. 7})$$

Where

- $L_j$  = market value of liability  $j$  ( $j$  equals  $1, 2, \dots, m$ )
- $z_j$  =  $L_j$  divided by the market value of all bank liabilities (MVL) ( $MVL = L_1 + L_2 + \dots + L_m$ )
- $Dl_j$  = Macaulay's duration of liability  $j$
- $m$  = number of different bank liabilities

$$\Delta MVE = \Delta MVA - \Delta MVL \quad (\text{Eq. 8})$$

Using Equation 3,  $\Delta A_i = -D a_i [\Delta y / (1 + y)] A_i$ ; and  $\Delta L_j = -D l_j [\Delta y / (1 + y)] L_j$ , such that:

$$\Delta MVE = -[DA - (MVL / MVA) DL] [\Delta y / (1 + y)] MVA \quad (\text{Eq. 9})$$

If a bank's duration gap is defined as in Koch and Macdonald (2003:328):

$$(DGAP) = DA - (MVL / MVA) DL, \text{ then}$$

$$\Delta MVE \approx -DGAP [\Delta y / (1 + y)] MVA \quad (\text{Eq. 10})$$

Both DA and DL take the present value of all promised or expected cash flows into account. There is no need for time buckets nor for classifying assets and liabilities. Thus, duration gap "indicates the difference between the weighted average duration of assets and the leverage-adjusted weighted average duration of liabilities" (Koch & Macdonald, 2003:328). As such, it is an approximate estimate of the sensitivity of the MVE to changes in the level of interest rates. The leverage adjustment takes the existence of equity as a means of financing assets into account. The interest factor (y) is usually measured as "some average earning asset yield across all interest-earning assets" (Koch & Macdonald, 2003:328).

Equation 10 shows that the greater the DGAP, the greater the potential variation in MVE for a given change in interest rates. Thus, DGAP provides information about when a bank "wins" and "loses" and the amount of risk assumed.

- If DGAP is positive
  - An increase in rates will lower MVE
  - A decrease in rates will increase MVE
- If DGAP is negative
  - An increase in rates will increase MVE
  - A decrease in rates will lower MVE

Koch and Macdonald (2003:328) point out that the closer DGAP is to zero, the smaller is the potential change in MVE for any change in rates.

### **iii. A Duration Application for Banks**

As Koch and Macdonald (2003:328) mention, most bank managers are concerned with the bank's total risk exposure from all assets and liabilities.

- When the bank receives cash inflows from assets before making its required payments on liabilities, it bears the risk that it may have to reinvest the proceeds at reduced rates
- When the bank makes debt payments before it receives cash inflows, it bears the risk that borrowing costs will rise

Any differential in the timing of asset and liability cash flows is reflected in average durations. Duration gap analysis requires that a bank specify a performance target (like the market value of equity) and strategically manage the difference between the average duration of total assets and the average duration of total liabilities.

The general relationship between the sign of a bank's duration gap and the impact of changing rates on MVE is summarised in Figure<sup>66</sup> 3.6. below:

DGAP Summary						
DGAP	Change in Interest Rates	Change in Market Value				
		Assets		Liabilities		Equity
Positive	Increase	Decrease	>	Decrease	→	Decrease
Positive	Decrease	Increase	>	Increase	→	Increase
Negative	Increase	Decrease	<	Decrease	→	Increase
Negative	Decrease	Increase	<	Increase	→	Decrease
Zero	Increase	Decrease	=	Decrease	→	None
Zero	Decrease	Increase	=	Increase	→	None

**Figure 3.6. Table illustrating the relationship between the sign of DGAP and the change in interest rates on MVE.**

Duration measures can be used by bank management to evaluate interest rate risk. However, it is a static measure. The greater the absolute value of DGAP, the greater the interest rate risk. According to Koch and Macdonald (2003:330), a bank that is perfectly hedged will have a DGAP of zero and therefore, function with its average asset duration slightly below its average liability duration.

DGAP measures can be used to approximate the expected change in market value of equity for a given change in interest rates. Equation 10 can be used to estimate

<sup>66</sup> From Koch and Macdonald (2003:329).

the change in MVE. As an approximation, the average yield on total assets may be used as the market interest rate,  $y$ .

#### iv. Duration Analysis: Advantages and Disadvantages

- Advantages

Duration analysis has certain advantages, such as the following, mentioned by Cade (1997:156):

1. It provides a simple and accurate basis for hedging a portfolio, by taking a new equal and opposite position in a security with the same duration;
2. Duration can be used as a prudential standard of comparison for alternative business development and funding strategies;
3. Duration and yield to maturity provide the two essential elements for calculation of **interest rate elasticity** or **price elasticity**<sup>67</sup>. If the same modelling is applied to the bank's non-equity liabilities as to its assets, then assets less liabilities will be a projection of the expected present value of the bank's equity capital, its market value and its share price. The calculation is relevant in ALCO deliberations regarding possible hedging strategies.

Cade (1997:159) points out that duration analysis offers advantages for modelling and hedging purposes, especially where the book has more longer term maturities.

- Disadvantages

The main weaknesses of duration analysis lie in its simplicity – the single number may not reveal the entire picture. Other weaknesses include the following, from Cade (1997:157):

- Like gap analysis, the emphasis remains on open position risk
- As with gap analysis, the focus is essentially "gone concern", although the approach allows some scope for modelling
- Preparation of duration analysis requires large volumes of data input

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<sup>67</sup> According to Cade (1997:156), interest rate elasticity or price elasticity "projects the approximate percentage change in the present value of a financial instrument (or a portfolio) that will result from a given percentage change (say 1%) in interest rates".

- Apart from bond market and trading operations, most commercial banks find that duration methodology has a limited practical pay-off

### 3.8.2.2. Market Value of Equity Sensitivity Analysis

Many bank managers use a MVE sensitivity analysis framework (similar to that for earnings sensitivity), to assess interest rate risk better. This framework extends the static duration gap analysis by making it dynamic, through model simulation. Model simulation consists of conducting “what if” analysis of all the factors that affect MVE across a wide range of interest rate environments. The analysis repeats static DGAP analysis under different assumed interest rates and is often labelled “net present value (NPV) or economic value of equity (EVE) analysis” (Koch & Macdonald, 2003:332).

The output of the analysis is a comparison of changes in MVE across different interest rate environments. Koch and Macdonald (2003:332) state that it signals how volatile MVE might be compared to some base case or most likely rate scenario. As before, the normal comparison takes seven rate environments into consideration – starting with the base case and then other scenarios that alternatively consider rates one, two and three percent higher and lower, respectively.

An important component of this sensitivity analysis is, according to Koch and Macdonald (2003:332), the projection of when embedded customer options will be exercised and also what their values will be. In addition, management varies assumptions about rate spreads and shifts in the yield curve. The same embedded options that affect earnings sensitivity (loan prepayments, callable and putable bonds and early deposit withdrawals, for example) influence the estimated volatility in MVE. The greater the potential volatility in MVE, the greater the risk.

Koch and Macdonald (2003:332) point out that, generally:

1. Prepayments that exceed that expected, will shorten duration;  
Prepayments that fall short of that expected, will lengthen duration;
2. A bond being called will shorten duration;

3. A deposit that is withdrawn early will shorten duration;  
A deposit that is not withdrawn as expected will lengthen duration.

Changes in interest rates that are not anticipated, usually “cause durations to vary over time” (Koch & Macdonald, 2003:332). The effective duration calculation (which is supposed to account for some of this variation) should be used in MVE analysis. As an alternative, analysts may use an estimated price consistent with call price, expected prepayment impact and others for each asset or liability with an embedded option.

Koch and Macdonald (2003:335) explain that, by definition, duration measures the percentage change in market value for a given change in interest rates. Hence, a bank's *duration of equity* measures the *percent* change in MVE that will occur with a 1 percent change in rates.

#### 3.8.2.3. DGAP and MVE Sensitivity Analysis: Strengths and Weaknesses

- Strengths

DGAP and MVE sensitivity analysis have various positive points, which include the following, from Koch and Macdonald (2003:335):

- The main strength of duration analysis lies in that it provides a comprehensive measure of interest rate risk for the whole portfolio
- The smaller the absolute value of DGAP, the less sensitive the market value of equity is to interest rate changes
- In contrast to GAP, DGAP recognises the time value of each cash flow, avoiding the difficulty with time buckets
- Cash flows that arise after one year are included in duration calculations (often ignored in GAP calculations)
- Duration measures are additive, so the bank can match total assets with total liabilities instead of matching individual accounts
- Duration analysis takes a longer-term view and because managers are able to use a wide range of instruments to balance value sensitivity, it provides them with larger flexibility in adjusting rate sensitivity

- Weaknesses

Inevitably, duration and MVE sensitivity analysis also have various weaknesses.

Koch and Macdonald (2003:335/336) point out the following:

1. It is difficult to compute duration accurately. Duration measurement requires many subjective assumptions and a lot of information<sup>68</sup>. Routinely, the bank has to:
  - Assess the probability that contracted cash flows will be received on a timely basis
  - Forecast the timing of base rate changes and the level of rates at the time of future cash flows
  - Constantly monitor whether actual cash flows conform to expectations

Furthermore, in order to be meaningful, DGAP and sensitivity analysis need accurate forecasts of when embedded options will be exercised and also what their value is. This is the same information that is needed to conduct earnings sensitivity analysis;

2. In order to be correct, duration analysis requires that every future cash flow be discounted by a distinct discount rate reflecting the expected future rate at the time the cash flow arises;
3. A bank must monitor and adjust the duration of its portfolio continuously. Since duration changes with changes in interest rates, a bank should recalculate duration and MVE sensitivity and possibly restructure its balance sheet when rates change significantly. This could be daily or weekly. The duration calculation is accurate only for small changes in interest rates. The duration of assets and liabilities may “drift” at different rates and need constant rebalancing. When embedded options are involved, problems like these are made worse by difficulties in estimating price effects and effective durations;
4. It is difficult to estimate the duration on assets and liabilities that do not earn or pay interest. To get an accurate assessment of cash flows and market value

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<sup>68</sup> Koch and Macdonald (2003:335) suggest that information on each account's

- |                                       |                              |
|---------------------------------------|------------------------------|
| – Interest rate                       | – Call and put options       |
| – Repricing schedule                  | – Early withdrawal potential |
| – Possibility of principal prepayment | – Default probability        |
- is needed.

changes, a bank must estimate the true rate sensitivity of demand deposits and estimate their duration. There is no set way of doing this.

In short, duration measures are highly subjective. Koch and Macdonald (2003:336) state that active management requires constant "tinkering" with the bank portfolio to adjust the duration gap. For those firms with simple balance sheets that have no significant amounts of customer options that are commonly exercised, it may not be worthwhile.

### 3.8.3. Earnings Sensitivity Analysis vs. MVE Sensitivity Analysis

According to Koch and Macdonald (2003:335), when assessing interest rate risk, bankers use both static GAP and duration gap models as well as earnings sensitivity and MVE sensitivity analysis. Each has different objectives and implications and thus, addresses different issues:

- GAP and earnings sensitivity analysis focus on the potential volatility of net interest income (which is calculated in book value terms, not market values) over distinct time intervals. The effects of volatile interest rates are managed within each time period separately
- The duration and MVE sensitivity approach focuses on the "potential variability" of a bank's market value of equity. Duration gap is a single measure that summarises the cumulative impact of interest rate changes on a bank's total portfolio. Therefore, the bank manages total firm rate risk continuously, according to this single number

### 3.8.4. Management Strategies

The business of banking involves taking risks. However, generally, bankers are less comfortable taking interest rate risk. The type of risks assumed in managing GAP, DGAP and the sensitivity of net interest income and MVE to changes in interest rates can be emphasised. The important implication is to "know your bets" (Koch & Macdonald, 2003:336).

#### 3.8.4.1. GAP and DGAP Management Strategies

In general, it is accepted that banks do and should assume some interest rate risk. The challenge is to determine how much risk is acceptable and how to achieve the desired risk profile the best.

It is difficult to vary GAP and DGAP actively and win consistently. Koch and Macdonald (2003:337) mention two reasons for this:

1. Interest rate forecasts are often incorrect. Management must try to predict future interest rates better than consensus market forecasts embedded in current rates and then act accordingly;
2. Even if rate changes are predicted correctly, banks have limited flexibility in varying GAP and DGAP and must frequently sacrifice yield to do so.

#### 3.8.4.2. Yield Curve Strategies

Koch and Macdonald (2003:338) suggest that many portfolio managers know about general macroeconomic and business cycle<sup>69</sup> impacts on the yield curve. They try to take advantage of long-term trends in rates.

### 3.9. Summary: Some Important Key Points

Since no one is able to forecast interest rates accurately all the time, interest rate risk management is highly important. A bank's asset and liability management committee (ALCO) or its risk management committee, is responsible for measuring and monitoring interest rate risk (the ALM committee is responsible for monitoring and managing a bank's interest rate risk profile).

Asset and liability management involves "the offsetting of risks that endanger the operating and financing flexibility of a financial institution" (Falkena & Kok, 1991:41). It involves managing maturing assets and liabilities consistent with expected interest rate movements.

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<sup>69</sup> Interest rates and the business cycle discussed earlier.

According to Koch and Macdonald (2003:340), conventional ALM focuses on measuring interest rate risk and monitoring performance, setting policies to stabilise or increase net interest income. Several methods may be followed by banks to achieve the basic objectives of asset and liability management. Two such methods are: static gap analysis and earnings sensitivity analysis.

The traditional static GAP model is used as a means of measuring interest rate risk. Gap analysis is an income or flow concept and measures the income effect of interest rate changes. It is a future-value calculation.

Koch and Macdonald (2003:292) explain how interest rate risk is measured by calculating GAPs over different time intervals based on aggregate balance sheet data at a fixed point in time. These GAP values are then examined to deduce how much net interest income will change if rates change.

Static GAP focuses on managing net interest income in the short run. The use of absolute value shows that the sign of GAP indicates whether net interest income rises or falls when rates change in a specific direction. It does not influence the volatility of net interest income. Furthermore, the static gap report is "mathematically naïve" (Cade, 1997:155) in ignoring interest flows and the time value of money.

Koch and Macdonald (2003:304) point out that most banks employ earnings sensitivity analysis to address weaknesses in the static GAP concept. Earnings sensitivity analysis, in essence, represents net income simulation under different assumed interest rate environments. It allows management to assess:

- The sensitivity of net interest income to changes in balance sheet volume and composition
- Shifts in the relationship between asset yields and the costs of interest-bearing liabilities
- General shifts in the level of interest rates

Koch and Macdonald (2003:323) state that the management of a bank's interest rate risk position can also be examined in terms of duration-based measures of relative

asset and liability price sensitivity (duration gap) and the sensitivity of the market value of stockholders' equity to changes in interest rates. Thus, as alternatives, duration gap model and market value of equity sensitivity analysis can be used to analyse interest rate risk.

Duration-based sensitivity analysis represents an alternative to GAP and earnings sensitivity analysis. Duration gap analysis takes a bank's whole balance sheet into account.

Duration analysis is a more sophisticated approach, borrowed from the bond markets, that takes account of interest flows and the time value of money. Basically, the present value of all future cash flows within a portfolio is aggregated and then weighted by their respective periods to maturity. The total of weighted values divided by present values gives a single number representing the duration of the portfolio, usually expressed in years. The longer the duration, the greater the interest rate risk.

One calculation is performed for the bank's assets and another for its liabilities. Comparison of their respective durations gives an alternative to a gap report. If, for example, the assets show a shorter duration than the liabilities, then the bank is asset-sensitive. Net interest income will tend to benefit from a general rise in rates and to suffer from a fall in rates, according to the gapping principles.

As Koch and Macdonald (2003:340) explain, duration gap analysis calculates measures of the weighted average durations of all assets and all liabilities. The difference in these weighted durations adjusted for financial leverage is labelled duration gap. It provides a measure of how the market value of stockholders' equity will change when interest rates change.

Duration analysis is a wealth or stock concept and assesses the wealth effects of rate volatility as measured by current market values. It employs present-value calculations. Duration-based sensitivity analysis is, as Koch and Macdonald (2003:340) point out, useful because it focuses on the present value of all cash flows over the entire range of maturities. The biggest difficulties in applying duration

analysis, according to Falkena and Kok (1991:41), are the estimation and predictability of discount rates and the cost of accurate cash flow information.

With duration gap analysis the target measure of performance is usually the market value of bank equity. Risk is measured by the sign and size of duration gap and the potential variation in MVE. Again, a bank's ALCO conducts sensitivity analysis across different assumed interest rate environments in order to assess this potential variation in market value of stockholders' equity, as Koch and Macdonald (2003:340) mention. Bigger risk is evidenced by bigger potential variation.

Duration gap analysis represents an application of duration concepts to a bank's whole balance sheet. It parallels static GAP and earnings sensitivity analysis.

Pertaining to MVE, the analysis is dynamic in that it "incorporates the impact of potential rate increases and decreases" (Koch & Macdonald, 2003:324) and it recognises that customers' exercise of embedded options will affect a bank's true risk exposure, depending on how interest rates change. Therefore, the analytical procedure is similar to that for earnings sensitivity analysis.

Inevitably, all measures have their limitations. According to Koch and Macdonald (2003:340), for duration, these limitations include the fact that the effective price sensitivity and duration of individual assets and liabilities change with changes in interest rates. In addition, it is difficult to forecast rate changes and the price impact on customer options embedded in bank assets and liabilities accurately.

Once armed with information, management might

- Position itself to gain, if it wants to take on additional risk
- Hedge, if it wants to reduce overall risk

Different analysis techniques are applied to the future than to a known past in interest rate risk management models. An interest rate forecast should be consistent with the bank's broad economic forecast, as well as with its internal pricing policy. Interest rate fluctuations modify bank earnings as well as the value of stockholders' claims, unless management implements strategies to reduce their impact. Although

computers may aid in asset/ liability management, the final decision is based on human experience and judgement.

Interest rates are extremely important since they have an impact on the overall health of the economy because they affect not only consumers' willingness to spend or save but also business' investment decisions. Therefore, it is important to be able to predict interest rates but perhaps more importantly, to predict them correctly. Regrettably, there are no guarantees.

Traditionally, banks have "borrowed short and loaned long" – their sources of funds are mostly short-term, which they use to buy longer-term assets. Borrowing short and lending long, however, exposes banks to the consequences of interest rate risk, if rates should rise. They have responded by shifting the risk to their customers, by charging floating instead of fixed rates, when they make loans. Although this may decrease interest rate risk, it increases credit risk. Ultimately, banks should find a balance.

Therefore, it is impossible to predict exactly: when rates will change, what will happen in the future, when the current trend will change, or what will trigger that change. Nevertheless, people keep trying to achieve their cash flow objectives and minimise the likelihood of surprises. Any business that borrows funds, aims to minimise the financial risk of interest rate fluctuations.

### 3.10. Conclusion

Interest rates are linked to just about everything in the economic markets in which people and banks operate. They are part of: what people use to make financial decisions for borrowing and lending money, what businesses use to make certain investment decisions and what banks use to sustain themselves and ensure proper functioning of the economy of the country. Evidently, interest rates are important.

Indeed, it is even more crucial for banks to be able to predict interest rates correctly because they form part of the basis on which decisions are made that affect the future of the bank. In addition, it is essential that banks are able to deal with the

many risks that occur in the economy but especially those risks associated with interest rates. Thus, the focus of this chapter was on interest rates and more specifically, on some of the means that bank managers have at their disposal to anticipate and minimise interest rate risk.

The structure of the asset-liability committees (ALCOs) of banks was explained as well as the role these committees play in managing interest rates and risk. The business cycle and the ways in which it affects interest rates was described. Consequently, ways in which bank managers have learned to predict future rates based on this cycle were mentioned.

To manage interest rate risk, specifically, banks rely on: GAP and earnings sensitivity analysis. In this context, interest rate risk refers to the volatility in net interest income due to changes in the level of interest rates and shifts in the composition and volume of bank assets and liabilities. Factors affecting net interest income were discussed, as were both methods. Earnings sensitivity builds on GAP analysis. Size and sign of GAP offer more information.

Two alternative methods of analysing interest rate risk and managing the interest rate risk position of a bank that were also discussed are: duration gap (DGAP) and market value of equity sensitivity analysis (MVE). Duration gap analysis takes a bank's whole balance sheet into account and is a more sophisticated approach that takes account of interest flows and the time value of money. The target measure of performance is usually the market value of bank equity. Again, size and sign of DGAP provide pertinent information.

Although each of the four methods has its own basic characteristics and focuses on specific targets, similarities do exist between them. Each one has strengths and weaknesses and bank managers must choose those methods that are best suited to aid their particular bank in managing interest rate risk.

Forecasting interest rates is a time-honoured profession. Economists are hired (sometimes at extremely high salaries) to forecast interest rates. Businesses need to

know what interest rates will be in order to plan their future spending. Banks and investors require interest rate forecasts in order to decide which assets to buy.

Interest rate forecasters predict what will happen to the factors that affect the supply and demand for bonds and for money, in other words, the:

- Strength of the economy
- Attractiveness of investment opportunities
- Expected inflation rate
- Size of government budget deficits and borrowing

Then, they use the supply and demand analysis to come up with their interest rate forecasts.

Regrettably, there are many perils in the business of forecasting interest rates. Even top forecasters (quite to their embarrassment) are frequently far off in their forecasts. Nevertheless, banks keep trying to forecast interest rates with as much accuracy as possible in the hopes of maintaining stability and certainly, gaining an advantage over other banks. Forecasting interest rates using selected models is the subject of the next chapter.

**CHAPTER 4: SHORT-TERM PREDICTIONS WITH SIMPLE FORECASTING**

**MODELS**

The models used in Chapter 4 are:

<b><u>REFERENCE IN TEXT</u></b>	<b><u>MODEL</u></b>	<b><u>COMMENT</u></b>
	<b><u>Naïve Models</u></b>	
4.4.1.1.	$Y'_{t+1} = Y_t$	Model 1.1. Also referred to as the simple, first naïve or same-value model
4.4.1.2.	$Y'_{t+1} = Y_t + (Y_t - Y_{t-1})$	Model 1.2. Also referred to as the second naïve, straight line or same absolute-change model
4.4.1.3.	$Y'_{t+1} = Y_t * (Y_t / Y_{t-1})$	Model 1.3. Also referred to as the third naïve, percentage or same percentage-change model
	<b><u>Moving Average Models</u></b>	
4.4.2.1.	$(Y_t + Y_{t-1}) / 2$	Model 2.1. Also referred to as the first MA or moving average of two values model
4.4.2.2.	$(Y_t + Y_{t-1} + \dots + Y_{t-m+1}) / m$	Model 2.2. Also referred to as the second MA or moving average of $m$ values model, where $m = 3$
	<b><u>Exponential Smoothing Models</u></b>	
	$Y'_{t+1} = \alpha Y_t + (1 - \alpha) Y'_t$	With smoothing constant $\alpha$ (also referred to as alpha or A in the text, graphs or tables)
4.4.3.1.	Single Smoothed	Model 3.1. Also referred to as the first exponential smoothing models, where $\alpha$ is alternately equal to 0.1, 0.4, 0.6 and 0.9
4.4.3.2.	Double Smoothed	Model 3.2. Also referred to as the second exponential smoothing models, where combinations of $\alpha_1$ and $\alpha_2$ are used

#### 4.1. Introduction

The focus of this chapter is on the different forecasting models used in this study to predict interest rates. One of the aims of this study is to determine which model (of the ones chosen) is able to predict interest rates as close to the actual ones as possible and with as little error as possible. Thus, it is important to select and experiment with simple, existing models and also to set more specific criteria as to what makes a "good" model (and later on the "best" model) in terms of the results obtained.

Once the criteria have been set and the models that are to be used selected, they should be applied to the data sets and the results of each analysed. Following this, decisions can be made as to whether the results are sufficient, whether better results could be achieved by combining the previously used models, or if finding and implementing other models not yet used would yield better<sup>70</sup> results.

#### 4.2. About the Data

As a starting point, looking at the data and finding basic information (such as mean, standard deviation, variance, minimum and maximum values) should be done before it is mined in greater detail. This reveals simple information about the data that is being dealt with and acts as a guide to deciding what types of models should be considered when attempting to predict. Thereafter, it is necessary to find such simple models that have previously been established and apply them to the data sets at hand.

Two data sets are used in this study:

- Bankers' Acceptances (**BA rates**) which is money market short-term month-end data and
- Eskom (**Esc rates**) which is capital market long-term month-average data.

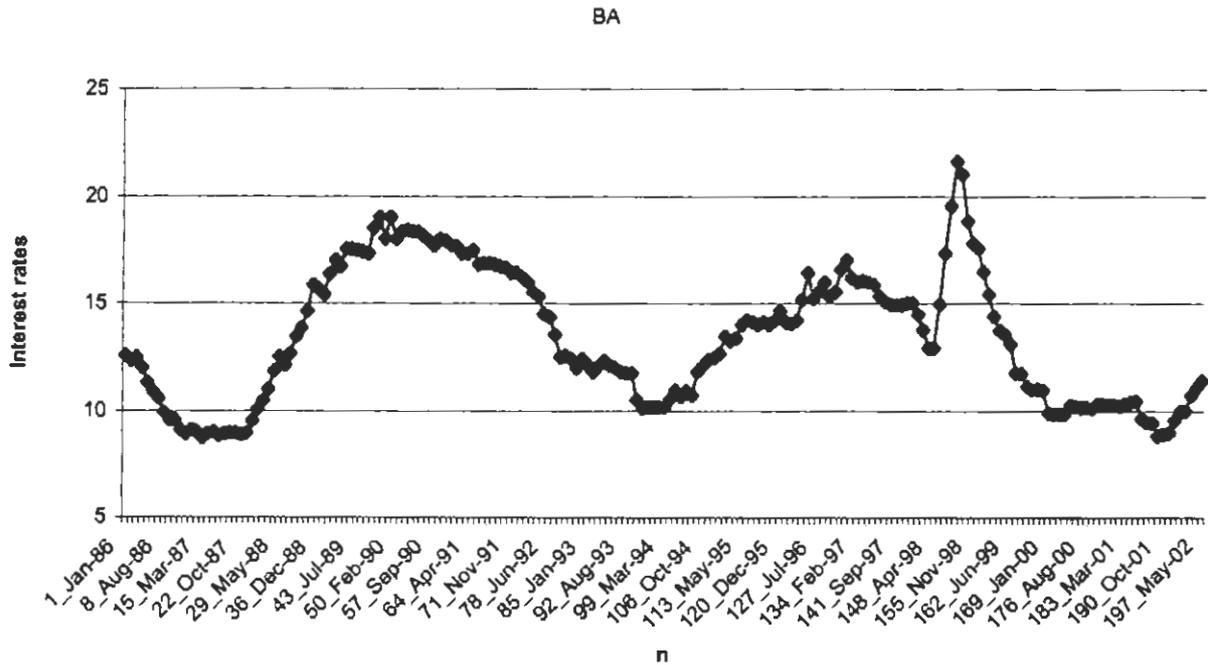
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<sup>70</sup> According to the set criteria.

Both data sets contain data starting on January 1986 and thereafter, monthly data until

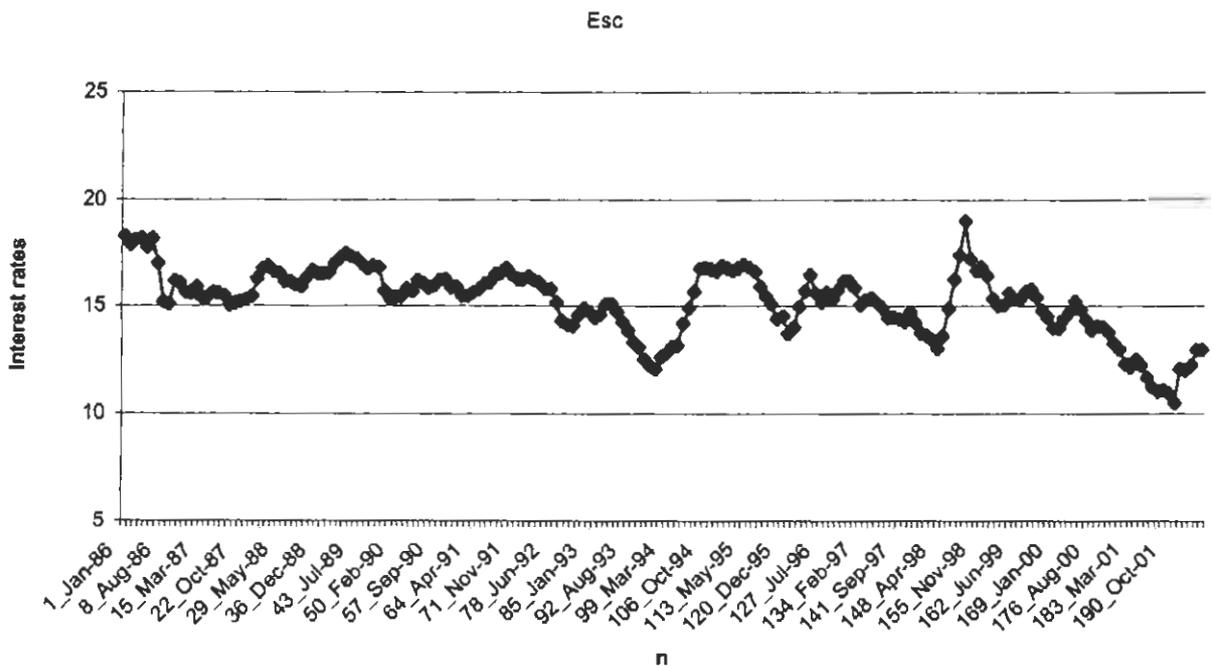
- May 2002 for the BA data set (197 observations) and
- April 2002 for the Esc data set (196 observations).

The data sets are illustrated in the following two graphs:



**Graph 4.1. [Above] BA data set.**

**Graph 4.2. [Below] Esc data set.**



Below is a short summary table of some simple information about each of the data sets:

	<b>BA</b>	<b>Esc</b>
<b>SUM</b>	2 640.98	2 980.74
<b>AVERAGE</b>	13.406	15.208
<b>STD DEV</b>	3.115	1.567
<b>MIN</b>	8.70	10.47
<b>MAX</b>	21.60	18.97

It was decided to apply simple forecast models to each of the data sets. However, to have some idea of what the models were expected to show and how each model would be compared with the others, criteria needed to be set first.

#### 4.3. Criteria

It is necessary to set criteria for what is expected of these models since they are being used to predict interest rates. Each model is different and in some cases there are several versions of the model in an attempt to optimise it. Thus, two types of outcomes are possible, namely: “good” models and the “best” model.

##### 4.3.1. Criteria for a “Good” Model

It was decided to find several measures that could be used to determine how “good” the model was in predicting.

##### 4.3.1.1. 1<sup>st</sup> Criterion – Percentage of Correct Direction Predictions (PCD)

It would be difficult to get the exact interest rate number correct using the chosen (or any other) models. Therefore, the intention was to determine whether the model could at least predict the correct direction of the next interest rate accurately.

The procedure is that if from the current to the next period the actual interest rate goes UP, for example, then the model is required to predict the direction UP to get a match (a value or score of one point); if the interest rate goes DOWN, then the model is required to predict DOWN also; and if the interest rate remains the same, then the

model is required to predict CONSTANT. At the end of all possible comparisons, the points are added up and divided by this number of possible comparisons giving a percentage score to each model.

The best possible result for this criterion is a correct direction prediction of 100%. If no model is able to get such a score, then the model that obtains the highest percentage of correct direction predictions is classified as a "good" model and considered for the "best" model, subject to other criteria.

#### **i. Turning point errors**

In addition to the other criteria, "a separate evaluation of *turning point errors* needs to be made" (Shim, *et al.*, 1994:278). A turning point error takes place when the forecast that is made is either a projection of an increase in interest rate levels when really the rates decline, or when a decline in interest rate levels is anticipated when really the rates increase.

It can be argued that the ability of forecasters to foresee reversals of interest rate trends is more important than the precise accuracy of the forecast. This is because there are more extensive gains or losses from a shift from generally upward moving rates to downward rate trends (or vice versa) than gains or losses from predicting the extent of a continued increase or decrease in rates incorrectly.

According to Shim, *et al.* (1994:279), the forecasting ability of the model "should be judged in terms of its ability to anticipate major changes in the direction (or turning point) of rates". A good balance between a quantitative evaluation and expert opinions can help determine the future direction of interest rates.

#### **4.3.1.2. 2<sup>nd</sup> Criterion – Mean Squared Error (MSE)**

Since not all the models (if any) were going to predict the direction of the next interest rate correctly all the time, it was decided to determine (at the times where the model did not predict correctly) how much of an error was made in terms of the actual interest rates. Seeing as the later models require the use of a specific technique

(MSE), it was decided to use this as the second criterion for determining a "good" model.

The idea here is to determine the error that is made from the actual value to the one that is predicted. Then each of these errors is squared and the average of all is taken. This technique is described in greater detail later on in this chapter when the models are discussed.

The best possible result for this criterion is a mean squared error of zero. Again, if no model is able to get such a score, then the model that obtains the smallest MSE is classified as a "good" model.

#### 4.3.1.3. 3<sup>rd</sup> Criterion – Tracking Signals (TS)

In addition to percentage of correct direction predictions (PCD) and mean squared error (MSE) described above, another criterion can be used to determine which of the seven models (and their versions) can be classified as "good" models. This is tracking signals.

According to Render, *et al.* (2003:171), "one way to monitor forecasts to ensure that they are performing well is to employ a tracking signal. A *tracking signal* is a measurement of how well the forecast is predicting actual values".

A TS was calculated for each model according to the following formula:

$$\text{Tracking Signal} = \frac{\text{Running Sum of the Forecast Errors (RSFE)}}{\text{Mean Absolute Deviation (MAD)}}$$

Where  $\text{RSFE} = \sum (\text{actual rate in period } i - \text{forecast rate in period } i)$

and  $\text{MAD} = \sum |\text{forecast errors}| / n$

Positive tracking signals indicate that the actual interest rate is greater than the forecast. Negative signals mean that the interest rate is less than the forecast. A

good tracking signal (one that centres closely around zero) is one with a low RSFE – it has about as much positive error as it has negative error.

Render, *et al.* (2003:172) explain that “when tracking signals are calculated, they are compared with predetermined control limits. When a tracking signal exceeds an upper or lower limit, a signal is tripped”. In this study, 4 was used as the Upper Limit (UL) and –4 as the Lower Limit (LL). In this way, it is possible to see if there is a problem with the forecasting method and whether it needs to be re-evaluated. In each case, maximums of  $\pm 4$  MADs were used. This suggests that for a forecast to be “in control”, 99.9% of the errors are expected to fall within  $\pm 4$  MADs<sup>71</sup>.

#### **i. SUMMARY OF CRITERIA**

- 1 – PCD – the higher, the better
- 2 – MSE – the smaller, the better
- 3 – TS – low RSFE and within  $\pm 4$  MADs

#### **4.3.2. Criteria for the “Best” Model**

The “best” model is likely to be the one that predicts values (in this study, interest rates) equal to the actual ones. If this is not possible, then the next “best” model is the one that predicts values as close to the actual ones as possible.

Setting criteria for what is the “best” model or the “best” version of a model comes from the criteria for a “good” model. Indeed, if only the percentage of correct direction predictions is to be considered, then the highest percentage of correct direction predictions is of interest. The best result here would be that the model is able to predict the direction of the interest rate correctly 100% of the time.

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<sup>71</sup> According to Render, *et al.* (2003:174), Mean Absolute Deviation (MAD) is a “technique for determining the accuracy of a forecasting model by taking the average of the absolute deviations”. It is a measure of the overall forecast error. A value of 12.5 for example means that on average, each forecast missed the actual value by 12.5 units.

Alternatively, if the MSE is to be considered as the only criterion for finding the “best”, then the model that produces the smallest mean squared error would be the one. The best result here is for the MSE to be zero.

If, instead, a combination of percentage of correct direction predictions as well as MSE are used as criteria to find the “best” model (or version of the model), then there has to be a compromise between the two. In this case, the better option is to find a *large* percentage and a *small* MSE instead of the *largest* percentage and the *smallest* MSE.

#### 4.4. Simple Forecasting Models

Three forecasting methods that fall into the quantitative approach category are: naive models, moving averages and exponential smoothing. These are the models that are used in this study.

##### 4.4.1. Naïve Models

These models are based solely on past observations of (in this study) interest rates. They do not rely on any other information or variables to predict the next value: “naive forecasting models are based exclusively on historical observation.... They do not attempt to explain the underlying causal relationships that produce the variable being forecast” (Shim, Siegel & Liew, 1994:35).

This method has the advantage of being economical – “it is inexpensive to develop, store data, and operate” (Shim, *et al.*, 1994:35). Yet, it has the distinct disadvantage of not supplying any other information about the interest rates being forecasted – “it does not consider any possible causal relationships that underly the forecasted variable” (Shim, *et al.*, 1994:35).

In this study, three naïve models are considered, namely:

- ◆ Same-value Model:  $Y'_{t+1} = Y_t$
- ◆ Same absolute-change Model:  $Y'_{t+1} = Y_t + (Y_t - Y_{t-1})$
- ◆ Same percentage-change Model:  $Y'_{t+1} = Y_t * (Y_t / Y_{t-1})$

#### 4.4.1.1. Same-value Model $Y'_{t+1} = Y_t$

This is the simplest example of a naive model – “to use the actual sales of the current period as the forecast for the next period” (Shim, *et al.*, 1994:35). The symbol  $Y'_{t+1}$  is used to represent the forecast value and  $Y_t$  is used to represent the actual value. In this case, then, the actual interest rates of the current period are used as the forecast for the next period. Or, more simply, the next interest rate is just the current actual interest rate.

##### i. Procedure and Findings – Naive Models: 1.1.

Table 4.1 below is an example of a portion of the table that was created and used in Excel to represent the very first naïve model used in this study for the BA data set. It contains the row and column headings from Excel (rows five to 15 and columns B to J), as well as the first ten rows of data that were obtained using this model.

In the table, when a reference is made to a cell (intersection of a column and a row), it is done by quoting the column name and then the row number. For example, if a reference is made to cell D7, it refers to column D, row 7 which corresponds to the predicted or forecasted interest rate of 12.55.

...	B	C	D	E	F	G	H	I	J
5	t	$Y_t$	$Y'_{t+1}=Y_t$	$e_t=Y_t-Y'_{t+1}$	Prediction	Actual	Direction		
6	1	12.55							
7	2	12.3	12.55	-0.250	Constant	Down	0		0 = Wrong
8	3	12.45	12.30	0.150	Constant	Up	0		1 = Correct
9	4	12	12.45	-0.450	Constant	Down	0		
10	5	11.3	12.00	-0.700	Constant	Down	0		
11	6	10.85	11.30	-0.450	Constant	Down	0		
12	7	10.55	10.85	-0.300	Constant	Down	0		
13	8	9.9	10.55	-0.650	Constant	Down	0		
14	9	9.55	9.90	-0.350	Constant	Down	0		
15	10	9.55	9.55	0.000	Constant	Constant	1		

**Table 4.1. Representative portion of the table used in Excel, depicting the first naive model using the BA data set**

The headings in Table 4.1 (as in the other tables) represent the following:

- Cell B5 = column heading "t" – observation number. For example, t=1 refers to the first observation, t=2 to the second observation and so on
- Cell C5 = column heading "Y<sub>t</sub>" – actual interest rate. For example, the first actual observed interest rate in the BA data set is 12.55 (in cell C6)
- Cell D5 = column heading "Y\*<sub>t+1</sub> = Y<sub>t</sub>"<sup>72</sup> – representation of the first naïve model. For this particular model, the actual interest rate of the current period is used as the forecast for the next period so that, for example: the first actual observed interest rate in cell C6 (12.55) is used as the first forecasted interest rate in cell D7; the second actual observed interest rate in cell C7 (12.3) is used as the second forecasted interest rate in cell D8 and so on.

Below is Table 4.2 – a representation of a portion of the table that was created in Excel for the first naïve model showing some of the formulae that were used.

...	B	C	D	E	F	G	H
5	t	Y <sub>t</sub>	Y* <sub>t+1</sub> =Y <sub>t</sub>	e <sub>t</sub> =Y <sub>t</sub> -Y* <sub>t+1</sub>	Prediction	Actual	Direction
6	1	12.55					
7	2	12.3	=C6	=C7-D7	Constant	=IF(C7<C6;"Down";(IF(C7>C6;"Up";"Constant")))	=IF(F7=G7;1;0)
8	3	12.45	=C7	=C8-D8	Constant	=IF(C8<C7;"Down";(IF(C8>C7;"Up";"Constant")))	=IF(F8=G8;1;0)
9	4	12	=C8	=C9-D9	Constant	=IF(C9<C8;"Down";(IF(C9>C8;"Up";"Constant")))	=IF(F9=G9;1;0)

***Table 4.2. Representative portion of the table used in Excel, showing some of the formulae used to create the first naïve model for the BA data set***

- Cell E5 = column heading "e<sub>t</sub>=Y<sub>t</sub>-Y\*<sub>t+1</sub>" – error calculated by subtracting the predicted value from the actual observed value
- Cell F5 = column heading "Prediction" – direction predictions that can be made. There are three choices here, namely: UP, CONSTANT or

<sup>72</sup> Throughout the study, the symbol Y\*<sub>t+1</sub> is equivalent to the symbol Y\*<sub>t,t</sub>. They both represent the forecast value or predicted interest rate value.

DOWN. The aim is to see if the prediction that was made is higher, the same as, or lower than the previous actual observed value, in terms of direction.

If the prediction is UP, it means that the predicted interest rate (in D7, for example) is bigger than the previous actual observed interest rate (in C6). In contrast, if the prediction is DOWN, it means that the predicted interest rate is smaller than the previous actual observed interest rate.

Alternatively, if the prediction is CONSTANT, it means that there was no change from the previous actual observed value to the predicted one. This is the case for the first naïve model: the first predicted interest rate (12.55 in cell D7) is the same as the first actual interest rate (also 12.55 in cell C6), the second predicted interest rate (12.3 in cell D8) is the same as the second actual interest rate (12.3 in cell C7) and so on. There is no change.

- Cell G5 = column heading “**Actual**” – contains information about what actually happens to the observed interest rates. Here, the first actual observed interest rate ( $Y_1$ ) is compared to the second one ( $Y_2$ ) to determine whether the second actual observed interest rate was higher than (the interest rate went UP), lower than (the interest rate went DOWN) or the same as (the interest rate remained CONSTANT) the first one. Thereafter, the second interest rate is compared to the third, the third to the fourth and so on. The formulae used (essentially an IF statement in Excel) can be seen in Table 4.2 above.
- Cell H5 = column heading “**Direction**” – indicates a match (1) or no match (0) between **Prediction** and **Actual**. For example, if the prediction that was made was that the interest rate would remain CONSTANT and the observed interest rate did, in fact, remain CONSTANT, then the model was correct (1) in predicting the action or direction of the interest rate. In contrast, if for example, the prediction

was that the interest rate would go UP but it actually (the actual observed value) went DOWN, then the model was incorrect (0) in predicting the action of the interest rate. These 1s and 0s help to determine how “good” this model is in predicting the direction of the interest rate. Once again, the formulae that were used (IF statement in Excel, column H) can be seen in Table 4.2 above.

From column H then, 196 comparisons<sup>73</sup> were made and in the end, there were only 12 correct direction matches. This means that the first naïve model is correct in predicting the direction<sup>74</sup> of the interest rates only  $12 / 196 = 0.06$  or 6.12% of the time.

The same procedure was followed for the Esc data set. The results are below:

1.1.	Matches	Comparisons	Total	Predict Correct Direction
<b>BA</b>	12	196	0.06	6.12%
<b>Esc</b>	4	195	0.02	2.05%

However, once all the models (naïve, moving average and exponential smoothing models) had been applied to each of the two data sets, it was felt that it would be more accurate to compare and evaluate them if they all had the same number of comparisons. Consequently, all the models were modified to accommodate only 194 comparisons (since this is the maximum number that the second moving average model<sup>75</sup> could have) for the BA data set and 193 comparisons for the Esc data set.

Thus, the new summary table and the graphs are shown below. The tracking signal graphs indicate that this is not such a good model, since most of the values do not lie between the  $-4, 4$  lines and the signal is regularly tripped.

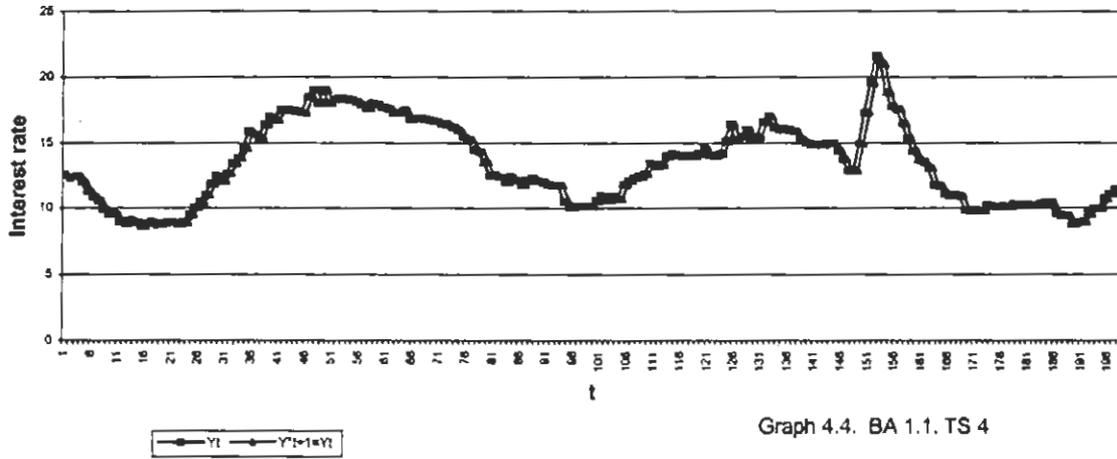
<sup>73</sup> There are 197 observations in the BA data set as well as 197 predictions. BA starts at  $t=1$  and ends at  $t=197$ . However, the first prediction starts at  $t=2$  (since the first observation is needed to make the first prediction) and the last ends at  $t=198$ . Therefore, only 196 comparisons between “Prediction” and “Actual” are possible.

<sup>74</sup> The first criterion that was used to decide how “good” the models are is the percentage of correct direction predictions. That is how well the model can predict the correct direction (UP, DOWN, or CONSTANT) of the interest rates.

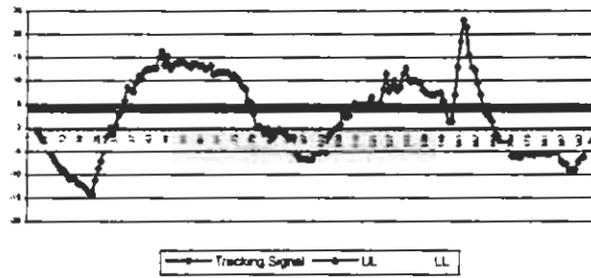
<sup>75</sup> This model has a maximum of 194 comparisons for the BA data set and 193 comparisons for the Esc data set. It is discussed in greater detail in section 4.4.2.2.

1.1.	MSE	Matches	Comparisons	PCD
BA	0.3508	12	194	6.19%
Esc	0.2402	4	193	2.07%

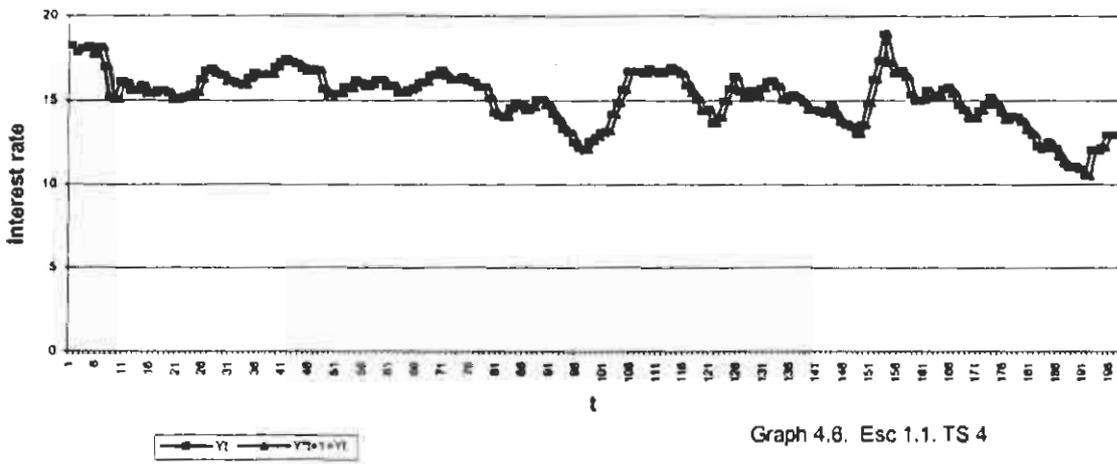
Graph 4.3. Actual vs. Predicted BA 1.1.



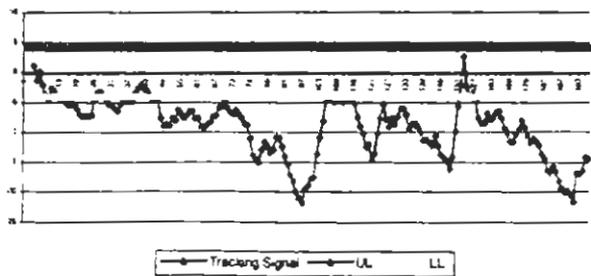
Graph 4.4. BA 1.1. TS 4



Graph 4.5. Actual vs. Predicted Esc 1.1.



Graph 4.8. Esc 1.1. TS 4



#### 4.4.1.2. Same absolute-change Model $Y'_{t+1} = Y_t + (Y_t - Y_{t-1})$

The second type of naive model builds on the first and considers trends. It “adds the latest observed absolute period-to-period change to the most recent observed level of the variable” (Shim, *et al.*, 1994:36). In practical terms, this means that the actual interest rate of the current period with a term added to it is taken as the forecast for the next period. This term is  $(Y_t - Y_{t-1})$  – the difference between  $Y_t$  (the actual current interest rate value) and  $Y_{t-1}$  (the previous actual value).

##### i. Procedure and Findings – Naive Models: 1.2.

Table 4.3 below is an example of a portion of the table that was created and used also in Excel to represent the second naïve model used in this study. It contains the same column headings as before and the first five rows of data. The structure of this model is similar to the first naïve model but there are certain differences between the two models.

...	B	C	D	E	F	G	H
5	t	$Y_t$	$Y'_{t+1}$	$e_t = Y_t - Y'_{t+1}$	Prediction	Actual	Direction
6	1	12.55					
7	2	12.3					
8	3	12.45	12.05	0.400	Down	Up	0
9	4	12	12.60	-0.600	Up	Down	0
10	5	11.3	11.55	-0.250	Down	Down	1

***Table 4.3. Representative portion of the table used in Excel, depicting the first few rows of the second naïve model using the BA data set.***

The first difference is in column D – where the model is represented. The first naïve model was just  $Y'_{t+1} = Y_t$ . Now,  $Y'_{t+1} = Y_t + (Y_t - Y_{t-1})$  which means that the previous, as well as the current actual values are needed to make a prediction. The first forecast will, thus, start only at  $t=3$  and not  $t=2$  as in the first naïve model<sup>76</sup>.

However, due to reasons mentioned in section 4.4.1.1. the model was modified to

<sup>76</sup> Consequently, there would be 195 comparisons for the BA data set and 194 comparisons for the Esc data set.

accommodate only 194 comparisons for the BA data set and 193 comparisons for the Esc data set. In this way, all the models used in the study can be compared more fairly later on.

Another noticeable difference in the second naïve model is that the **Predictions** (column F) are not all CONSTANT as in the first naïve model. Now, the predicted value is not always the same as the previous actual observed interest rate value. A sample of the formulae that were used to make the direction predictions (UP, DOWN and CONSTANT) of the interest rates are shown in Table 4.4.

...	B	C	D	E	F
5	t	Yt	Y <sup>t+1</sup>	et=Yt-Y <sup>t+1</sup>	Prediction
6	1	12.55			
7	2	12.3			
8	3	12.45	=C7+(C7-C6)	=C8-D8	=IF(D8>C7;"Up";IF(D8<C7;"Down";"Constant"))
9	4	12	=C8+(C8-C7)	=C9-D9	=IF(D9>C8;"Up";IF(D9<C8;"Down";"Constant"))
10	5	11.3	=C9+(C9-C8)	=C10-D10	=IF(D10>C9;"Up";IF(D10<C9;"Down";"Constant"))

...	G	H
5	Actual	Direction
6		
7		
8	=IF(C8<C7;"Down";(IF(C8>C7;"Up";"Constant")))	=IF(F8=G8;1;0)
9	=IF(C9<C8;"Down";(IF(C9>C8;"Up";"Constant")))	=IF(F9=G9;1;0)
10	=IF(C10<C9;"Down";(IF(C10>C9;"Up";"Constant")))	=IF(F10=G10;1;0)

**Table 4.4.** Representative portion of the table used in Excel, showing some of the formulae used to create the second naïve model for the BA data set. This table is represented in two parts due only to the limited space of the page. Column G follows on Column F.

The **Prediction** and **Actual** columns are calculated in the same way as in the first naïve model and in column H they are compared. The **Direction** is assigned a value of 0 if **Prediction** is not the same as **Actual** and a value of 1 if both are the same. The 1s (correct direction predictions) from the **Direction** column are counted and the results for both data sets are shown below:

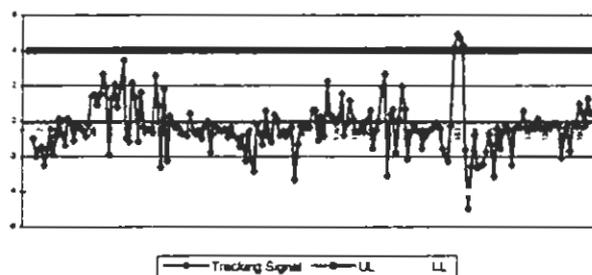
1.2.	MSE	Matches	Comparisons	PCD
BA	0.4247	110	194	56.70%
Esc	0.3330	116	193	60.10%

There is a considerable improvement in the percentage of correct direction predictions from the first to the second naïve model for both data sets. The latter model is correct in predicting the direction of the interest rates for the Esc data set just over 60% of the time (the highest so far). In both cases the MSE is a bit higher for the second naïve model but the TS graphs indicate a better model:

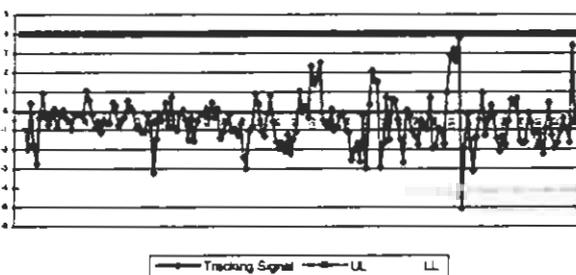
Graph 4.7. Actual vs. Predicted BA 1.2.



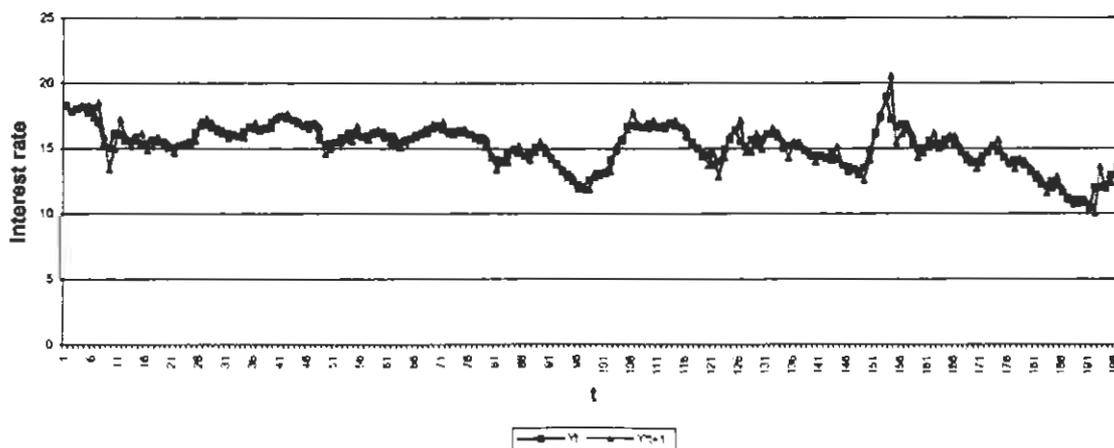
Graph 4.8. BA 1.2. TS 4



Graph 4.10. Esc 1.2. TS 4



Graph 4.9. Actual vs. Predicted Esc 1.2.



#### 4.4.1.3. Same percentage-change Model

$$Y'_{t+1} = Y_t \times \left( \frac{Y_t}{Y_{t-1}} \right)$$

The third type of naive model incorporates “the rate of change rather than the absolute amount” (Shim, *et al.*, 1994:36). In this case, each predicted interest rate value ( $Y'_{t+1}$ ) is now the actual interest rate ( $Y_t$ ) multiplied with a new term (a ratio of the actual and the previous values).

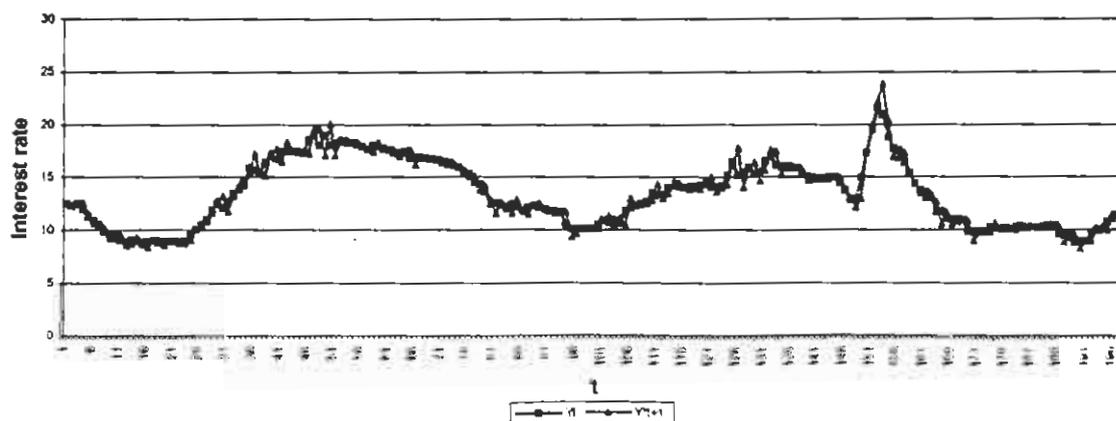
##### i. Procedure and Findings – Naive Models: 1.3.

A similar procedure to that of the first two models was carried out. This may be seen in the **Appendix**. As before, from the **Prediction** and **Actual** results, the **Direction** is found and subsequently, the total number of correct direction predictions (using the corrected number of comparisons, that is, 194 for BA and 193 for Esc). The results are summarised in the table below:

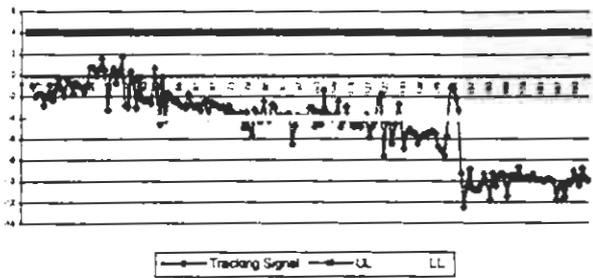
1.3.	MSE	Matches	Comparisons	PCD
BA	0.4295	110	194	56.70%
Esc	0.3377	58	193	30.05%

The PCD for the BA data set remains the same using the third naïve model but for the Esc data set it is half of what was obtained using the second naïve model. In terms of tracking signals, the graphs below show how the model does well initially but then falls beyond the lower limit and as a result, trips the signal. Also, the MSE is slightly higher using the third naïve model.

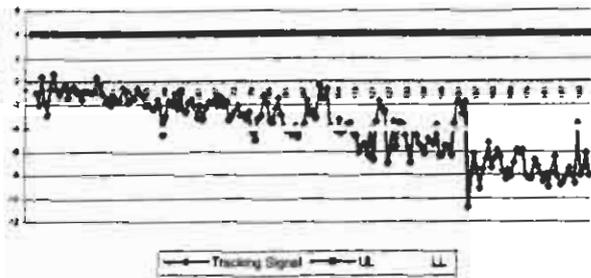
Graph 4.11. Actual vs. Predicted BA 1.3.



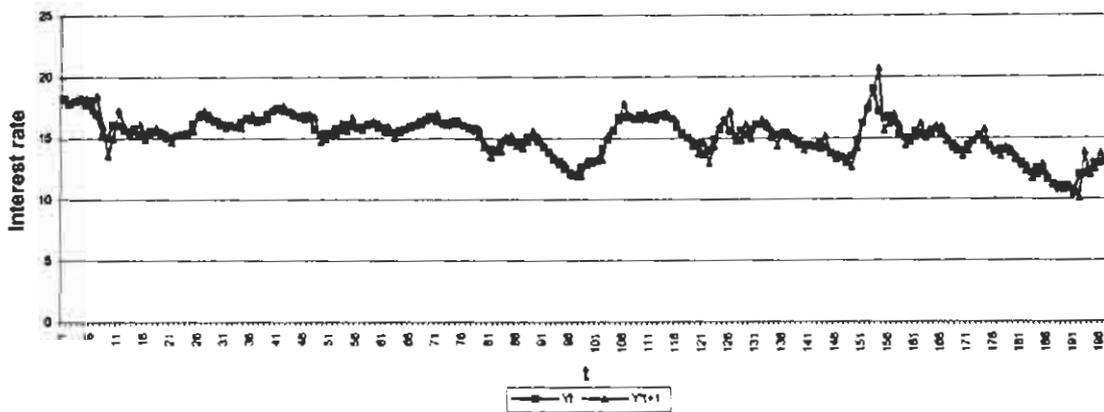
Graph 4.12. BA 1.3. TS 4



Graph 4.14. Esc 1.3. TS 4



Graph 4.13. Actual vs. Predicted Esc 1.3.



**i. Note: Naïve Models**

These are thus, the three naive models that were used in this study. Shim, Siegel and Liew (1994:37), state that the naive models “can be applied, with very little need of a computer, to develop forecasts for sales, earnings, and cash flows”. In this case, the naive models were applied to two rather large data sets of interest rates. Therefore, Excel was used on the computer to create and represent the three models.

Shim, Siegel and Liew (1994:37) go on to say that the naive models “must be compared with more sophisticated models” like the regression and Box-Jenkins methods for forecasting efficiency. The moving average models are a bit more complex than the naive ones. They are addressed next.

**4.4.2. Moving Average Models**

According to Shim, *et al.* (1994:37), **smoothing techniques** are a “higher form” of naive models. There are two characteristic forms of these techniques: moving average and exponential smoothing. The simpler one is moving averages or MA.

“Moving averages are averages that are updated as new information is received” (Shim, *et al.*, 1994:37). With the moving average, the most recent observations are used to calculate an average. This average is used as the forecast for the next period. For this model, the predicted interest rate ( $Y'_{t+1}$ ) is an average of the most recent previous observations (of interest rates). In order to predict the interest rate for the  $m^{\text{th}}$  term, the number of previous observations that are to be used, has to be decided on for “averaging purposes” (Shim, *et al.*, 1994:38).

Since weights are given to observations, determining the number of observations to use for the average can be difficult. If, for example, a six-observation moving average is chosen, then old data receives a weight of 5/6 and the current observation receives a weight of 1/6. If, instead, a three-observation moving average is chosen, then the old data receives a weight of just 2/3, while the current observation receives a weight of 1/3. Evidently, the choice of the number of periods to use in a moving average is “a measure of the relative importance attached to old versus current data” (Shim, *et al.*, 1994:38).

Below are the two variations of the moving average model that were used in this study:

- ◆ Moving Average of two values Model:  $(Y_t + Y_{t-1}) / 2$
- ◆ Moving Average of  $m$  values Model:  $(Y_t + Y_{t-1} + \dots + Y_{t-m+1}) / m$

#### 4.4.2.1. Moving Average of two values Model

$$Y'_{t+1} = \frac{Y_t + Y_{t-1}}{2}$$

In this first variation of the MA model, the average is found using only two observations of actual interest rate values at a time.

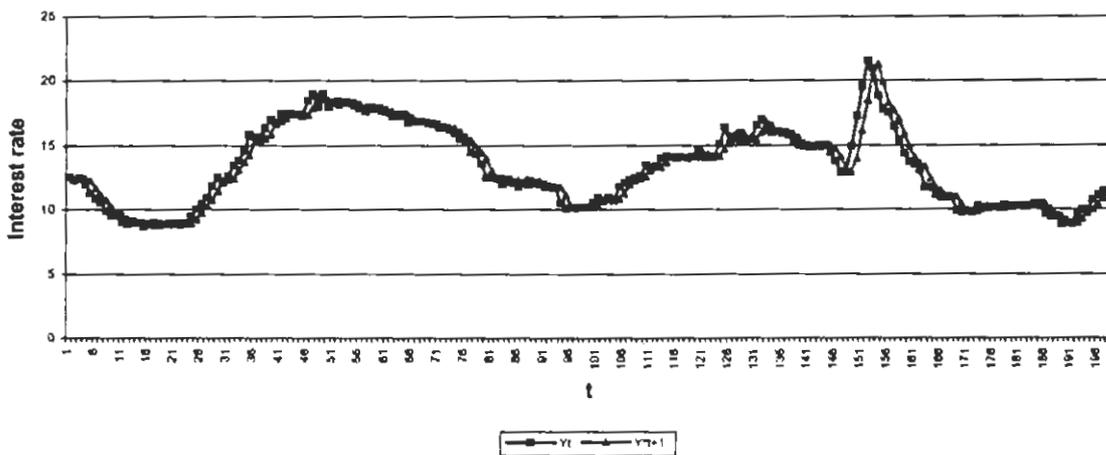
i. Procedure and Findings – MA Models: 2.1.

The procedure that was carried out may be seen in the **Appendix**. The table below is a short summary of the findings using the corrected number of comparisons:

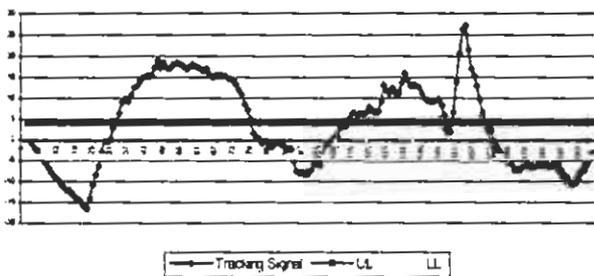
2.1.	MSE	Matches	Comparisons	PCD
BA	0.5766	66	194	34.02%
Esc	0.3740	69	193	35.75%

This first MA model is correct in predicting the direction of the interest rate only about 34% of the time for the BA data set and almost 36% of the time for the Esc data set. These results are not as good as the second naïve model in terms of percentage of correct direction predictions as well as MSE.

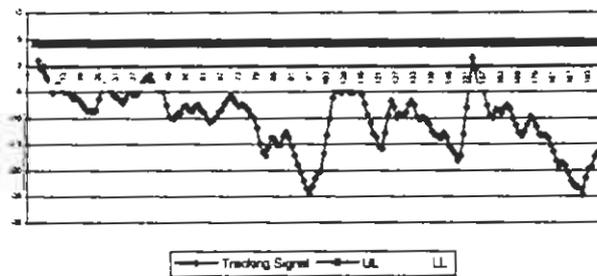
Graph 4.15. Actual vs. Predicted BA 2.1.



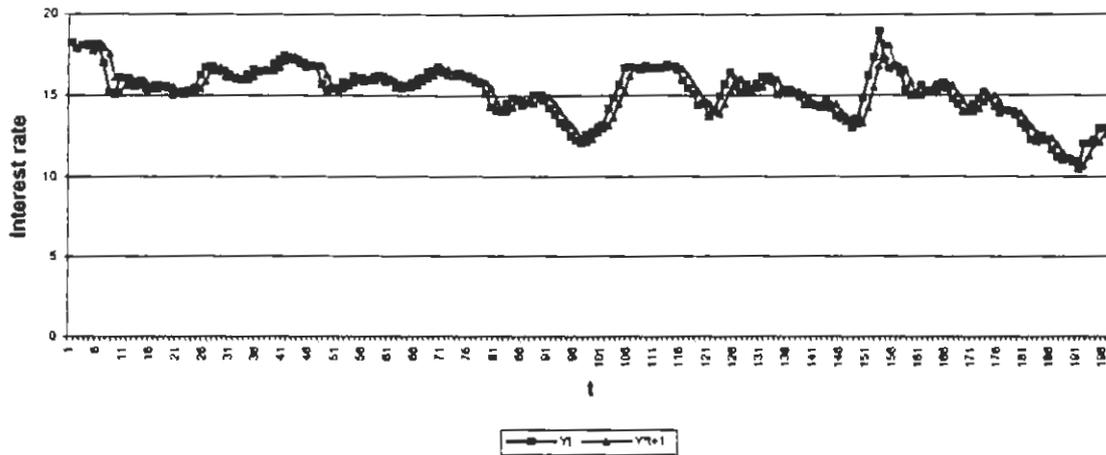
Graph 4.16. BA 2.1. TS 4



Graph 4.18. Esc 2.1. TS 4



Graph 4.17. Actual vs. Predicted Esc 2.1.



#### 4.4.2.2. Moving Average of $m$ values Model

$$Y'_{t+1} = \frac{Y_t + Y_{t-1} + \dots + Y_{t-m+1}}{m}$$

In the second variation of the MA models, the average is found using  $m$  observations of actual interest rate values.

##### i. Procedure and Findings – MA Models: 2.2.

A description and a sample of the procedure may be seen in the **Appendix**. Several values for  $m$  were selected for this second MA model and were applied to the data sets, one at a time. The results are summarised in Table 4.5.

From Table 4.5 (a) it can be seen that using the BA data set, the second moving average model with any  $m$  from 189 to 195 is able to predict the direction of the interest rate correctly 100% of the time. These are the best direction results yet – at least with the BA data set, since the same does not occur when the Esc data set is used with the model (although the results are higher with some of these  $m$ s).

However, these results of 100% may be misleading in that, although they do predict the direction correctly all the time, they have only two comparisons (when  $m=195$ ) to get correct. It is easier to predict correctly twice than it is, say, 194 times.

2.2.	<i>m</i>	Matches	Comparisons	PCD	2.2.	<i>m</i>	Matches	Comparisons	PCD
BA	2	67	195	34.36%	Esc	2	70	194	36.08%
	3	74	194	38.14%		3	76	193	39.38%
	5	72	192	37.50%		5	78	191	40.84%
	10	64	187	34.22%		10	86	186	46.24%
	50	73	147	49.66%		50	72	146	49.32%
	100	54	97	55.67%		100	49	96	51.04%
	150	24	47	51.06%		150	20	46	43.48%
	180	11	17	64.71%		180	5	16	31.25%
	185	8	12	66.67%		185	4	11	36.36%
	186	8	11	72.73%		186	4	10	40.00%
	187	8	10	80.00%		187	4	9	44.44%
	188	8	9	88.89%		188	4	8	50.00%
	189	8	8	100.00%		189	3	7	42.86%
	190	7	7	100.00%		190	3	6	50.00%
	191	6	6	100.00%		191	3	5	60.00%
	192	5	5	100.00%		192	2	4	50.00%
	193	4	4	100.00%		193	2	3	66.67%
	194	3	3	100.00%		194	1	2	50.00%
	195	2	2	100.00%		195	-	-	-

*(a)* *(b)*  
**Table 4.5. Results from applying various values for *m* to the second moving average model using (a) the BA data set and (b) the Esc data set.**

With regard to the BA data set in particular, if more data were to be obtained, perhaps the degree of accuracy of these models could be found – are these results really good predictions or do they just predict a certain direction because the latest previous values all predict that same direction. For example, using  $m=193$  suggests that the past 193 values are being used to predict the next one. If the past values have been predictions of UP, then it is likely that the next prediction will be UP as well. If, in reality, the values start to go DOWN, then the model would not be able to predict the downward movement immediately.

As stated before, the best way to evaluate the models is when they all have the same number of comparisons. Therefore, one way to proceed would be to change the models already discussed to accommodate the different number of comparisons for the various chosen *ms*. Realistically, however, this would expand the study superfluously. Thus, it was done only to the BA data set as an example. The results can be seen in Tables 4.6 and 4.7, which show the PCD and MSE, respectively<sup>77</sup>.

<sup>77</sup> The third type of models (exponential smoothing) are included in the tables for comparison purposes. They are discussed in greater detail after the moving average models.

PCD	BA 1.1.	BA 1.2.	BA 1.3.	BA 2.1.	BA 2.2.		BA 3.1.	BA 3.2.
C	$Y'_{t+1} = Y_t$	$Y_t + (Y_t - Y_{t-1})$	$Y_t * (Y_t / Y_{t-1})$	$(Y_t + Y_{t-1}) / 2$	$(Y_t + Y_{t-1} + \dots + Y_{t-m+1}) / m$		$\alpha Y_t + (1-\alpha)Y'_t$ with $\alpha=0.6$	Double Smoothed with $\alpha_1=1, \alpha_2=0.2$
195	6.15%	56.41%	56.41%	34.36%	m=2	34.36%	37.95	61.54%
194	6.19%	56.70%	56.70%	34.02%	m=3	38.14%	37.63	61.86%
192	6.25%	56.77%	56.77%	33.85%	m=5	37.50%	37.50	61.46%
187	5.88%	56.15%	56.15%	34.76%	m=10	34.22%	38.50	60.96%
147	6.12%	58.50%	58.50%	33.33%	m=50	49.66%	37.41	62.59%
97	2.06%	60.82%	60.82%	35.05%	m=100	55.67%	41.24	65.98%
47	0.00%	70.21%	70.21%	29.79%	m=150	51.06%	38.30	72.34%
17	0.00%	82.35%	82.35%	17.65%	m=180	64.71%	29.41	64.71%
12	0.00%	83.33%	83.33%	16.67%	m=185	66.67%	33.33	66.67%
11	0.00%	90.91%	90.91%	9.09%	m=186	72.73%	27.27	63.64%
10	0.00%	90.00%	90.00%	10.00%	m=187	80.00%	30.00	60.00%
9	0.00%	88.89%	88.89%	11.11%	m=188	88.89%	33.33	55.56%
8	0.00%	87.50%	87.50%	12.50%	m=189	100.00%	37.50	87.50%
7	0.00%	100.00%	100.00%	0.00%	m=190	100.00%	0.00	85.71%
6	0.00%	100.00%	100.00%	0.00%	m=191	100.00%	0.00	83.33%
5	0.00%	100.00%	100.00%	0.00%	m=192	100.00%	0.00	80.00%
4	0.00%	100.00%	100.00%	0.00%	m=193	100.00%	0.00	75.00%
3	0.00%	100.00%	100.00%	0.00%	m=194	100.00%	0.00	66.67%
2	0.00%	100.00%	100.00%	0.00%	m=195	100.00%	0.00	50.00%

**Table 4.6.** Table showing the PCD results when all the models are adapted to accommodate the different number of comparisons for the various chosen ms (using the BA data set).

MSE	BA 1.1.	BA 1.2.	BA 1.3.	BA 2.1.	BA 2.2.		BA 3.1.	BA 3.2.
C	$Y'_{t+1} = Y_t$	$Y_t + (Y_t - Y_{t-1})$	$Y_t * (Y_t / Y_{t-1})$	$(Y_t + Y_{t-1}) / 2$	$(Y_t + Y_{t-1} + \dots + Y_{t-m+1}) / m$		$\alpha Y_t + (1-\alpha)Y'_t$ with $\alpha=0.6$	Double Smoothed with $\alpha_1=1, \alpha_2=0.2$
195	0.3491	0.4233	0.4281	0.5737	m=2	0.5737	0.5740	1.8100
194	0.3508	0.4247	0.4295	0.5766	m=3	0.8263	0.5763	1.8225
192	0.3509	0.4269	0.4317	0.5775	m=5	1.3851	0.5779	1.8045
187	0.3558	0.4361	0.4413	0.5820	m=10	2.7446	0.5796	1.8169
147	0.3641	0.3988	0.4009	0.6245	m=50	11.3065	0.6147	1.7825
97	0.4855	0.4927	0.5020	0.8465	m=100	6.5482	0.8274	2.2868
47	0.5401	0.4526	0.4629	1.0753	m=150	17.0177	1.1029	2.7562
17	0.1380	0.1781	0.1751	0.2166	m=180	14.2605	0.2237	0.4007
12	0.1940	0.2509	0.2467	0.3043	m=185	14.7562	0.3177	0.5887
11	0.1549	0.2141	0.2095	0.2767	m=186	14.5479	0.3028	0.3788
10	0.1664	0.2007	0.2023	0.2689	m=187	14.1723	0.2850	0.3961
9	0.1849	0.2190	0.2209	0.2975	m=188	13.7437	0.3098	0.4397
8	0.1615	0.2014	0.2036	0.2874	m=189	12.5730	0.3018	0.4273
7	0.1831	0.1581	0.1684	0.3224	m=190	11.2553	0.3546	0.4626
6	0.2134	0.1839	0.1959	0.3748	m=191	9.6155	0.4070	0.5276
5	0.1865	0.1602	0.1746	0.3753	m=192	8.3821	0.4341	0.3132
4	0.1931	0.1912	0.2051	0.3484	m=193	7.3350	0.3924	0.2618
3	0.2571	0.2093	0.2236	0.4469	m=194	5.7182	0.4466	0.3489
2	0.1193	0.0689	0.0905	0.3929	m=195	4.8222	0.4550	0.0652

**Table 4.7.** Table showing the MSE results when all the models are adapted for the ms.

Another way forward (which was the way elected) was to choose one  $m$  and change the other models to accommodate the number of comparisons for that  $m$  only.

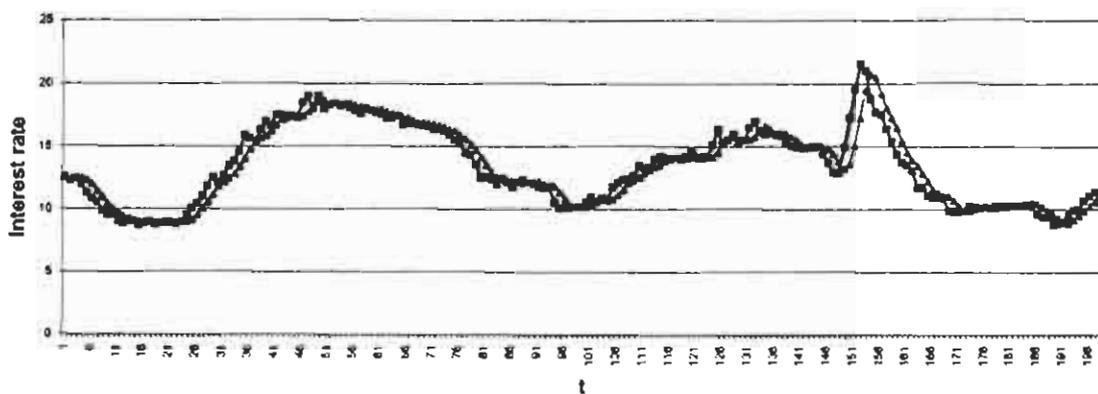
Expanding the second moving average model further, results in the following tables:

PCD	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2
C	with $m=3$	$m=5$	$m=10$	$m=50$	$m=100$	$m=150$	$m=180$	$m=185$	$m=188$	$m=187$	$m=188$	$m=189$	$m=190$	$m=191$	$m=192$	$m=193$	$m=194$	$m=195$
194	38.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
192	38.02	37.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
187	39.04	38.50	34.22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
147	37.41	36.73	32.65	49.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-
97	39.18	40.21	38.14	52.58	55.67	-	-	-	-	-	-	-	-	-	-	-	-	-
47	31.91	38.30	40.43	46.81	48.94	51.08	-	-	-	-	-	-	-	-	-	-	-	-
17	23.53	41.18	41.18	64.71	64.71	64.71	64.71	-	-	-	-	-	-	-	-	-	-	-
12	25.00	33.33	41.67	66.67	66.67	66.67	66.67	66.67	-	-	-	-	-	-	-	-	-	-
11	18.18	27.27	36.36	72.73	72.73	72.73	72.73	72.73	72.73	-	-	-	-	-	-	-	-	-
10	20.00	30.00	40.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	-	-	-	-	-	-	-	-
9	22.22	33.33	44.44	88.89	88.89	88.89	88.89	88.89	88.89	88.89	88.89	-	-	-	-	-	-	-
8	25.00	37.50	50.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-	-	-	-	-	-
7	14.29	28.57	42.86	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-	-	-	-	-
6	0.00	16.67	33.33	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-	-	-	-
5	0.00	0.00	20.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-	-	-
4	0.00	0.00	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-	-
3	0.00	0.00	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-
2	0.00	0.00	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

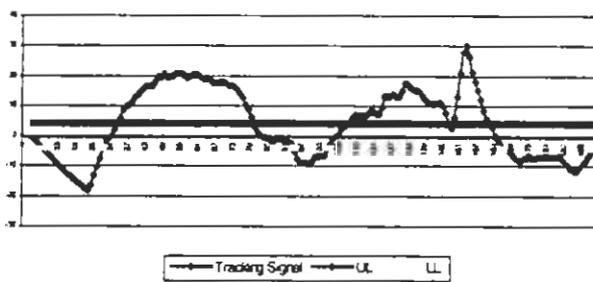
MSE	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2	BA 2.2
C	with $m=3$	$m=5$	$m=10$	$m=50$	$m=100$	$m=150$	$m=180$	$m=185$	$m=188$	$m=187$	$m=188$	$m=189$	$m=190$	$m=191$	$m=192$	$m=193$	$m=194$	$m=195$
194	0.8283	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
192	0.8293	1.3851	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
187	0.8310	1.3787	2.7446	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
147	0.9008	1.4611	2.6244	11.3065	-	-	-	-	-	-	-	-	-	-	-	-	-	-
97	1.2244	1.9548	3.3190	9.5398	6.5482	-	-	-	-	-	-	-	-	-	-	-	-	-
47	1.7605	3.1726	5.4949	14.4312	11.7649	17.0177	-	-	-	-	-	-	-	-	-	-	-	-
17	0.3145	0.5212	0.7021	9.9584	10.7594	16.2047	14.2605	-	-	-	-	-	-	-	-	-	-	-
12	0.4422	0.7347	0.9653	9.4154	11.5545	18.8963	15.4418	14.7562	-	-	-	-	-	-	-	-	-	-
11	0.4317	0.7585	1.0395	9.0381	11.4240	18.5782	15.3613	14.6442	14.5479	-	-	-	-	-	-	-	-	-
10	0.4230	0.7756	1.0823	8.5304	11.1357	18.0922	15.1049	14.3591	14.2581	14.1723	-	-	-	-	-	-	-	-
9	0.4516	0.8194	1.1440	8.0070	10.7972	17.5300	14.7878	14.0158	13.9100	13.8199	13.7437	-	-	-	-	-	-	-
8	0.4497	0.7840	1.0923	6.8743	9.7846	16.1093	13.7019	12.9226	12.8108	12.7176	12.6385	12.5730	-	-	-	-	-	-
7	0.5002	0.8389	1.1046	5.8758	8.6451	14.5166	12.4483	11.8748	11.5583	11.4597	11.3781	11.3103	11.2553	-	-	-	-	-
6	0.5820	0.9647	1.1742	4.2829	7.2243	12.5515	10.8451	10.0926	9.9753	9.8729	9.7866	9.7174	9.6611	9.6155	-	-	-	-
5	0.6140	1.1197	1.4036	3.2943	6.1838	11.0439	9.8406	8.9100	8.7925	8.6887	8.5979	8.5239	8.4665	8.4196	8.3821	-	-	-
4	0.6048	1.2339	1.7262	2.5172	5.3223	9.7464	8.6085	7.9061	7.7881	7.6839	7.5918	7.5130	7.4509	7.4034	7.3651	7.3350	-	-
3	0.7252	1.4627	2.2414	1.4372	3.9850	7.7967	6.9566	6.3038	6.1930	6.0916	6.0015	5.9241	5.8598	5.8087	5.7719	5.7427	5.7182	-
2	0.6977	1.4278	2.6445	0.9249	3.2863	6.8716	6.0426	5.4291	5.3236	5.2259	5.1346	5.0573	4.9922	4.9370	4.8961	4.8688	4.8446	4.8222

The tables above illustrate how much this model can enlarge. Therefore, it was decided to consider only  $m=3$  (for both data sets) for the second moving average model and adjust the other models (with the number of comparisons) accordingly. This would yield a reasonable 194 comparisons for the BA data set and 193 comparisons for the Esc data set and would not require a dramatic change in the previous models (as well as the models that are to follow). Hence, the changes in the given summary results of the previous models. The graphs for this second MA model are shown below:

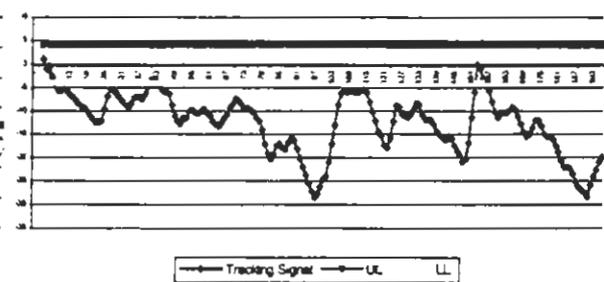
Graph 4.19. Actual vs. Predicted BA 2.2.  $m=3$



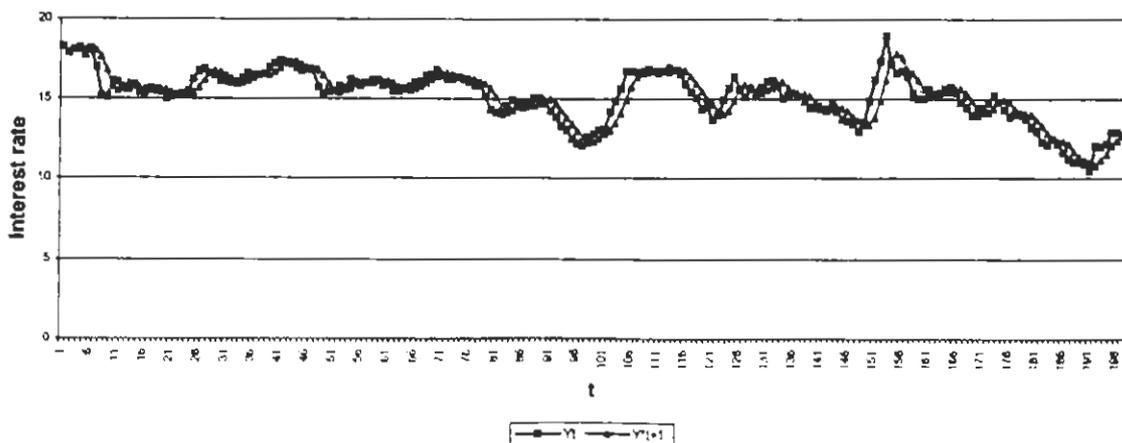
Graph 4.20. BA 2.2.  $m=3$  TS 4



Graph 4.22. Esc 2.2.  $m=3$  TS 4



Graph 4.21. Actual vs. Predicted Esc 2.2.  $m=3$



i. Note: Moving Average Models

The advantage in using the moving average is that it is simple to use and easy to understand. There are, however, two shortcomings that Shim, *et al.* (1994:39) identify:

- It requires you to retain a great deal of data and carry it along with you from forecast period to forecast period
- All data in the sample are weighted equally. If more recent data are more valid than older data, perhaps they should be given greater weight

4.4.3. Exponential Smoothing

$$\alpha = 0.90$$

$$Y'_{t+1} = \alpha Y_t + (1 - \alpha) Y'_t$$

The second and more complicated of the two **smoothing techniques** is the forecasting method known as exponential smoothing. This method gets around the disadvantages of the moving average model in that it uses a weighted average of past data as the basis for a forecast. The procedure “gives heaviest weight to more recent information and smaller weights to observations in the more distant past” (Shim, *et al.*, 1994:39). This is because the future is more dependent on the recent rather than on the distant past.

According to Shim, *et al.* (1994:39), exponential smoothing is a popular technique used by financial managers for short-run forecasting and it is known to be effective when there is “randomness and no seasonal fluctuations in the data” (Shim, *et al.*, 1994:39). Yet, the disadvantage of the method is that it “does not include industrial or economic factors such as market conditions, prices, or the effects of competitors’ actions” (Shim, *et al.*, 1994:39).

The formula given above is how this model is represented in this study. However, it can certainly be written with other symbols<sup>78</sup>.

To initialise the exponential smoothing process, the initial forecast is needed. Shim, *et al.* (1994:40) state that the first smoothed forecast to be used can be:

1. First actual observations;
2. An average of the actual data for a few periods.

The latter was chosen.

Finding the correct  $\alpha$ <sup>79</sup> is important since “the higher the  $\alpha$ , the higher the weight given to the more recent information” (Shim, *et al.*, 1994:40). The person doing the forecast can use a higher or lower smoothing constant ( $\alpha$ ), in order to “adjust his/ her prediction as quickly as possible to large fluctuations in the data series” (Shim, *et al.*, 1994:41). A way of obtaining the most desirable  $\alpha$  is to work out the Mean Squared Error (MSE<sup>80</sup>) for several  $\alpha$ s and then use the  $\alpha$  that produces the smallest MSE – “for practical purposes, the optimal  $\alpha$  may be picked by minimizing what is known as the *mean squared error* (MSE)” (Shim, *et al.*, 1994:41).

The two types of exponential smoothing models used in this study are:

- ◆ Single Smoothed
- ◆ Double Smoothed

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<sup>78</sup> The exponential smoothing formula used in Shim, *et al.* (1994:40), is written as:

$$Y'_{new} = \alpha Y_{old} + (1-\alpha) Y'_{old}$$

where

$Y'_{new}$  = Exponentially smoothed average to be used as the forecast

$Y_{old}$  = Most recent actual data

$Y'_{old}$  = Most recent smoothed forecast

$\alpha$  = Smoothing constant

<sup>79</sup>  $\alpha$  (alpha): the smoothing constant used in the third type of forecasting model (Exponential Smoothing).

<sup>80</sup> According to Shim, *et al.* (1994:42),

$$MSE = \frac{\sum_{t=1}^n (Y_t - Y'_t)^2}{(n - i)}$$

where  $i$  = the number of observations used to determine the initial forecast

MSE is the “average sum of the variations between the historical sales data and the forecast values for the corresponding periods”.

### 4.4.3.1. Single Smoothed

The single smoothed form of the exponential smoothing model consists of finding the  $\alpha$  that minimises the MSE<sup>81</sup> and then applying this value to the exponential smoothing formula. The values that are obtained are, thus, the forecasts.

#### i. Procedure and Findings – Exponential Smoothing Models: 3.1.

Table 4.8. is a sample of the model that was created in Excel to represent the first exponential smoothing model using  $\alpha=0.9$  for the BA data set.

...	B	C	D	E	F	H	I	J
8	t	$Y_t$	$Y'_{t+1}$	$e_t=Y_t-Y'_{t+1}$	$e^2$	Prediction	Actual	Direction
9	1	12.55						
10	2	12.3						
11	3	12.45	12.43	0.025	0.001	Up	Up	1
12	4	12	12.45	-0.448	0.200	Down	Down	1
13	5	11.3	12.04	-0.745	0.555	Up	Down	0

**Table 4.8. Representative portion of the table created in Excel, depicting the first few rows of the first exponential smoothing model using the BA data set for  $\alpha=0.9$ . The highlighted column is used to find the MSE.**

Column D is where the model is represented, while the new column F (highlighted in the table) takes each prediction error from column E and squares it. The MSE is found by dividing the Sum of these Squared Errors (SSE) by the number of possible comparisons or, alternatively, just by finding the mean or average of all the squared errors.

The  $\alpha$  that produces the smallest MSE is then used for the model. As before, the model was modified to accommodate 194 comparisons for the BA data set and 193 comparisons for the Esc data set and then applied to both data sets separately. The  $\alpha$  values that were experimented with are: 0.9, 0.6, 0.4 and 0.1.

<sup>81</sup> The second criterion that can be used to decide how “good” the models are, is thus, the mean squared error (**MSE**). The smaller the MSE, the better. The MSE can be found for the earlier models and in the exponential smoothing models, has the advantage of revealing the correct  $\alpha$  values for the model.

Once the correct  $\alpha$  value is identified, the **Prediction, Actual and Direction** columns are calculated in the same way as for the naïve and moving average models. From this, the percentage of correct direction predictions is found which demonstrates how “good” the model is in predicting the direction or movement (UP, DOWN or CONSTANT) of the interest rates.

A sample of the formulae that were used to create the first exponential smoothing model can be seen in the **Appendix**. This model differs slightly from the previous ones. Table 4.9. below summarises the results of the experiments that were conducted for the four  $\alpha$  values.

For both data sets,  $\alpha = 0.9$  gives the smallest MSE. However, in both cases this corresponds to the lowest percentage of correct direction predictions. For the BA data set, the PCD is less than 36%.

BA			3.1.		
Alpha	MSE		M	C	PCD
0.1	3.8427	Biggest	72	194	37.11
0.4	0.8966	Bigger	71	194	36.60
0.6	0.5763	Big	73	194	37.63
0.9	0.3831	Smallest	69	194	35.57

(a)

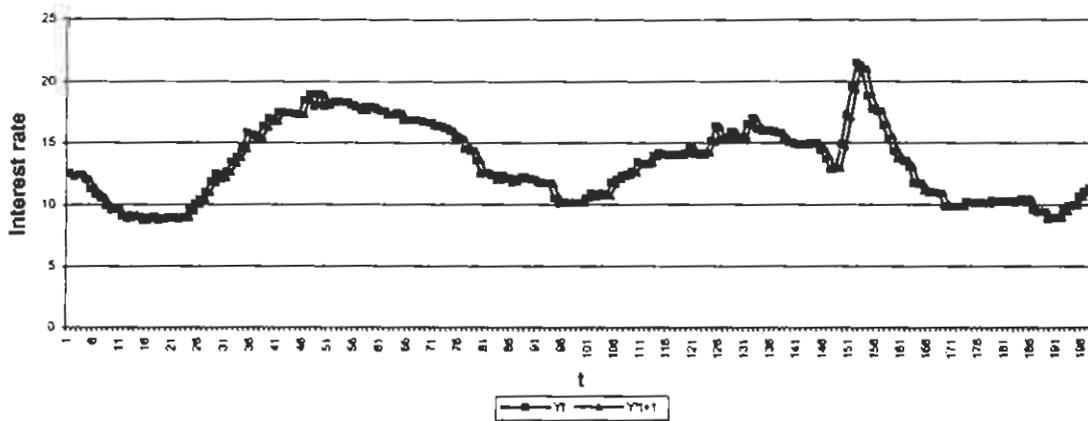
M = Matches
C = Comparisons
PCD = Predict Correct Direction

Esc			3.1.		
Alpha	MSE		M	C	PCD
0.1	1.2319	Biggest	95	193	49.22
0.4	0.5023	Bigger	79	193	40.93
0.6	0.3567	Big	77	193	39.90
0.9	0.2577	Smallest	74	193	38.34

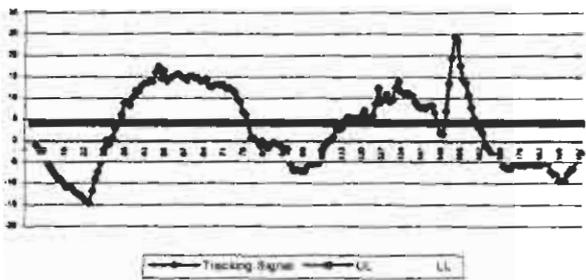
(b)

**Table 4.9. Results from applying different  $\alpha$  values to the first exponential smoothing model using (a) the BA data set and (b) the Esc data set. The smaller the MSE, the better.**

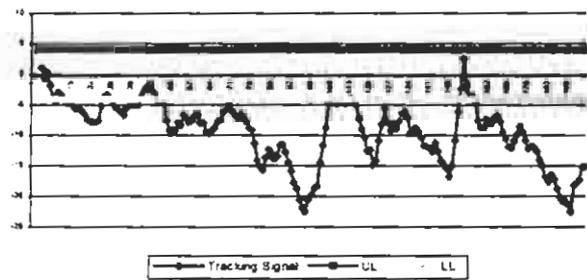
Graph 4.23. Actual vs. Predicted BA 3.1. 0.9



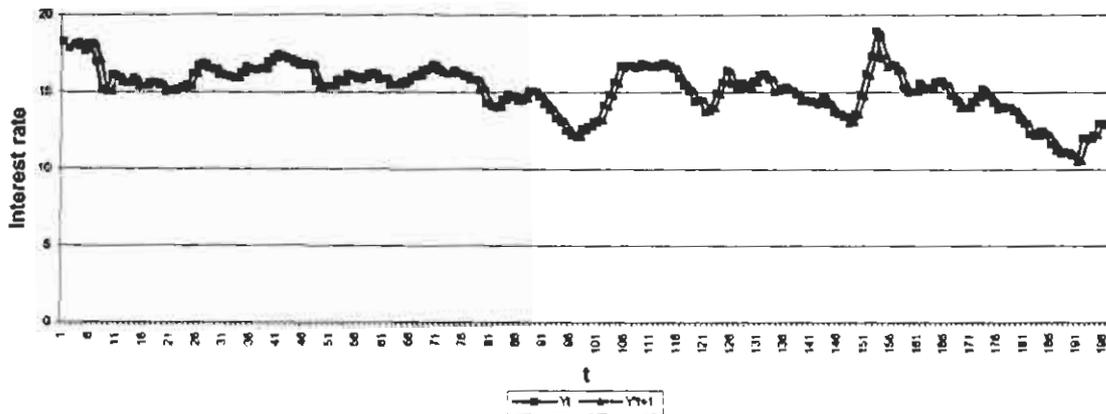
Graph 4.24. BA 3.1. 0.9 TS 4



Graph 4.26. Esc 3.1. 0.9 TS 4



Graph 4.25. Actual vs. Predicted Esc 3.1. 0.9



#### 4.4.3.2. Double Smoothed

The second form of exponential smoothing is the double smoothed form. When data show a sign of trend, a trend factor can be added to account for it. Another weighting (smoothing) constant can be used. Thus, "it involves two smoothings" (Shim, *et al.*, 1994:45).

In this case, the single smoothed form of the model is applied twice to the data. The original data is smoothed as above. The results are then taken and smoothed again, using the same method as before. Shim, *et al.* (1994:45/46) explain it like this: “first, the original data are smoothed as in single smoothing. Then the resulting values are smoothed as if they are original values”.

According to Shim, *et al.* (1994:46), the double-smoothed values have two useful properties:

1. They are smoother than the single-smoothed values, which means they will provide a clearer indication of the trend;
2. The double-smoothed values lag the single-smoothed values by about as much as the single-smoothed values lag the original data.

Shim, *et al.* (1994:46) explain that once the values have been smoothed a second time, the difference between the single- and double-smoothed values can be added to the single-smoothed values. The resulting list will be close to the original one. If an allowance is made for trend, then the predicted values should be close to the actual future values.

In symbol form, the above can be written as in Shim, *et al.* (1994:46):

$Y'_{t+1} = \text{Single-smoothed} + (\text{Single-smoothed} - \text{Double-smoothed}) + \text{Trend Adjustment}$

$$= Y'_t + (Y'_t - S''_t) + b_t$$

where  $Y'_t = \alpha Y_{t-1} + (1 - \alpha) Y'_{t-1}$ , and the trend adjustment,  $b_t$ , can be approximated by the amount of change each period in  $S''$ . That is:  $b_t = S''_t - S''_{t-1}$ .

#### **i. Procedure and Findings – Exponential Smoothing Models: 3.2.**

The second exponential smoothing model makes use of two alpha values, namely:  $\alpha_1$  and  $\alpha_2$ . The model that provides the most correct predictions and that has the smallest MSE is found by experimenting with these alpha values.

As can be seen in Table 4.10., the method that was used to represent this model in Excel is slightly different from the way the naïve, moving average and single exponential smoothing models were represented. Here, two smoothings take place.

...	<b>E</b>	<b>F</b>	<b>G</b>
3	Alpha 1	1	0
4	Alpha 2	0.2	0.8

...	B	C	D	E	F	I	K	L	M	N
8	t	Y <sub>t</sub> (data)	Y' <sub>t</sub> (single)	S'' <sub>t</sub> (double)	S'' <sub>t</sub> -S'' <sub>t-1</sub> (b <sub>t</sub> )	Forecast	Real e <sup>2</sup>	Prediction	Actual	Direction
9	1	12.55	12.550	12.550						
10	2	12.3	12.300	12.500	-0.050	12.550	0.063	Constant	Down	0
11	3	12.45	12.450	12.490	-0.010	12.050	0.160	Down	Up	0
12	4	12	12.000	12.392	-0.098	12.400	0.160	Down	Down	1
...	...	...	...	...	...	...	...	...	...	...
206							354.0287			
207							SSE			
208							1.8063			
209							MSE			

**Table 4.10. Representative portion of the table created in Excel, depicting the first few rows of the second exponential smoothing model using the BA data set for  $\alpha_1=1$  and  $\alpha_2=0.2$ . The SSE and MSE are also shown.**

The headings are as follows:

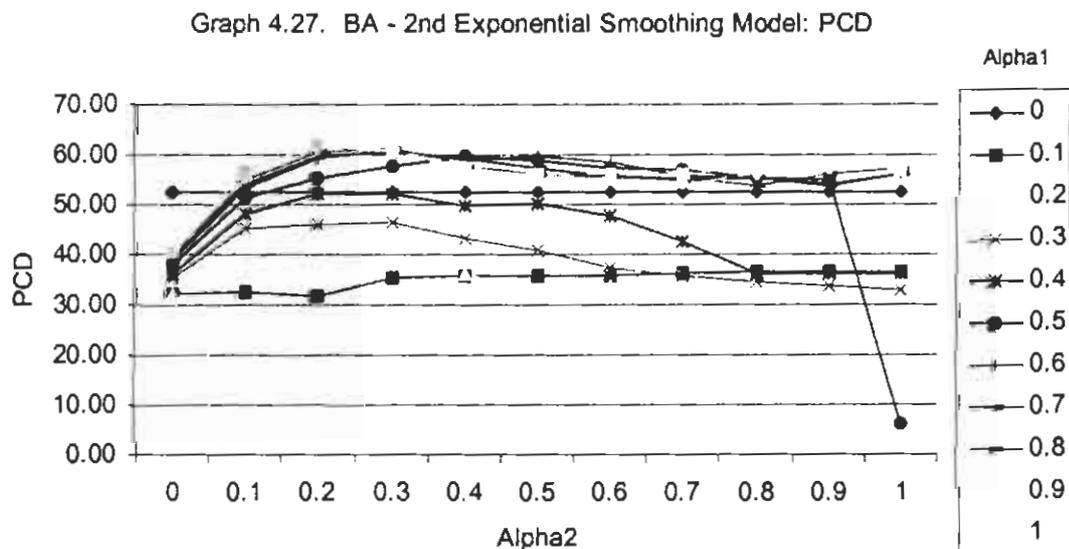
- Cell C8 = column heading "**Y<sub>t</sub>(data)**" – this column contains the BA data
- Cell D8 = column heading "**Y'<sub>t</sub>(single)**" – the first smoothing takes place in column D
- Cell E8 = column heading "**S''<sub>t</sub>(double)**" – the second smoothing takes place in column E
- Cell F8 = column heading "**S''<sub>t</sub> - S''<sub>t-1</sub> (b<sub>t</sub>)**" – the trend adjustment
- Cell I8 = column heading "**Forecast**" – the column that contains the forecasts for this second exponential smoothing model
- Cell K8 = column heading "**Real e<sup>2</sup>**" – the squared error from which the SSE and MSE are found

- Cells L8, M8 and N8 = column headings “**Prediction**”, “**Actual**” and “**Direction**” – the same as for the previous models. These columns are used to find out how “good” the model is in predicting the direction of the interest rates.

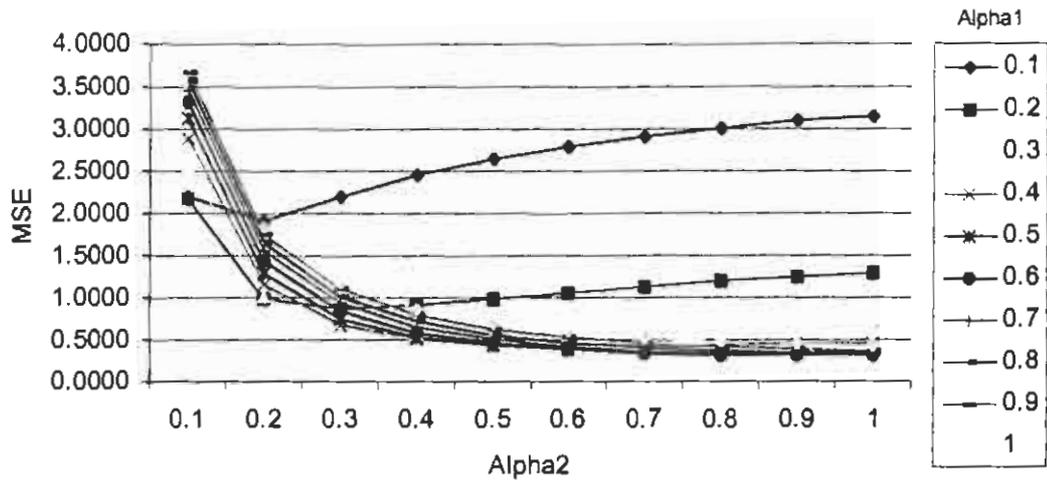
A sample of the formulae used can be seen in the **Appendix**. The example shown uses  $\alpha_1=1$  and  $\alpha_2=0.2$ .

Experiments were conducted with various combinations of alpha values for  $\alpha_1$  and  $\alpha_2$  and the same procedure was followed for the Esc data set. The results (a sample of which is summarised in a table in the **Appendix**) are summarised in Graphs 4.27.- 4.30. below.

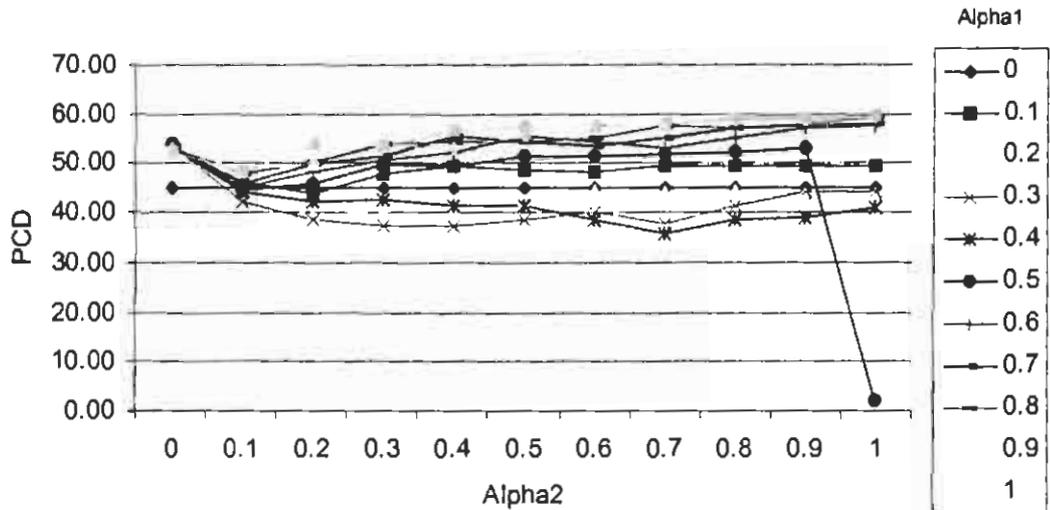
They show the PCD and MSE separately. For example, Graph 4.27. shows the PCD when the second exponential smoothing model is applied to the BA data set for the different alpha values. It can be seen, for instance, that when  $\alpha_1=0$  and  $\alpha_2=0$ , the PCD is 52.58%. The highest PCD (61.86%) is with  $\alpha_1=1$  and  $\alpha_2=0.2$ . Again, the models were modified to accommodate 194 comparisons for the BA data set and 193 comparisons for the Esc data set.



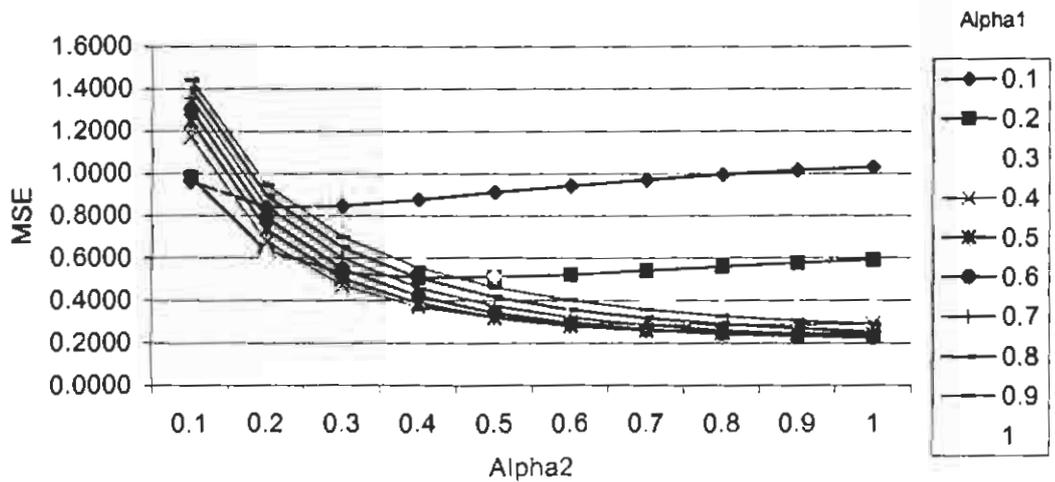
Graph 4.28. BA - 2nd Exponential Smoothing Model: MSE



Graph 4.29. Esc - 2nd Exponential Smoothing Model: PCD



Graph 4.30. Esc - 2nd Exponential Smoothing Model: MSE



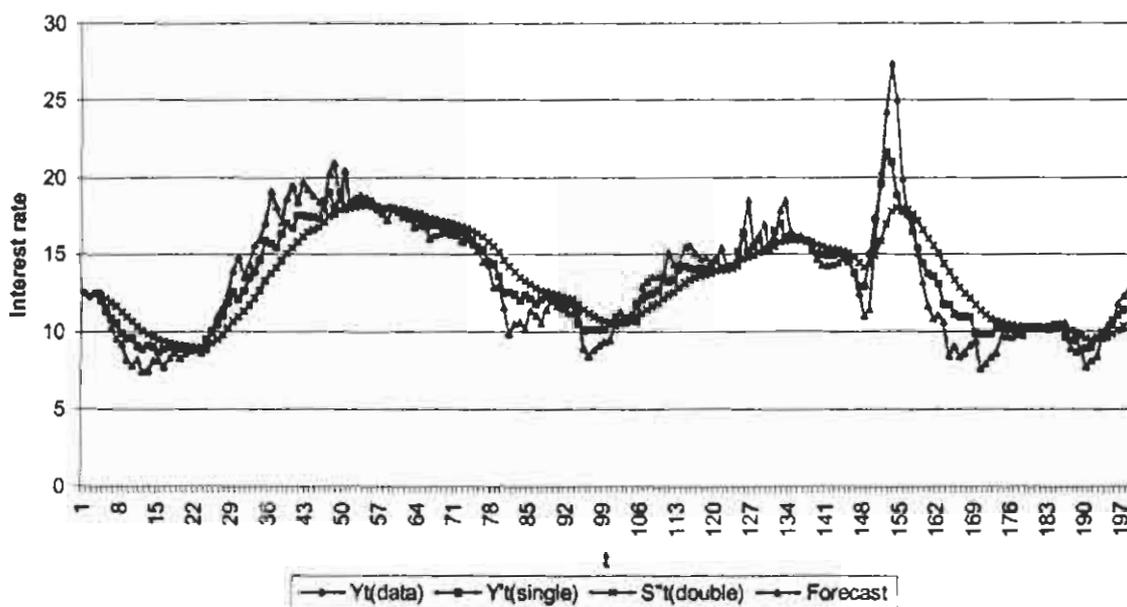
The summary table below highlights the “extremes” from the four graphs above, for the two data sets:

BA		$\alpha_1$	$\alpha_2$	
MIN MSE	0.3018	0.7	1	PCD 56.19%
MAX MSE	11.4235	1	0	PCD 40.21%
MIN PCD	6.19%	0.5	1	MSE 0.3508
MAX PCD	61.86%	1	0.2	MSE 1.8225

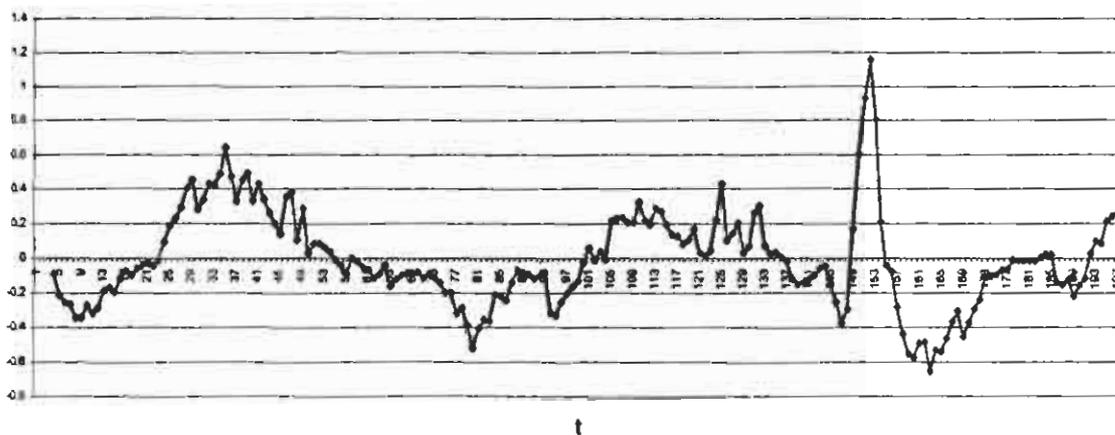
Esc		$\alpha_1$	$\alpha_2$	
MIN MSE	0.2246	0.6	1	PCD 57.51%
MAX MSE	11.0059	1	0	PCD 52.33%
MIN PCD	2.07%	0.5	1	MSE 0.2402
MAX PCD	59.59%	1	1	MSE 0.3330

The graphs with the highest PCD look as follows:

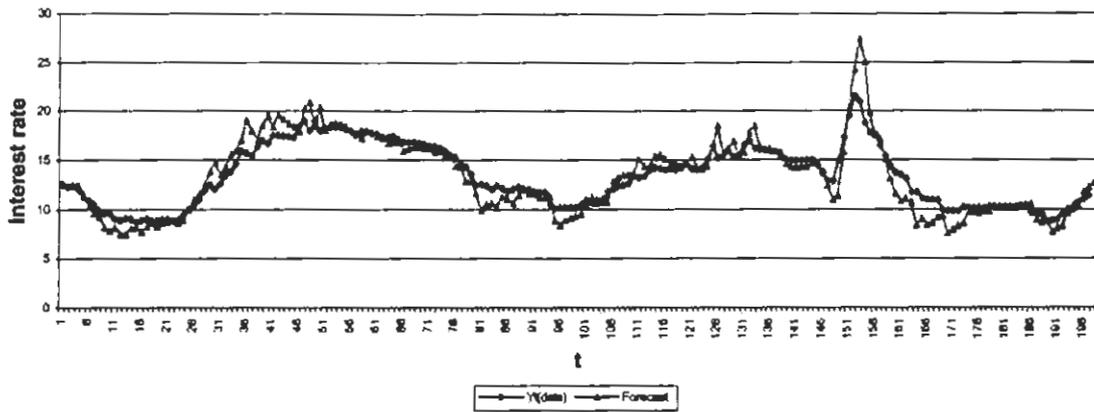
Graph 4.27. BA 3.2. Alpha1=1 Alpha2=0.2



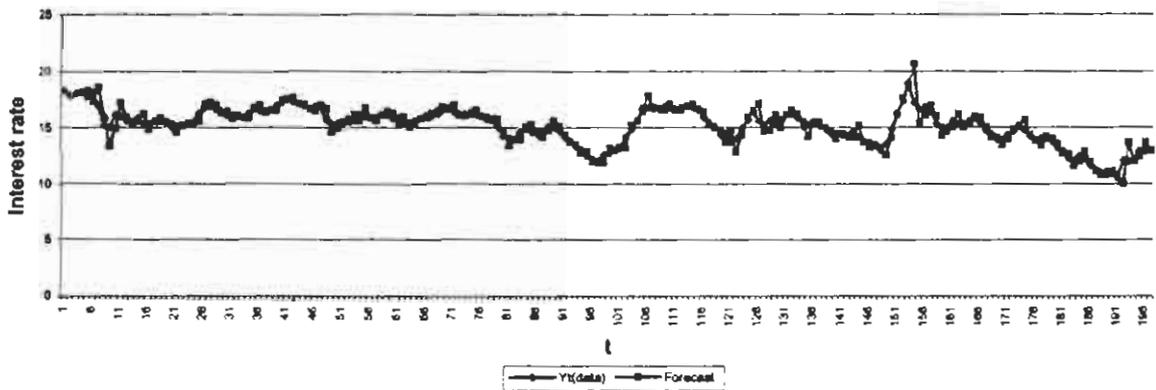
Graph 4.28. BA 3.2. Trend [ $S^t - S^{t-1}(b)$ ]



Graph 4.29. Actual vs. Predicted BA 3.2. Alpha1=1 Alpha2=0.2

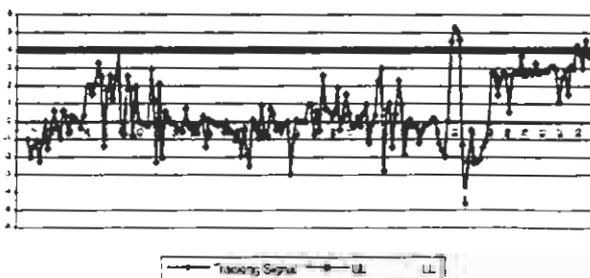


Graph 4.30. Actual vs. Predicted Esc 3.2. Alpha1=1 Alpha2=1

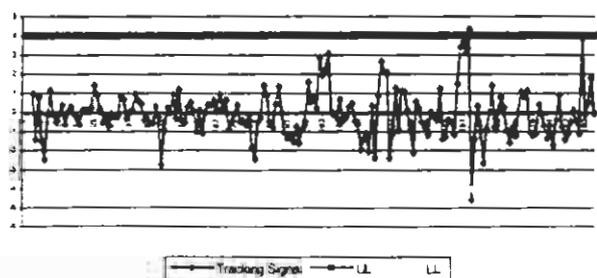


All the MADs lie between  $-4$  and  $4$ . Therefore, the models with a low RSFE were selected to demonstrate the tracking signals for the second exponential smoothing models (double smoothed) and are shown below. In addition, the graphs of the TS for the models with the maximum PCD and minimum MSE referred to in the summary table above are also shown below:

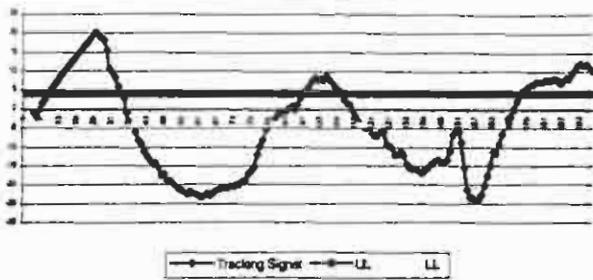
Graph 4.31. BA 3.2. A1=1 A2=1 TS 4 (Good TS Graph)



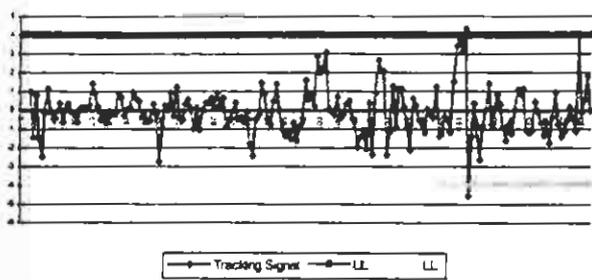
Graph 4.32. Esc 3.2. A1=1 A2=1 TS 4 (Good TS Graph)



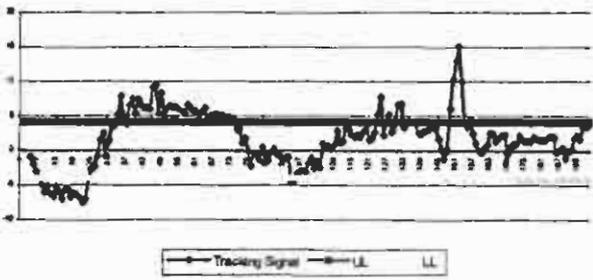
Graph 4.33. BA 3.2. A1=1 A2=0.2 TS 4 (Max PCD)



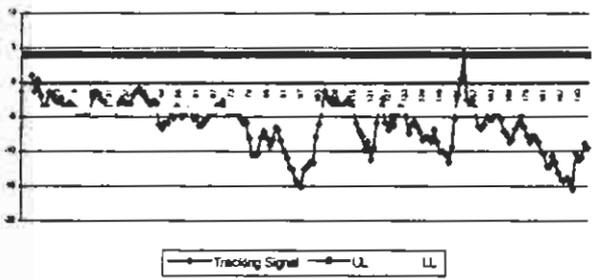
Graph 4.34. Esc 3.2. A1=1 A2=1 TS 4 (Max PCD)



Graph 4.35. BA 3.2. A1=0.7 A2=1 TS 4 (Min MSE)



Graph 4.36. Esc 3.2. A1=0.6 A2=1 TS 4 (Min MSE)



#### i. Note: Exponential Smoothing Models

Often, the data set that is being examined is too large to analyse “by hand”. Indeed, the computer has become an indispensable tool in data mining and analysis. It is, therefore, extremely important to understand what functions and conventions have been accepted by the software package that is being used. For example, Shim, *et al.* (1994:49) note that “virtually all forecasting software calculates forecasts based on exponential smoothing with trends”.

It is also important to take special care to understand the goals and procedures of each forecasting model as well as the different forms and variations of each model in this study. This is necessary to ensure that, firstly, the correct procedures and formulae are applied to represent the model on the computer and secondly, that the output given by the computer does, in fact, reflect what was being modelled.

#### 4.5. Summary

The results are summarised in the tables and graphs below:

BA							Esc						
Model	Symbol	Value	MSE	M	C	PCD	Model	Symbol	Value	MSE	M	C	PCD
1.1.	-	-	0.3508	12	194	6.19%	1.1.	-	-	0.2402	4	193	2.07%
1.2.	-	-	0.4247	110	194	56.70%	1.2.	-	-	0.3330	116	193	60.10%
1.3.	-	-	0.4295	110	194	56.70%	1.3.	-	-	0.3377	58	193	30.05%
2.1.	-	-	0.5766	66	194	34.02%	2.1.	-	-	0.3740	69	193	35.75%
2.2.	<i>m</i>	3	0.8263	74	194	38.14%	2.2.	<i>m</i>	3	0.5072	76	193	39.38%
3.1.	$\alpha$	0.1	3.8427	72	194	37.11%	3.1.	$\alpha$	0.1	1.2319	95	193	49.22%
	$\alpha$	0.4	0.8966	71	194	36.60%		$\alpha$	0.4	0.5023	79	193	40.93%
	$\alpha$	0.6	0.5763	73	194	37.63%		$\alpha$	0.6	0.3567	77	193	39.90%
	$\alpha$	0.9	0.3831	69	194	35.57%		$\alpha$	0.9	0.2577	74	193	38.34%
3.2.	Refer to Graphs 4.37. and 4.38. below						3.2.	Refer to Graphs 4.37. and 4.38. below					

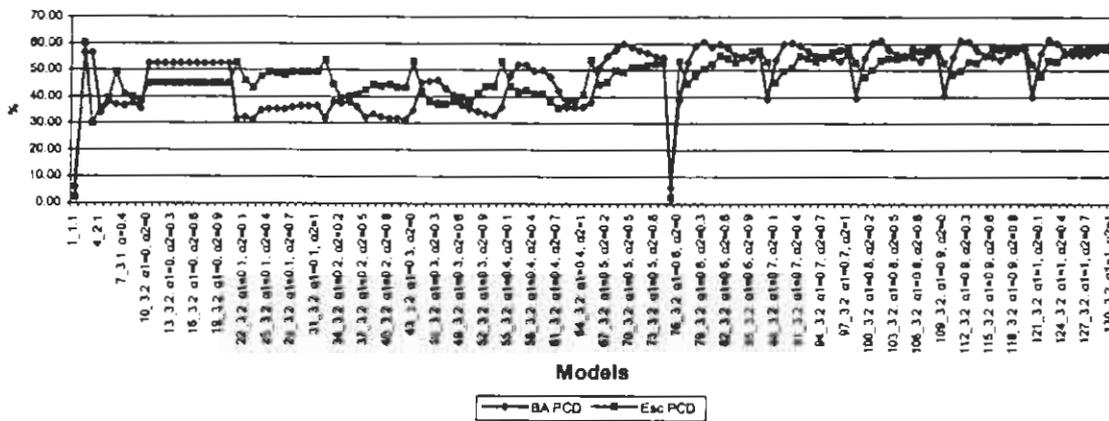
(a)

(b)

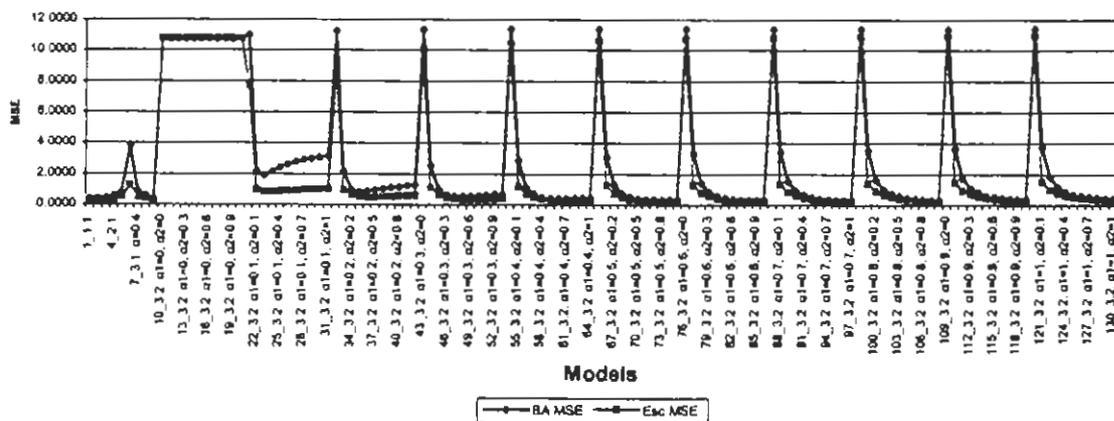
Table 4.11. Summary table for the models using (a) BA data set and (b) Esc data set.

M = Matches	1 = Naïve models
C = Comparisons	2 = Moving Average models
PCD = Predict Correct Direction	3 = Exponential Smoothing models

Graph 4.37. PCD All Models



Graph 4.38. MSE All Models



From the earlier double exponential smoothing model graphs as well as from the ones above, it can be seen that when  $\alpha_1=0.5$  and  $\alpha_2=1$  the percentage of correct

direction predictions is extremely low. In fact, it is the same 6.19% that the first naïve model produces. The MSE is also the same as the earlier model. What happens at these points is that the model predicts CONSTANT all the time, when the actual values are going UP, DOWN or (very seldom) CONSTANT.

Thus, from the above were chosen “good” and “bad” models with regard to percentage of correct direction predictions and mean squared errors<sup>82</sup>. They are, for the two data sets:

BA 194	Model	$\alpha_1$	$\alpha_2$	MSE	PCD	RSFE	MAD	TS
MAX PCD	3.2.	1	0.2	1.8225	<b>61.86</b>	9.8081	0.9569	10.2503
MIN MSE	3.2.	0.7	1	<b>0.3018</b>	56.19	21.4364	1.4838	14.4472
MIN PCD	1.1.	-	-	0.3508	<b>6.19</b>	-1.0500	0.3939	-2.6659
	3.2.	0.5	1	0.3508	<b>6.19</b>	0.9200	0.3837	2.3976
MAX MSE	3.2.	1	0	<b>11.4235</b>	40.21	-187.2500	2.8086	-66.6700

Esc 193	Model	$\alpha_1$	$\alpha_2$	MSE	PCD	RSFE	MAD	TS
MAX PCD	1.2.	-	-	0.3330	<b>60.10</b>	-0.2100	0.4092	-0.5132
MIN MSE	3.2.	0.6	1	<b>0.2246</b>	57.51	-3.3026	0.3461	-9.5427
MIN PCD	1.1.	-	-	0.2402	<b>2.07</b>	-5.1300	0.3563	-14.3971
	3.2.	0.5	1	0.2402	<b>2.07</b>	-5.1300	0.3563	-14.3971
MAX MSE	3.2.	1	0	<b>11.0059</b>	52.33	550.7100	2.9064	189.4836

*Table 4.12. Table showing: selected “good” models (with regard to PCD and MSE) for each data set, from which the “best” model may be chosen; as well as selected “bad” models, which should be avoided.*

However, the models with the best tracking signals<sup>83</sup> are the following:

BA							
Model	$\alpha_1$	$\alpha_2$	PCD	MSE	RSFE	MAD	TS
1.2	-	-	56.70	0.4247	0.1800	0.4495	0.4005
3.2	0.1	0.1	32.47	2.1800	0.4273	1.1545	0.3701
3.2	0.3	0.6	37.11	0.5770	0.3493	0.4983	0.7010
3.2	0.3	0.7	35.57	0.6080	-0.1495	0.5243	-0.2852
3.2	0.3	0.8	34.54	0.6417	-0.4983	0.5473	-0.9104
3.2	0.4	1	36.08	0.4617	0.3527	0.4513	0.7817

<sup>82</sup> The tracking signals are also shown for comparison purposes.

<sup>83</sup> A small summary table of the tracking signals for both data sets (excluding the exponential smoothing models) may be seen in the **Appendix**.

Esc							
Model	$\alpha_1$	$\alpha_2$	PCD	MSE	RSFE	MAD	TS
1.2	-	-	60.10	0.3330	-0.2100	0.4092	-0.5132
3.2	0.8	0.8	56.99	0.2855	0.3218	0.3793	0.8484
3.2	0.9	0.9	58.55	0.3022	0.1449	0.3890	0.3726
3.2	1	1	59.59	0.3330	-0.0100	0.4091	-0.0244

***Table 4.13. Table showing: selected "good" models (with regard to tracking signals) for both data sets, from which the "best" model may also be chosen.***

Only the Esc data set has one model that is present in both tables – the second naïve model (highlighted in the TS table). Perhaps this one could be considered the "best" overall model for the Esc data set. As for the BA data set, the "best" overall model would have to be chosen amongst those listed above. In this case, choosing the "best" model would depend on what criteria is most valued or sought after.

#### 4.6. Conclusion

The focus of this chapter was on the different simple forecasting models that can be used to predict interest rates and how accurate they really are in predicting those rates. Three types of quantitative forecasting methods were used – naïve models, moving average models and exponential smoothing.

Naïve techniques are based solely on previous experience. Moving averages and exponential smoothing "employ a weighted average of past data as the means of deriving the forecast" (Shim, *et al.*, 1994:50). All three methods, as well as their different variations, were applied to two data sets (BA and Esc).

In order to decide on the "best" model, three criteria were used, namely: PCD (percentage of correct direction predictions), MSE (mean squared error) and TS (tracking signals). Using this criteria, the best model (the one that can produce the interest rates closest to the actual observed interest rates) can be chosen for each data set.

For the BA data set, the “best” model should be chosen from a few “good” models – each the best with regard to PCD, MSE and TS, separately – depending on what criterion is most desired. For the Esc data set, the “best” model might be the second naïve model, as it appears as a good model for PCD and TS and the MSE (0.3330) is not that much higher than the minimum MSE (0.2246). Nevertheless, other models (of the ones listed above) may also be considered for the “best” model, for the same reason as that for the BA data set – they are good with respect to individual criteria.

In addition, while the maximum and minimum results are pointed out, it may be useful to consider other models that are not the extremes but that do well all around. For that, perhaps a more in-depth look at the results is required.

However, from the results given above, it was decided to test whether the same results would be obtained if the data sets were “cut” into several “sections” of one-year each and the same models applied to each section. Since both data sets have a different overall pattern and because including the exponential smoothing models would increase the exercise substantially, it was decided to experiment just with the BA data set. This is the topic of the next chapter.

## CHAPTER 5: FURTHER WORK ON BA DATA SET – SECTIONS

### 5.1. Introduction

The focus of Chapter 4 was on the different simple forecasting models that can be used to predict interest rates and how accurate they are in predicting those rates. Three types of quantitative forecasting methods were used – naïve models, moving average models and exponential smoothing. Each model (and where applicable, each variation of that model) was applied to both the BA and Esc data sets. Then, based on set criteria, the “best” models were chosen.

The focus of this chapter is to analyse the BA data set further. More specifically, the aim of this chapter is to determine whether the same results are obtained if the same models are applied to one-year sections of BA data. Thus, it was decided to experiment with the BA data set only, dividing it into specific sections according to its distinct pattern. Thereafter, the same models were applied to each of the sections (the new one-year data sets) as before.

### 5.2. Sections

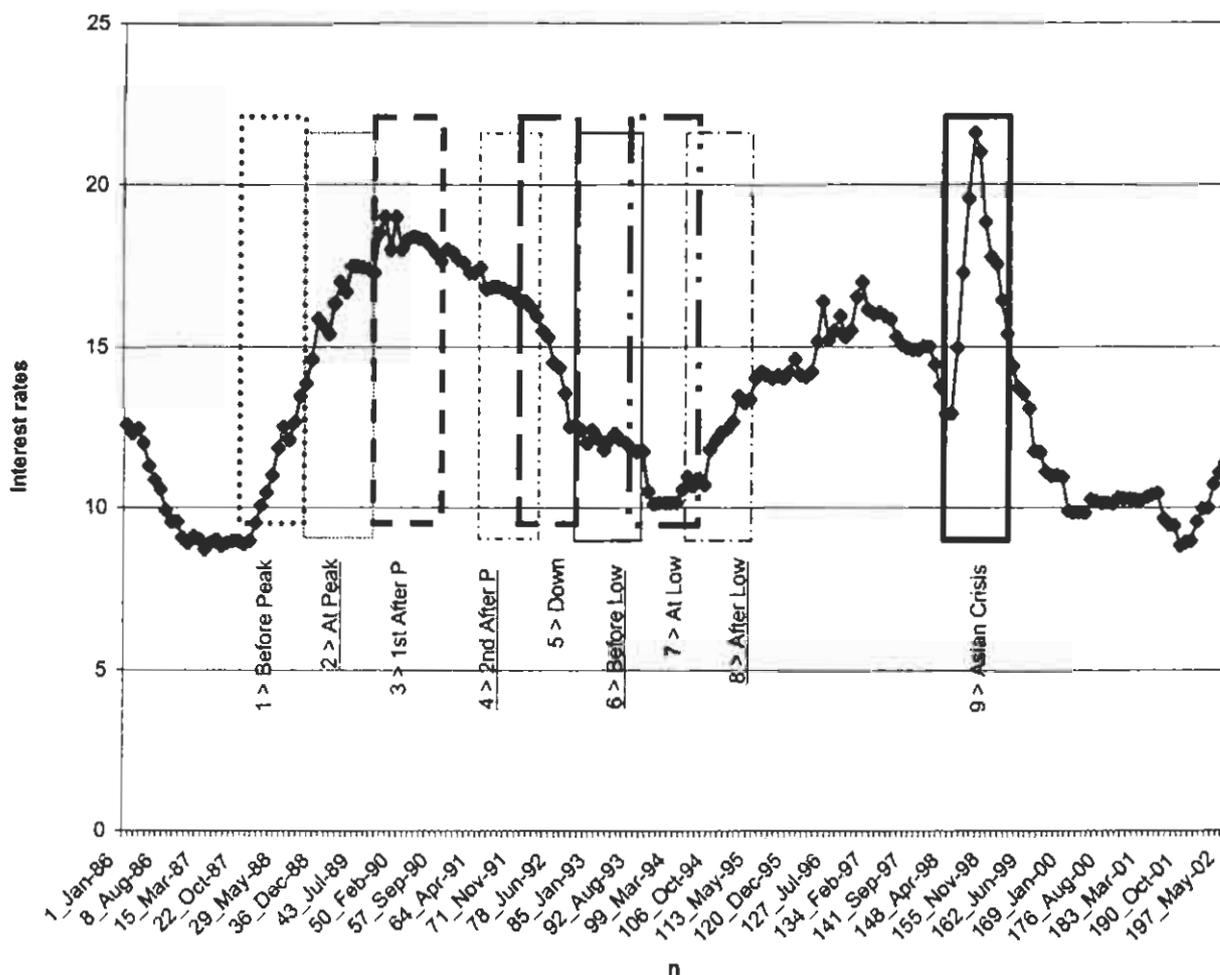
It was decided to divide the BA data set into sections of one year each (12 months), according to the shape of the graph. By looking at the original BA data set graph, a pattern of a type of “dome” emerged with interest rates rising before reaching a peak and then falling towards a low. Eight sections were chosen looking at the first “dome” and an additional one-year section was assigned for the Asian Crisis. Each section was given a name based on the general movement of the interest rates within that segment. The following sections were chosen, from the original observations (n):

Reference	Section Name	n
1	Before Peak	27 - 38
2	At Peak	39 - 50
3	1st After P	51 - 62
4	2nd After P	68 - 79
5	Down	75 - 86
6	Before Low	85 - 96
7	At Low	94 - 105
8	After Low	104 - 115
AC	Asian Crisis	148 - 159

The first section consists of the 12 data points before the peak, section two consists of the 12 data points at the peak. Section three refers to the first 12 data points after the peak and section four refers to the second set of 12 data points after the peak. The rest of the sections are self-explanatory.

As is evident, some of the sections overlap. This can also be seen in the graph below, which illustrates the nine chosen sections:

Graph 5.1. BA 1-Year Sections



### 5.3. Empirical Work

With each section as a new data set, all the models used in Chapter 4 were applied to each of the nine new data sections. Table 5.1. below shows the results that are obtained when the first naïve model is applied to the first section. As before, the

mean squared error (MSE) and percentage of correct direction predictions (PCD) are obtained. Also shown are the standard deviation (s) and mean absolute deviation (MAD). The cell references are as explained in the previous chapter.

...	B	C	D	E	F	G	H	I	J	K	L	M
6	1	Before Peak										
7	1 year	n	$Y_t$	$Y_{t+1}^*$	$e_t = Y_t - Y_{t+1}^*$	$e^2$	ABS(e)	Prediction	Actual	Direction		
8	1	27	11									
9	2	28	11.85	11.00	0.850	0.722	0.850	Constant	Up	0		0 = Wrong
10	3	29	12.5	11.85	0.650	0.423	0.650	Constant	Up	0		1 = Correct
11	4	30	12.1	12.50	-0.400	0.160	0.400	Constant	Down	0		
12	5	31	12.65	12.10	0.550	0.303	0.550	Constant	Up	0		
13	6	32	13.45	12.65	0.800	0.640	0.800	Constant	Up	0		
14	7	33	13.85	13.45	0.400	0.160	0.400	Constant	Up	0		
15	8	34	14.6	13.85	0.750	0.563	0.750	Constant	Up	0		
16	9	35	15.85	14.60	1.250	1.563	1.250	Constant	Up	0		
17	10	36	15.65	15.85	-0.200	0.040	0.200	Constant	Down	0		
18	11	37	15.4	15.65	-0.250	0.063	0.250	Constant	Down	0		
19	12	38	16.35	15.40	0.950	0.903	0.950	Constant	Up	0		
20			17	16.35		5.5375	0.6409			0		/ 11
21						SSE	MAD		Total	0.00		
22					0.5034	0.5034	0.7095		Total %	0.00		
23					Average	MSE	s					
24												

**Table 5.1. Representation of the table used in Excel, showing the results obtained when the first naïve model is applied to the first one-year section of the BA data set.**

In the table, SSE = Sum of Squared Errors; MAD = Mean Absolute Deviation;  
MSE = Mean Squared Error; s = standard deviation

found with the following formulas:

<b>=SUM(G8:G19)</b>	<b>=AVERAGE(H9:H19)</b>
<b>SSE</b>	<b>MAD</b>
<b>=G20/M20</b>	<b>=SQRT(G22)</b>
<b>MSE</b>	<b>s</b>

Using only the 12 data points for this section, 11 comparisons are possible when applying the first naïve model. However, similar to Chapter 4, subsequent models would allow only 10 comparisons over each section. In addition, the second moving average model would allow only nine comparisons.

Thus, the following was decided: since the second MA model had not performed well against any of the criteria in the previous chapter, it would not form part of the experiments in this chapter. In this way, to be able to compare all the models over each of the sections more accurately, the other models would be restricted to allow for only 10 comparisons for each.

Consequently, each of the models (except the second MA model) were applied to each of the nine sections and similar tables to that of Table 5.1. were obtained. The results for some of the models over the first section are shown below:

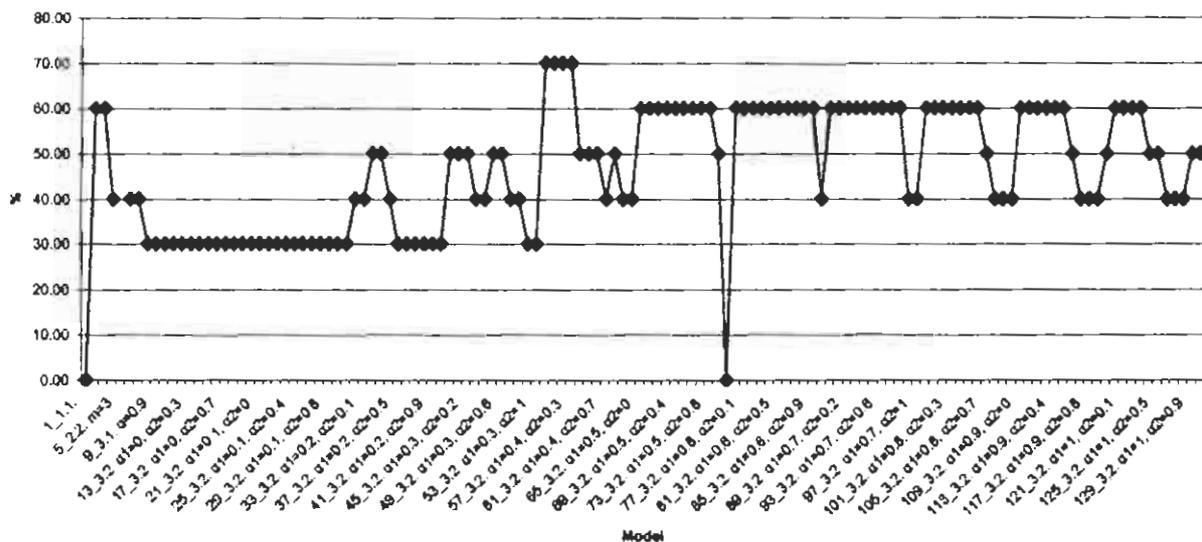
			1	BA 1 year	n	%	MSE	s	MAD	C
1			1.1.	Before Peak	27 - 38	0.00	0.4815	0.6939	0.6200	10
2			1.2.	Before Peak	27 - 38	60.00	0.6185	0.7864	0.6400	10
3			1.3.	Before Peak	27 - 38	60.00	0.6564	0.8102	0.6567	10
4			2.1.	Before Peak	27 - 38	40.00	0.7606	0.8721	0.7550	10
5		m=3	2.2.	Before Peak	27 - 38					
6		$\alpha=0.9$	3.1.	Before Peak	27 - 38	40.00	0.5805	0.7619	0.6602	10
7		$\alpha=0.6$	3.1.	Before Peak	27 - 38	40.00	0.8236	0.9075	0.7714	10
8		$\alpha=0.4$	3.1.	Before Peak	27 - 38	30.00	1.3629	1.1674	1.0538	10
9		$\alpha=0.1$	3.1.	Before Peak	27 - 38	30.00	5.3030	2.3028	2.1035	10
10	0.0	0.0	3.2.	Before Peak	27 - 38	30.00	7.8540	2.8025	2.3900	10
...	...	...	...	...	...	...	...	...	...	...
54	0.4	0.0	3.2.	Before Peak	27 - 38	70.00	1.6291	1.2764	0.8853	10
55	0.4	0.1	3.2.	Before Peak	27 - 38	70.00	0.8836	0.9400	0.7415	10
56	0.4	0.2	3.2.	Before Peak	27 - 38	70.00	0.5536	0.7440	0.6429	10
57	0.4	0.3	3.2.	Before Peak	27 - 38	70.00	0.4276	0.6539	0.5748	10
...	...	...	...	...	...	...	...	...	...	...
68	0.5	0.3	3.2.	Before Peak	27 - 38	60.00	0.5182	0.7199	0.5779	10
69	0.5	0.4	3.2.	Before Peak	27 - 38	60.00	0.4142	0.6436	0.5573	10
70	0.5	0.5	3.2.	Before Peak	27 - 38	60.00	0.3816	0.6177	0.5750	10
71	0.5	0.6	3.2.	Before Peak	27 - 38	60.00	0.3841	0.6198	0.5890	10
72	0.5	0.7	3.2.	Before Peak	27 - 38	60.00	0.4032	0.6349	0.6001	10
73	0.5	0.8	3.2.	Before Peak	27 - 38	60.00	0.4288	0.6548	0.6088	10
74	0.5	0.9	3.2.	Before Peak	27 - 38	50.00	0.4559	0.6752	0.6154	10
...	...	...	...	...	...	...	...	...	...	...
128	1.0	0.8	3.2.	Before Peak	27 - 38	40.00	0.6862	0.8284	0.7018	10
129	1.0	0.9	3.2.	Before Peak	27 - 38	50.00	0.6697	0.8183	0.6956	10
130	1.0	1.0	3.2.	Before Peak	27 - 38	50.00	0.6568	0.8104	0.6850	10
						70.00	0.3816			
						<b>MAX</b>	<b>MIN</b>			
						60.00				
						<b>2ndMAX</b>				

**Table 5.2. Summary table showing some of the results obtained when the different models are applied to the first section of the BA data set. Highlighted are the models that produce the maximum PCD and some of the models that produce the second highest PCD, as well as the model that produces the best (smallest) MSE.**

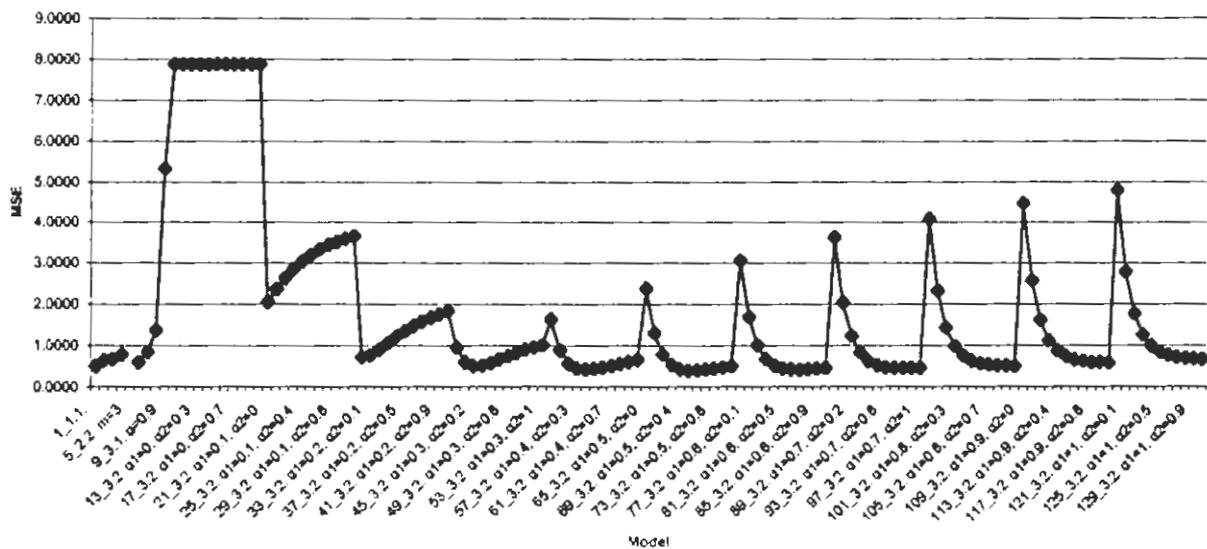
Highlighted in Table 5.2. above are the models that produce the best PCD results and some of the models that produce the second highest PCD results, as well as the model that produces the best MSE result. Other information (s and MAD) is also shown. In each case 10 comparisons were made. Evidently, with the inclusion of the second exponential smoothing models, the experiments grow quite large.

The same procedure was followed for each of the models for each of the nine sections. Graphs were drawn, showing how all the models perform over each of those sections.

Graph 5.2. 1 Before Peak: PCD



Graph 5.3. 1 Before Peak: MSE



Above are two graphs (the first illustrating the PCD and the second, MSE) of all the models over section one (Before Peak). Similar graphs were drawn for all sections.

Then, from each section, the "best" model was chosen, based on PCD and MSE<sup>84</sup>.

The results of the chosen "best" models are shown in the table below. For each model over each section, only 10 comparisons were allowed (denoted by the C in the rightmost column of the table):

Section	t	Model	$\alpha_1$	$\alpha_2$	BA 1 year	n	PCD	MSE	s	MAD	C
1	57	3.2.	0.4	0.3	Before Peak	27 - 38	70.00	0.4276	0.6539	0.5748	10
2	8	3.1.	0.4	-	At Peak	39 - 50	80.00	0.4420	0.6648	0.5321	10
3	82	3.2.	0.6	0.6	1st After P	51 - 62	80.00	0.0423	0.2057	0.1518	10
4	80	3.2.	0.6	0.4	2nd After P	68 - 79	80.00	0.0470	0.2167	0.1796	10
5	84	3.2.	0.6	0.8	Down	75 - 86	70.00	0.2388	0.4887	0.4152	10
6	86	3.2.	0.6	1.0	Before Low	85 - 96	60.00	0.1825	0.4272	0.2609	10
7	4	2.1.	-	-	At Low	94 - 105	70.00	0.1569	0.3961	0.2450	10
8	83	3.2.	0.6	0.7	After Low	104 - 115	70.00	0.1205	0.3471	0.2710	10
AC	2	1.2.	-	-	Asian Crisis	148 - 159	90.00	1.2356	1.1116	0.7760	10
							60.00	0.0423			
							90.00	1.2356			

***Table 5.3. Summary table showing the "best" models that were chosen over the different nine sections. Highlighted are the best and worst PCD and MSE results of these models.***

Thus, it can be seen, for example, that over the first one-year section (Before Peak), the model that produces the "best" results in terms of a combination of PCD and MSE is the second exponential smoothing model with  $\alpha_1=0.4$  and  $\alpha_2=0.3$ . As another example, the model that obtains the "best" results over the second section (At Peak)

<sup>84</sup> The process involved looking at all the results, one section at a time and determining the "best" model based on a combination of PCD and MSE and also making use of a type of "scoring" system. This system calculated a score for PCD and MSE separately:

- For PCD, if the model was able to predict 100% correct direction, a value of 10 (maximum) was assigned to it. If the model predicted 90% correct direction, it was assigned a value of 9 and so on
- As for MSE, the standard deviation (which is the squared root of MSE) was used as a standard measure. Thus, if the model produced an s equal to zero or less than 0.3162 (corresponding to MSE 0.1), a value of (maximum) 10 was assigned to it. If the model produced an s between 0.3162 and 0.4472 (corresponding to MSE between 0.1 and 0.2), a value of 9 was assigned to it and so on

Thus, in the end, a total score out of 20 was found for each model, which was also taken into consideration when determining the "best" model for each section.

is the first exponential smoothing model (single smoothed) with  $\alpha=0.4$ . The first naïve model is not selected in any of the sections.

The model with the “best” results of the one-year section over the Asian Crisis is the second naïve model. In fact, it produces the highest PCD results out of all the models over any section. However, it also produces the worst (highest) MSE results out of all the models over any section.

Overall, the models chosen above are able to predict the direction of the interest rate correctly at least 60% of the time (which is the lowest PCD). The MSE is reasonable most of the time (the biggest exception being at the Asian Crisis section).

Compared to the results of the previous chapter<sup>85</sup>, over the sections the models are able to predict the direction of the next interest rate correctly more of the time. Only over one section (Before Low) is the PCD lower than the 61.86% of Chapter 4 over the whole BA data set. However, over this section, the MSE produced is much lower than what was obtained for the entire data set (1.8225) in Chapter 4. In fact, the MSE at this section is lower than the lowest MSE produced by the second exponential smoothing model with  $\alpha_1=0.7$  and  $\alpha_2=1$  (0.3018) in the previous chapter.

From the “best” models over the sections, it is interesting to note that not one is the same as the chosen “best” models over the entire BA data set of the previous chapter. However, in most sections it is one of the second exponential smoothing models that is chosen.

Really, in six of the nine sections, it is one of the second exponential smoothing models that is chosen as the “best” model. This could be due to the fact that there are so many of these models that there is a higher chance of one of them being chosen. However, it is interesting to note that in five of these cases,  $\alpha_1=0.6$ .

<sup>85</sup> Recall from Chapter 4 that the chosen “best” models according to PCD and MSE were:

BA 194	Model	$\alpha_1$	$\alpha_2$	MSE	PCD
MAX PCD	3.2	1	0.2	1.8225	61.86
MIN MSE	3.2	0.7	1	0.3018	55.19

The same type of “scoring” system that was used to determine the “best” models over each of the sections was applied to the summary table shown in Table 5.3. The results are shown in Table 5.4. below:

Section	t	Model	$\alpha_1$	$\alpha_2$	BA 1 year	n	PCD	MSE	T1	T2	T
1	57	3.2.	0.4	0.3	Before Peak	27 - 38	70.00	0.4278	7	6	13
2	8	3.1.	0.4	-	At Peak	39 - 50	80.00	0.4420	8	6	14
3	82	3.2.	0.6	0.6	1st After P	51 - 62	80.00	0.0423	8	10	18
4	80	3.2.	0.6	0.4	2nd After P	68 - 79	80.00	0.0470	8	10	18
5	84	3.2.	0.6	0.8	Down	75 - 86	70.00	0.2388	7	8	15
6	86	3.2.	0.6	1.0	Before Low	85 - 96	60.00	0.1825	6	9	15
7	4	2.1.	-	-	At Low	94 - 105	70.00	0.1569	7	9	16
8	83	3.2.	0.6	0.7	After Low	104 - 115	70.00	0.1205	7	9	16
AC	2	1.2.	-	-	Asian Crisis	148 - 159	90.00	1.2356	9	0	9
						MIN	60.00	0.0423	67	67	134
						MAX	90.00	1.2356			

**Table 5.4. Summary table showing the scores given to each of the “best” models. T1 refers to the total score (out of 10) assigned to the model for PCD and T2 refers to the total score (out of 10) assigned to the model for MSE. T refers to the Total score (T1+T2) assigned to each model.**

From the table above, it can be seen that overall, 67 out of a possible 90 (74%) for T1 (total score out of 10 assigned to direction) is obtained and the same 67 out of a possible 90 for T2 (total score out of 10 assigned to technique) is obtained for the all of the “best” models. Most evident from the table is that, while the second naïve model is able to predict the interest rate direction correctly 9 out of 10 times, it scores no points on technique because the MSE obtained is much higher than with any of the other models.

The best all-round score goes to the second exponential smoothing model with  $\alpha_1=0.6$  and  $\alpha_2=0.6$  over the section of the first 12 values after the peak (1<sup>st</sup> After P) because it scores the second highest PCD and the smallest MSE. Certainly, other standards for assigning scores may be used.

#### 5.4. Further Empirical Work

Further experiments were conducted to see how well the chosen models perform over the other sections. Summary tables like the ones below were drawn for each of

the chosen nine models. In addition, summary tables for Models 1.1. and 1.3. were added just out of interest. As expected, the first naïve model performs rather poorly, the table of the third naïve model is also given below:

Section	t	Model	$\alpha_1$	$\alpha_2$	BA 1 year	n	PCD	MSE	s	MAD	C	Chosen
1	57	3.2.	0.4	0.3	Before Peak	27 - 38	70.00	0.4276	0.6539	0.5748	10	*
2	57	3.2.	0.4	0.3	At Peak	39 - 50	20.00	0.5154	0.7179	0.6050	10	
3	57	3.2.	0.4	0.3	1st After P	51 - 62	50.00	0.0391	0.1979	0.1623	10	
4	57	3.2.	0.4	0.3	2nd After P	68 - 79	70.00	0.0723	0.2690	0.2132	10	
5	57	3.2.	0.4	0.3	Down	75 - 86	60.00	0.4109	0.6410	0.5736	10	
6	57	3.2.	0.4	0.3	Before Low	85 - 96	10.00	0.2244	0.4737	0.3565	10	
7	57	3.2.	0.4	0.3	At Low	94 - 105	40.00	0.1324	0.3639	0.2444	10	
8	57	3.2.	0.4	0.3	After Low	104 - 115	50.00	0.1111	0.3334	0.2830	10	
AC	57	3.2.	0.4	0.3	Asian Crisis	148 - 159	10.00	5.4914	2.3434	2.1481	10	

**Table 5.5. Summary table showing how well the "best" model chosen over the first section (second exponential smoothing model with  $\alpha_1=0.4$  and  $\alpha_2=0.3$ ) performs across the other eight sections.**

Section	t	Model	$\alpha_1$	$\alpha_2$	BA 1 year	n	PCD	MSE	s	MAD	C	Chosen
1	8	3.1.	0.4	-	Before Peak	27 - 38	30.00	1.3629	1.1674	1.0538	10	
2	8	3.1.	0.4	-	At Peak	39 - 50	80.00	0.4420	0.6648	0.5321	10	*
3	8	3.1.	0.4	-	1st After P	51 - 62	30.00	0.0691	0.2629	0.2116	10	
4	8	3.1.	0.4	-	2nd After P	68 - 79	0.00	0.5171	0.7191	0.6030	10	
5	8	3.1.	0.4	-	Down	75 - 86	20.00	0.8675	0.9314	0.8189	10	
6	8	3.1.	0.4	-	Before Low	85 - 96	30.00	0.3881	0.6229	0.4361	10	
7	8	3.1.	0.4	-	At Low	94 - 105	50.00	0.1849	0.4300	0.2817	10	
8	8	3.1.	0.4	-	After Low	104 - 115	20.00	0.4936	0.7026	0.6620	10	
AC	8	3.1.	0.4	-	Asian Crisis	148 - 159	20.00	7.3228	2.7061	2.4270	10	

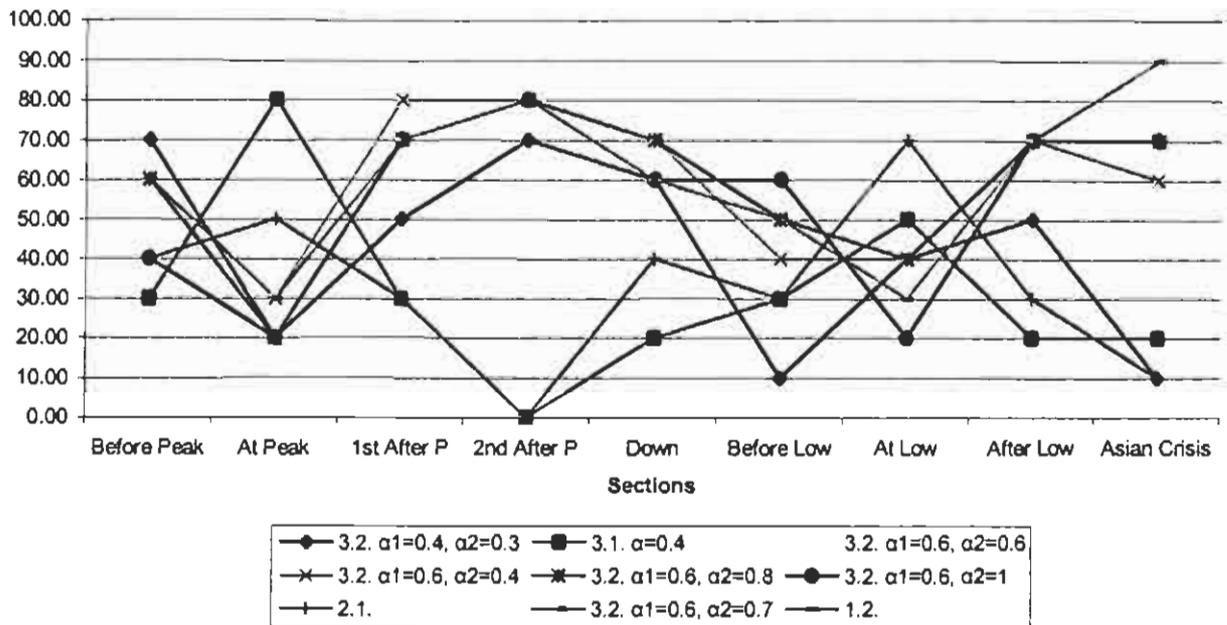
**Table 5.6. Summary table showing how well the "best" model chosen over the second section (first exponential smoothing model with  $\alpha=0.4$ ) performs across the other eight sections.**

Section	t	Model	$\alpha_1$	$\alpha_2$	BA 1 year	n	PCD	MSE	s	MAD	C
1	3	1.3.	-	-	Before Peak	27 - 38	60.00	0.6564	0.8102	0.6567	10
2	3	1.3.	-	-	At Peak	39 - 50	30.00	1.4516	1.2048	0.9632	10
3	3	1.3.	-	-	1st After P	51 - 62	70.00	0.0672	0.2593	0.1808	10
4	3	1.3.	-	-	2nd After P	68 - 79	80.00	0.1401	0.3743	0.3052	10
5	3	1.3.	-	-	Down	75 - 86	60.00	0.3456	0.5879	0.5183	10
6	3	1.3.	-	-	Before Low	85 - 96	50.00	0.2893	0.5379	0.3947	10
7	3	1.3.	-	-	At Low	94 - 105	30.00	0.3045	0.5518	0.3910	10
8	3	1.3.	-	-	After Low	104 - 115	70.00	0.3044	0.5518	0.4503	10
AC	3	1.3.	-	-	Asian Crisis	148 - 159	90.00	1.3362	1.1560	0.8011	10

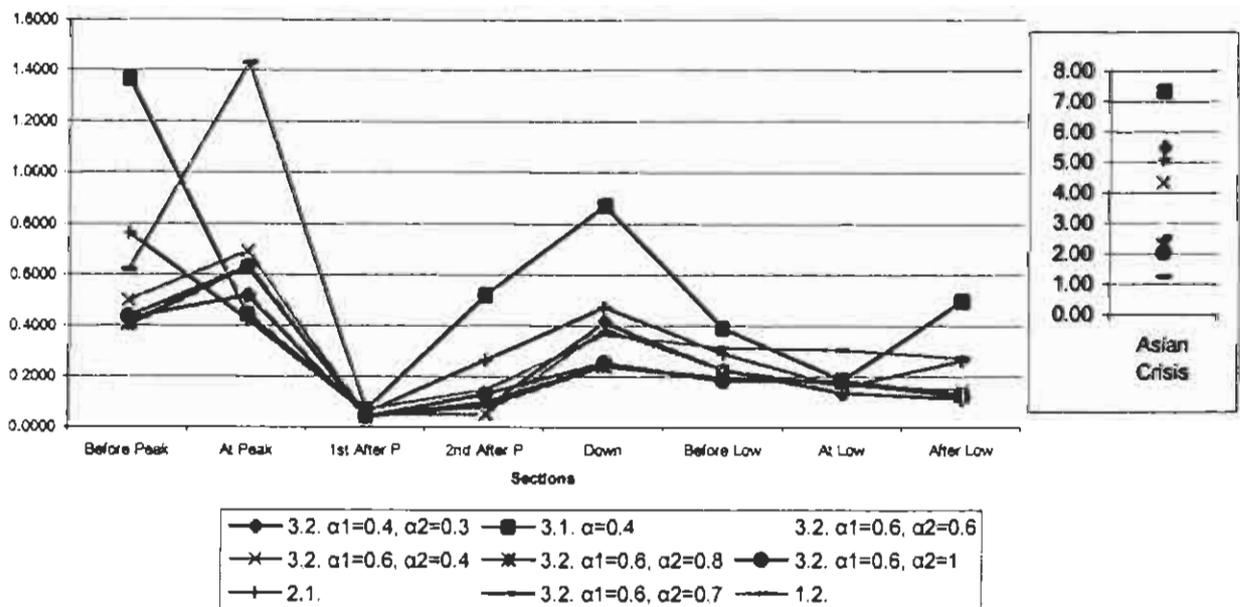
**Table 5.7. Summary table showing how Model 1.3. performs over all the sections.**

The graphs of the nine chosen models over all the sections are given below:

Graph 5.4. PCD of selected models over the different sections



Graph 5.5. MSE of selected models over the different sections



Once again, the same type of scoring system was applied to each table. From these scores, it was interesting to note that, with regard to PCD, when model 1.2. (the second naïve model) performed relatively well over a section, model 2.1. (first

moving average model) performed fairly poorly over that same section and vice versa. In fact, they seemed to be opposites at six of the nine sections. The following tables illustrate this:

Section	t	Model	$\alpha_1$	$\alpha_2$	BA 1 year	n	PCD	MSE	Chosen	T1	T2	T
1	4	2.1.	-	-	Before Peak	27 - 38	40.00	0.7606		4	3	7
2	4	2.1.	-	-	At Peak	39 - 50	50.00	0.4201		5	6	11
3	4	2.1.	-	-	1st After P	51 - 62	30.00	0.0550		3	10	13
4	4	2.1.	-	-	2nd After P	68 - 79	0.00	0.2653		0	8	8
5	4	2.1.	-	-	Down	75 - 86	40.00	0.4716		4	6	10
6	4	2.1.	-	-	Before Low	85 - 96	30.00	0.2909		3	8	11
7	4	2.1.	-	-	At Low	94 - 105	70.00	0.1569*		7	9	16
8	4	2.1.	-	-	After Low	104 - 115	30.00	0.2611		3	8	11
AC	4	2.1.	-	-	Asian Crisis	148 - 159	10.00	5.1007		1	0	1
										30	58	88

(a)

Section	t	Model	$\alpha_1$	$\alpha_2$	BA 1 year	n	PCD	MSE	Chosen	T1	T2	T
1	2	1.2.	-	-	Before Peak	27 - 38	60.00	0.6185		6	4	10
2	2	1.2.	-	-	At Peak	39 - 50	30.00	1.4285		3	0	3
3	2	1.2.	-	-	1st After P	51 - 62	70.00	0.0670		7	10	17
4	2	1.2.	-	-	2nd After P	68 - 79	80.00	0.1455		8	9	17
5	2	1.2.	-	-	Down	75 - 86	60.00	0.3653		6	7	13
6	2	1.2.	-	-	Before Low	85 - 96	50.00	0.3125		5	7	12
7	2	1.2.	-	-	At Low	94 - 105	30.00	0.3050		3	7	10
8	2	1.2.	-	-	After Low	104 - 115	70.00	0.2720		7	8	15
AC	2	1.2.	-	-	Asian Crisis	148 - 159	90.00	1.2356*		9	0	9
										54	52	106

(b)

**Table 5.8. Summary tables showing (a) how well model 2.1. chosen over the seventh section (At Low) scores across all sections and (b) how well model 1.2. chosen over the ninth section (Asian Crisis) scores across all sections. The "opposite" scores are highlighted.**

Consider the following two examples:

- At section one (Before Peak) model 2.1. scores 4 while model 1.2. scores 6
- At section seven (At Low) model 2.1. scores 7 while model 1.2. scores 3

The two models seemed to complement each other. In looking at the actual tables, the following could be seen:

$Y_t$	1.2.	$e_t=Y_t-Y_{t+1}$	$e^2$	ABS(e)	Prediction	Actual	Direction
11							
11.85							
12.5	12.70	-0.200	0.040	0.200	Up	Up	1
12.1	13.15	-1.050	1.103	1.050	Up	Down	0
12.65	11.70	0.950	0.903	0.950	Down	Up	0
13.45	13.20	0.250	0.062	0.250	Up	Up	1
...	...	...	...	...	...	...	...

(a)

$Y_t$	2.1.	$e_t=Y_t-Y_{t+1}$	$e^2$	ABS(e)	Prediction	Actual	Direction
11							
11.85							
12.5	11.43	1.075	1.156	1.075	Down	Up	0
12.1	12.18	-0.075	0.006	0.075	Down	Down	1
12.65	12.30	0.350	0.123	0.350	Up	Up	1
13.45	12.38	1.075	1.156	1.075	Down	Up	0
...	...	...	...	...	...	...	...

(b)

**Table 5.9. Portions of the tables used in Excel, showing how Model 1.2. (a) and Model 2.1. (b) appear to be complementing each other over section one.**

Perhaps this could mean that model 2.1. should be used when a more predictable and smooth forecast was expected and that model 1.2. should be used when interest rates were expected to behave more irregularly.

Hence, it was decided to combine these two models to ascertain whether one such combination model would produce better results than the two models separately.

The idea is illustrated in Table 5.8. below:

Section	t	Model	$\alpha_1$	$\alpha_2$	BA 1 year	n	PCD	MSE	Chosen	T1	T2	T
1	2	1.2.	-	-	Before Peak	27 - 38	60.00	0.6185		6	4	10
2	4	2.1.	-	-	At Peak	39 - 50	50.00	0.4201		5	6	11
3	2	1.2.	-	-	1st After P	51 - 62	70.00	0.0670		7	10	17
4	2	1.2.	-	-	2nd After P	68 - 79	80.00	0.1455		8	9	17
5	2	1.2.	-	-	Down	75 - 86	60.00	0.3653		6	7	13
6	2	1.2.	-	-	Before Low	85 - 96	50.00	0.3125		5	7	12
7	4	2.1.	-	-	At Low	94 - 105	70.00	0.1569*		7	9	16
8	2	1.2.	-	-	After Low	104 - 115	70.00	0.2720		7	8	15
AC	2	1.2.	-	-	Asian Crisis	148 - 159	90.00	1.2356*		9	0	9
										60	60	120

**Table 5.10. Summary table showing a combination model consisting of models 1.2. and 2.1., where the model with the best PCD score is chosen at each section.**

As expected, there is an improvement in scores. Furthermore, on closer examination of all the tables similar to those depicted in Table 5.7., it is evident that this combination table produces the highest scores of them all.

It was decided to carry out empirical work on the actual original BA data set to determine whether, in practice, a combination of the two models would yield better results. The experiment consisted of starting with the second naïve model as was discussed in Chapter 4. Then, at  $t=11$ , looking back at the last 10 directions, two different experiments were tested:

1. If the last 10 directions had produced a PCD of 70% or more, then Model 1.2. would be applied for another 10 time periods, based on the premise that if the model was producing good results, continued use should be made of it. Alternatively, if the PCD that had been obtained from the first 10 directions was less than 70%, then Model 2.1. would be introduced and applied for 10 time periods. Then these direction results would be evaluated and depending on the PCD, continued use would be made of Model 2.1., otherwise Model 1.2. would be reintroduced for the next 10 time periods. This was done for the entire BA data set;
  - Regrettably, the results that were obtained were not better than those that had been found for the chosen “good” models in Chapter 4
2. If the last 10 directions had produced a PCD of 70% or more, then Model 2.1. would be introduced and applied for the next 10 time periods, based on the premise that if the model had been producing good results for this long, then it was more likely that a change was going to take place and that another model should be used to handle or deal with it. Alternatively, if the PCD that had been obtained from the first 10 directions was less than 70%, then continued use would be made of it for another 10 time periods, based on the premise that it would be more likely that the model would start predicting the direction of the interest rates correctly using this model, since it had not done so for so long and the interest rates would be changing in such a way that the model would be able to predict their direction correctly now. This was done for the entire BA data set.

- However, again, the results were not better than those that had been found for the chosen "good" models in Chapter 4

Many different experiments of this nature were tested. Yet, although the PCD and MSE results were different from the original ones found for the whole BA data set, they were not better. In most cases the PCD was around 52% and the MSE around 0.40.

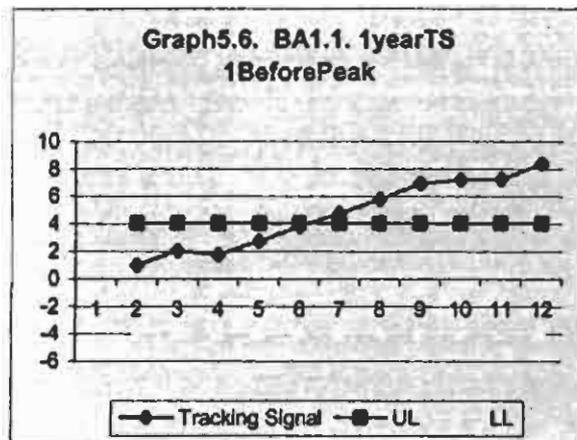
Other combination models were tested but the results were also not better. Thus, according to the criteria in Chapter 4, it was decided to continue with the nine data sections and find the tracking signals for each model across each section, using the same techniques as in the previous chapter.

A representation of the table that was created in Excel to find the TS for the first naïve model over section one can be seen below. This table (as well as many others) was modified to accommodate a maximum of 10 comparisons so that all the models over all the sections could be compared more fairly.

1 Before Peak		Upper Limit =4						Lower Limit =-4	
1 year	n	$Y_t$	$Y_{t-1}$	$e_t=Y_t-Y_{t-1}$	RSFE	Forecast e	Cumulative e	MAD	Tracking Signal
1	27	11							
2	28	11.85	11.00	0.850	0.850	0.850	0.850	0.850	1.000
3	29	12.5	11.85	0.650	1.500	0.650	1.500	0.750	2.000
4	30	12.1	12.50	-0.400	1.100	0.400	1.900	0.633	1.737
5	31	12.65	12.10	0.550	1.650	0.550	2.450	0.613	2.694
6	32	13.45	12.65	0.800	2.450	0.800	3.250	0.650	3.769
7	33	13.85	13.45	0.400	2.850	0.400	3.650	0.608	4.685
8	34	14.6	13.85	0.750	3.600	0.750	4.400	0.629	5.727
9	35	15.85	14.60	1.250	4.850	1.250	5.650	0.706	6.867
10	36	15.65	15.85	-0.200	4.650	0.200	5.850	0.650	7.154
11	37	15.4	15.65	-0.250	4.400	0.250	6.100	0.610	7.213
12	38	16.35	15.40	0.950	5.350	0.950	7.050	0.641	8.348
		17	16.35						MIN 1.000
						MAD	0.641		MAX 8.348
						TS	8.3475	MADs	

**Table 5.11.** Representation of the table that was created and used in Excel to find the tracking signal for the first naïve model over section one before it was modified to accommodate the maximum number of comparisons allowed.

Tracking signal graphs were drawn for each model over each section, making it easier to identify which models trip the signal and which ones manage to predict inside the 4, -4 limits. One such graph is also shown below. As expected, with the second exponential smoothing models included, the results obtained were many.



As before, the Upper Limit (UL) is 4 and the Lower Limit (LL) is -4. In the graph above, the signal is, indeed, tripped. This may indicate, among other things, that this model (Model 1.1.) is not very good in its predictions over this section (Section 1: Before Peak).

Undoubtedly, many results are obtained. These should be studied more carefully in order to determine whether they provide any insights that may assist in predicting interest rates better (as close to the original ones as possible).

The same techniques could be applied to other sections of the BA data set if these were to be chosen. The same goes for the Esc data set, which would have to be examined differently since it does not have the same shape as the BA data set.

Evidently, more can be done to analyse the results obtained. Difficulties in analyses may arise when these results increase considerably. Nonetheless, the aim is to try to predict interest rates as close as possible to the real ones and any insight that might help to do this may be worth pursuing.

## 5.5. Conclusion

The focus of Chapter 4 was on the different simple forecasting models that can be used to predict interest rates. Naïve models, moving average models and exponential smoothing models were applied to each of the two data sets (BA and Esc). Thereafter, specific criteria was used to compare and evaluate the accuracy of each model and to determine which of the models is able to predict interest rates as close to the original actual values as possible.

The focus of this chapter was on analysing the BA data set further, by applying the same techniques to smaller sections of the data set. Nine one-year sections were chosen by observing the shape of the BA graph. Subsequently, each of the models was applied to each of the sections of data, after which, Percentage of Correct Direction predictions (PCD), Mean Squared Error (MSE) and a new scoring system (used because of the volume of models and results produced) were the criteria that were used to determine the "best" models over each section.

It was interesting to note that not one of the models chosen as the "best" in the previous chapter was chosen as the "best" over any of the sections. PCD and MSE results at the sections were, on average, better than those obtained for the entire BA data set.

Each chosen model was then observed on how it performed over the other sections where it had not been chosen as the "best". A pattern seemed to emerge where Models 1.2. and 2.1. appeared to complement each other with regard to PCD. For example, when one model predicted the direction correctly 70% of the time, the other predicted 30%. Thus, it was decided to form a combination model and determine how well this new model performed. In theory, it was able to score the highest results. However, in practice (over the entire BA data set), the model did not do any better than the best results of Chapter 4. Other experiments seemed to do the same.

In keeping with the criteria of the previous chapter, results for tracking signals were obtained. However, such a large amount of results would have to be analysed in

greater detail in order to determine whether any meaningful insights could be found and used that would be advantageous in predicting interest rates better.

Evidently, more can be done to analyse any results obtained for whichever technique is being applied to whatever data set or part thereof. Difficulties in analyses may arise when these results increase considerably. Nonetheless, ultimately, the aim is to try to predict interest rates as close as possible to the real ones and any insight that might help to do this may be worth pursuing. The focus of the next chapter is on long-term predictions using more advanced forecasting models and volatility models.

## CHAPTER 6: LONG-TERM PREDICTIONS WITH FORECASTING AND VOLATILITY MODELS

### 6.1. Introduction

In pursuit of finding models that may help in predicting, remembering the importance of forecasting and the vital role it plays, not only for predicting interest rates (as in this study) but also for predicting many things in areas such as business, industry, government and our daily lives, is important. Pankratz (1983:3) explains that forecasting plays such a crucial role because “many important decisions depend on the anticipated future values of certain variables”. Moreover, Pankratz (1983:4) goes on to state that forecasts may be formed in many different ways and that the method chosen “depends on the purpose and importance of the forecasts as well as the costs of the alternative forecasting methods”.

In an attempt to manage interest rate risk by being able to predict the next rates correctly, in Chapter 4, several different forecasting models were used to try and predict interest rates for two data sets, namely, BA and Esc<sup>86</sup>. In this chapter, one of the aims is still to predict interest rates (as close to the actual ones as possible and with as little error as possible) but this time taking volatility models into account.

More specifically, the aim previously, was to try to predict the direction of the next interest rate (UP, CONSTANT, or DOWN) while supplying a point prediction of the next rate (one-step ahead). In contrast, the aim now is to try to find an interval wherein the future interest rates (not only in the short term but in the longer term as well<sup>87</sup>) are most likely to lie, using models based on the data, as well as first and possibly, second differences.

Thus, following on the aims set out for this chapter, two broad areas of work are investigated in the following sections: stationary time series is compared to non-stationary time series. Specifically:

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<sup>86</sup> Actual Banker's Acceptance data and Eskom data.

<sup>87</sup> Levenbach and Cleary (1984:22) define a *time horizon* as “the period of time into the future for which forecasts are required. The periods are generally short-term (one to three months), medium-term (three months to two years), and long-term (more than two years)”.

- ◆ Box-Jenkins<sup>88</sup> Forecasting Model
- ◆ Volatility Model

However, since long-term predictions are envisaged for this chapter, it is necessary to revise the data being used first, before continuing with the new models. This is done next.

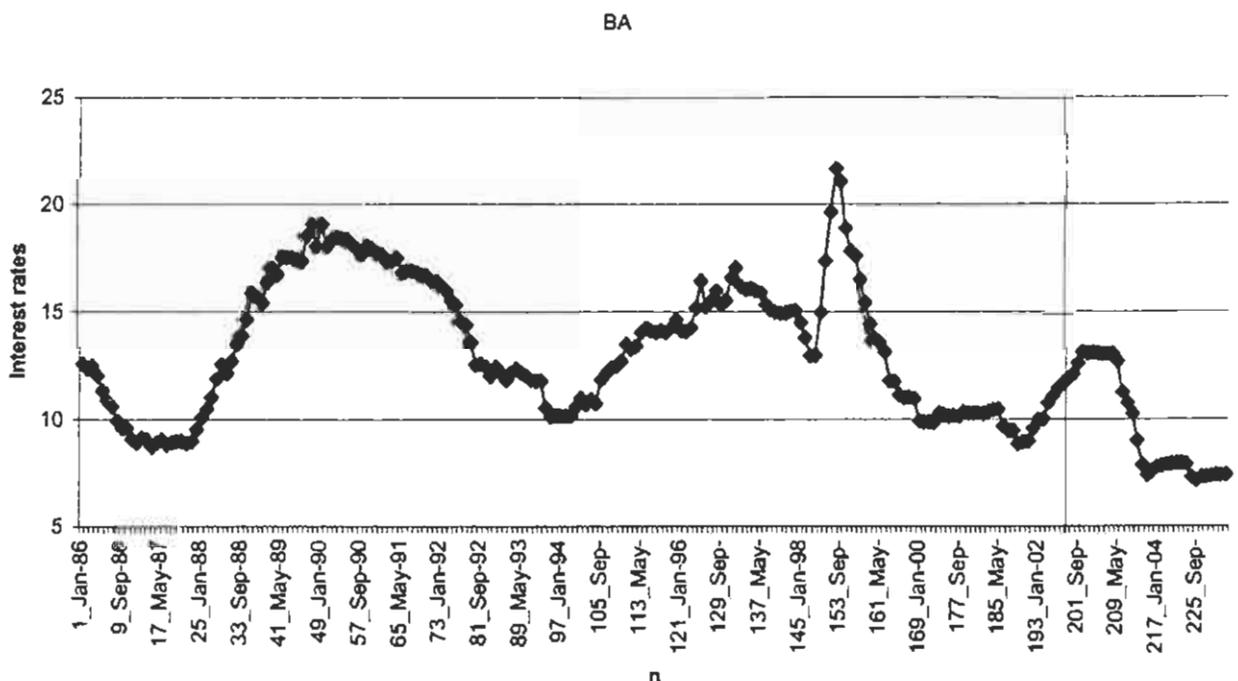
## 6.2. The Data

Clearly, more data is needed in order to ascertain whether future rates will lie within the intervals set out. Thus, more data was collected which includes all available real data up to the time of writing this chapter. As it happened, this was:

- Up to March 2005 for the BA data set (a total of 231 observations)
- Up to February 2005 for the Esc data set (a total of 230 observations)

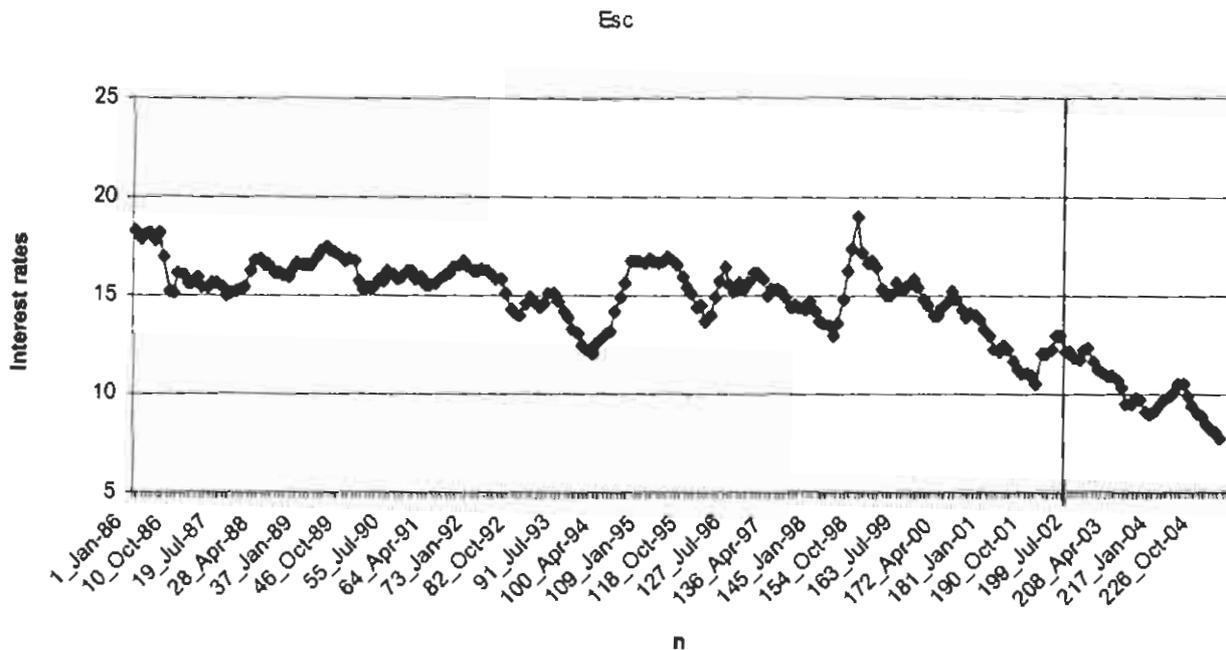
The graphs of the new (updated) data sets look as follows:

**Graph 6.1. New BA data set**



<sup>88</sup> Autoregressive models of order 2. The Autoregressive Integrated Moving Average (ARIMA) models introduced by George E. P. Box and Gwilym M. Jenkins contain autoregressive as well as moving average parameters and include differencing in the formulation of the model. The parameters are described by (p,d,q), where p refers to the autoregressive parameter, d is the number of differencing passes or "degree of differencing" (Gottman, 1981:262) and q refers to the moving average parameter.

**Graph 6.2. New Esc data set**



With this new data available, it is possible to apply different procedures or models to the previously known last data point and ascertain whether the predictions at that point are correct. The models used are explained next.

### 6.3. Box-Jenkins Forecasting Model

In Chapter 4 it was mentioned that the simple forecasting methods needed to be compared with more advanced or sophisticated models such as Box-Jenkins models.

In this section of Chapter 6, broadly, the following is looked at:

- A brief overview of what nonseasonal Box-Jenkins methods entail
- Requirements for a time series in order for it to be described by classical Box-Jenkins models
- What making a tentative identification of an appropriate Box-Jenkins model involves
- AR(2) models for the BA and Esc time series using Excel and STATISTICA

### 6.3.1. Box-Jenkins Methodology

According to Bowerman and O'Connell (1993:436), the Box-Jenkins methodology consists of a four-step iterative procedure:

- **Step 1:** Tentative identification: historical data are used to tentatively identify an appropriate Box-Jenkins model.
- **Step 2:** Estimation: historical data are used to estimate the parameters of the tentatively identified model.
- **Step 3:** Diagnostic checking: various diagnostics are used to check the adequacy of the tentatively identified model and, if need be, to suggest an improved model, which is then regarded as a new tentatively identified model.
- **Step 4:** Forecasting: once a final model is obtained, it is used to forecast future time series values.

In this section of the chapter, both data sets need to be analysed in turn, in order to make a tentative identification of an appropriate Box-Jenkins model. Since classical Box-Jenkins forecasting models describe *stationary* time series<sup>89</sup>, it has to be determined whether each time series that is being analysed is stationary. If the time series is, indeed, stationary, then it is possible to proceed with the tentative identification of an appropriate model. However, if the time series is nonstationary then **differencing** (taking first and sometimes even second differences<sup>90</sup>) may be used to transform the time series.

#### 6.3.1.1. A Stationary Time Series

Bowerman and O'Connell (1993:437) suggest that a time series is stationary "if the statistical properties (for example, the mean and the variance) of the time series are essentially constant through time". Pankratz (1983:11) states that a stationary time series "has a mean, variance, and autocorrelation function that are essentially constant through time". Thus, looking at a graph of the time series may give an indication as to whether it is stationary or nonstationary. The BA data set looks as

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<sup>89</sup> Bowerman and O'Connell (1993:4) define a time series as a "chronological sequence of observations on a particular variable".

<sup>90</sup> As explained in Bowerman and O'Connell (1993:437), the *first differences* of the time series values  $y_1, y_2, \dots, y_n$  are:  $z_t = y_t - y_{t-1}$  where  $t = 2, \dots, n$   
The *second differences* of the time series values  $y_1, y_2, \dots, y_n$  are, according to Bowerman and O'Connell (1993:441):  $z_t = (y_t - y_{t-1}) - (y_{t-1} - y_{t-2})$   
 $= y_t - 2y_{t-1} + y_{t-2}$  for  $t = 3, 4, \dots, n$

though it could be stationary, although the Esc data set looks more like a stationary time series than the BA series.

Therefore, there are more concrete ways to determine whether a time series is stationary or not. These include analysing the behaviour of the Sample Autocorrelation Function (SAC) and Sample Partial Autocorrelation Function (SPAC) for the values<sup>91</sup> of a stationary time series  $z_b, z_{b+1}, \dots, z_n$ .

a. Stationary Time Series: Three Conditions for Stationarity

Parameter estimates are used to determine whether the model that is chosen satisfies the stationarity conditions. These are discussed later on in the section on nonseasonal autoregressive models (6.3.1.2.).

b. Stationary Time Series: Sample Autocorrelation Function (SAC)

In considering a working series of time series values  $z_b, z_{b+1}, \dots, z_n$ , the sample autocorrelation function is, according to Bowerman and O'Connell (1993:445), a "listing, or graph, of the sample autocorrelations at lags  $k = 1, 2, \dots$ ". The *sample autocorrelation at lag k*, denoted by  $r_k$ , is, as Bowerman and O'Connell (1993:442) state:

$$r_k = \frac{\sum_{t=b}^{n-k} (z_t - \bar{z})(z_{t+k} - \bar{z})}{\sum_{t=b}^n (z_t - \bar{z})^2}$$

where  $\bar{z} = \frac{\sum_{t=b}^n z_t}{(n-b+1)}$

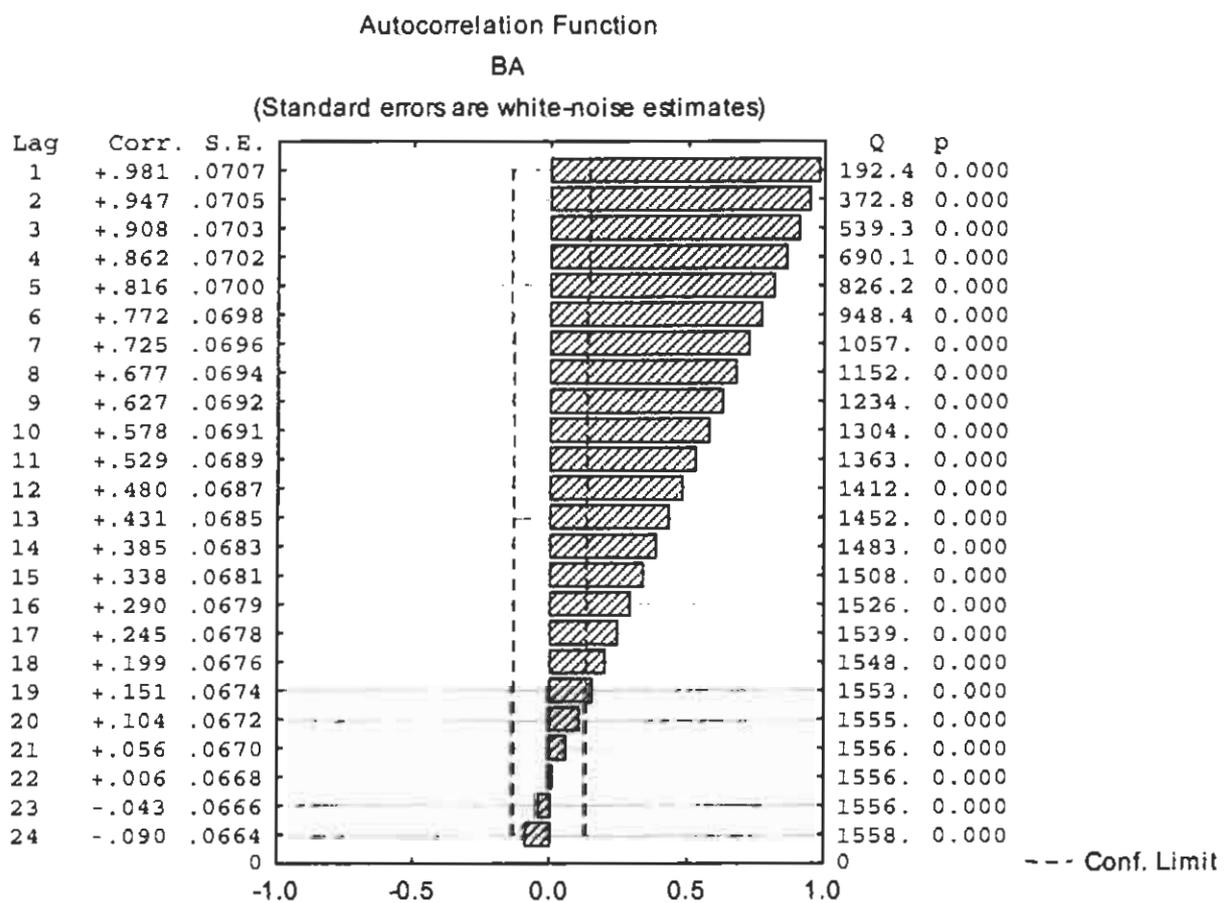
The SAC can be used to find a stationary time series because according to Bowerman and O'Connell (1993:450), in general, it can be shown that for *nonseasonal data*:

<sup>91</sup> Whether they be the original or transformed time series values.

1. If the SAC of the time series values  $z_b, z_{b+1}, \dots, z_n$  either *cuts off fairly quickly* or *dies down fairly quickly*, then the time series values should be considered *stationary*.
2. If the SAC of the time series values  $z_b, z_{b+1}, \dots, z_n$  *dies down extremely slowly*, then the time series values should be considered *nonstationary*.

The SAC was computed using STATISTICA for both the BA time series as well as the Esc time series and the resulting graphs are shown below:

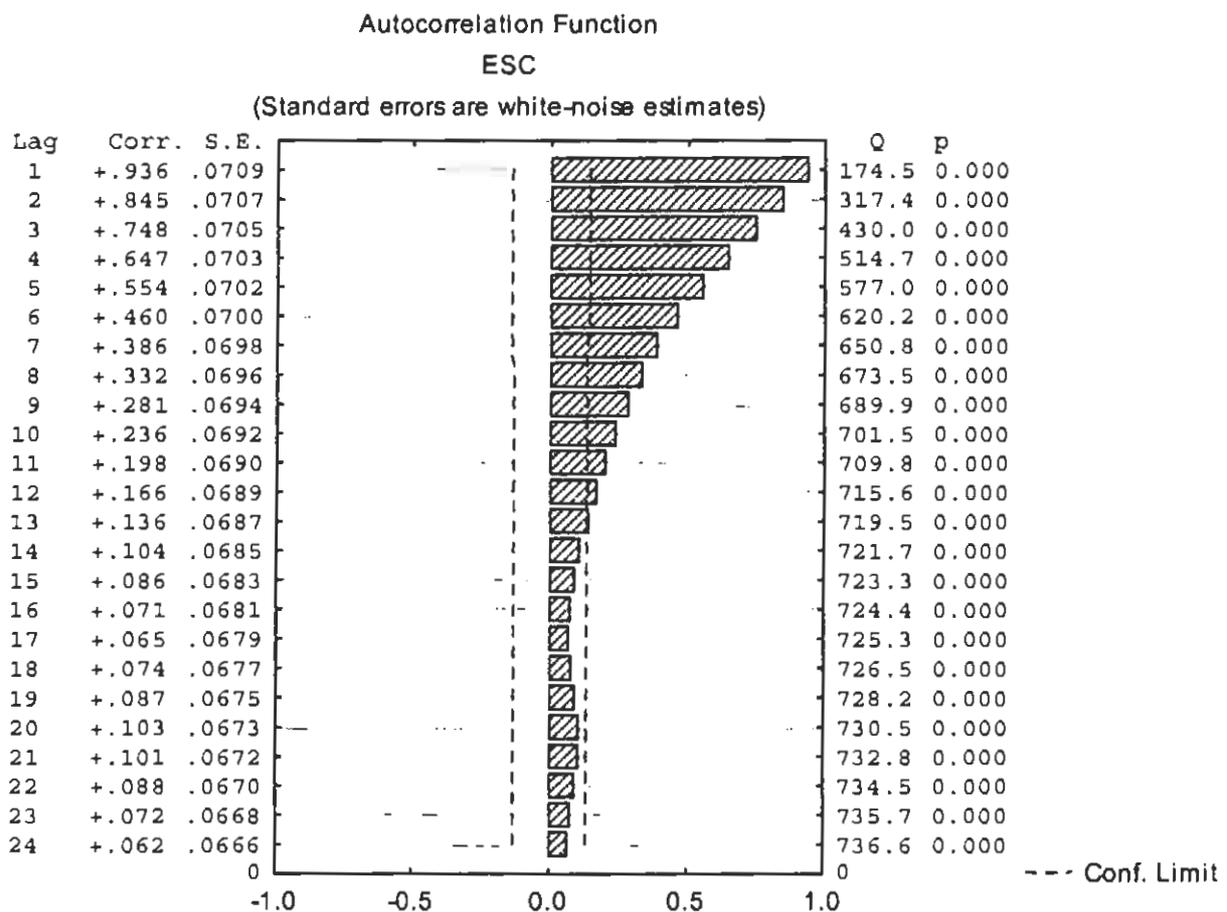
**Graph 6.3. STATISTICA output of the SAC for the original BA values**



In the graph of the SAC for the BA time series (above), it can be seen that the SAC does not cut off fairly quickly nor die down as quickly as for example, lag 10. Here, the terms "fairly quickly" and "extremely slowly" are, to some extent, subjective. Thus, it is possible that this time series is stationary. Nevertheless, it may be necessary to obtain first differences and find the SAC for those values.

In the graph of the SAC for the Esc time series (below), it can be seen that the SAC seems to die down in a damped exponential fashion with no oscillation. It does not cut off fairly quickly, however, it is still possible that this time series is stationary. Once again, the terms “fairly quickly” and “extremely slowly” are rather subjective. As before, it may be necessary to find the SAC for the first differences, although Gottman (1981:262) does warn about the dangers of overdifferencing – it will “introduce spurious and meaningless patterns into the transformed, overdifferenced series”.

**Graph 6.4. STATISTICA output of the SAC for the original Esc values**



c. Stationary Time Series: Sample Partial Autocorrelation Function (SPAC)

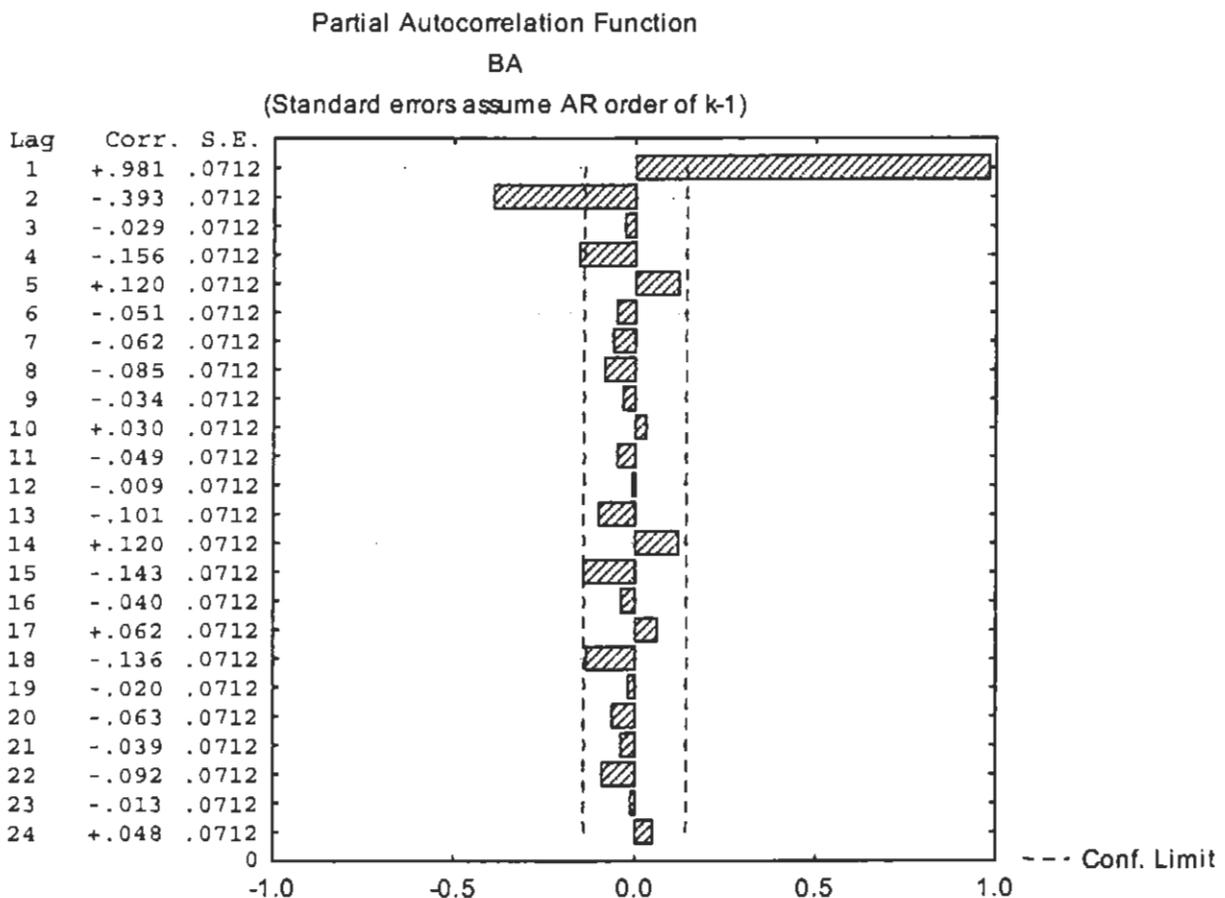
The sample partial autocorrelation function is a “listing, or graph, of the sample partial autocorrelations at lags  $k = 1, 2, \dots$ ” (Bowerman & O’Connell, 1993:454). The *sample partial autocorrelation at lag k*, denoted by  $r_{kk}$ , is defined in Bowerman and O’Connell (1993:453) as:

$$r_{kk} = \begin{cases} r_1 & \text{if } k = 1 \\ \frac{r_k - \sum_{j=1}^{k-1} r_{k-1,j} r_{k-j}}{1 - \sum_{j=1}^{k-1} r_{k-1,j} r_j} & \text{if } k = 2, 3, \dots \end{cases}$$

where  $r_{kj} = r_{k-1,j} - r_{kk} r_{k-1,k-j}$  for  $j = 1, 2, \dots, k-1$

The behaviour of the SPAC helps in identifying Box-Jenkins models. The lag at which the SPAC cuts off for the series gives an indication of what type of model it should be tentatively identified as. The SPAC for both the BA time series as well as the Esc time series were computed using STATISTICA and the resulting graphs are shown below:

**Graph 6.5. STATISTICA output of the SPAC for the original BA values**

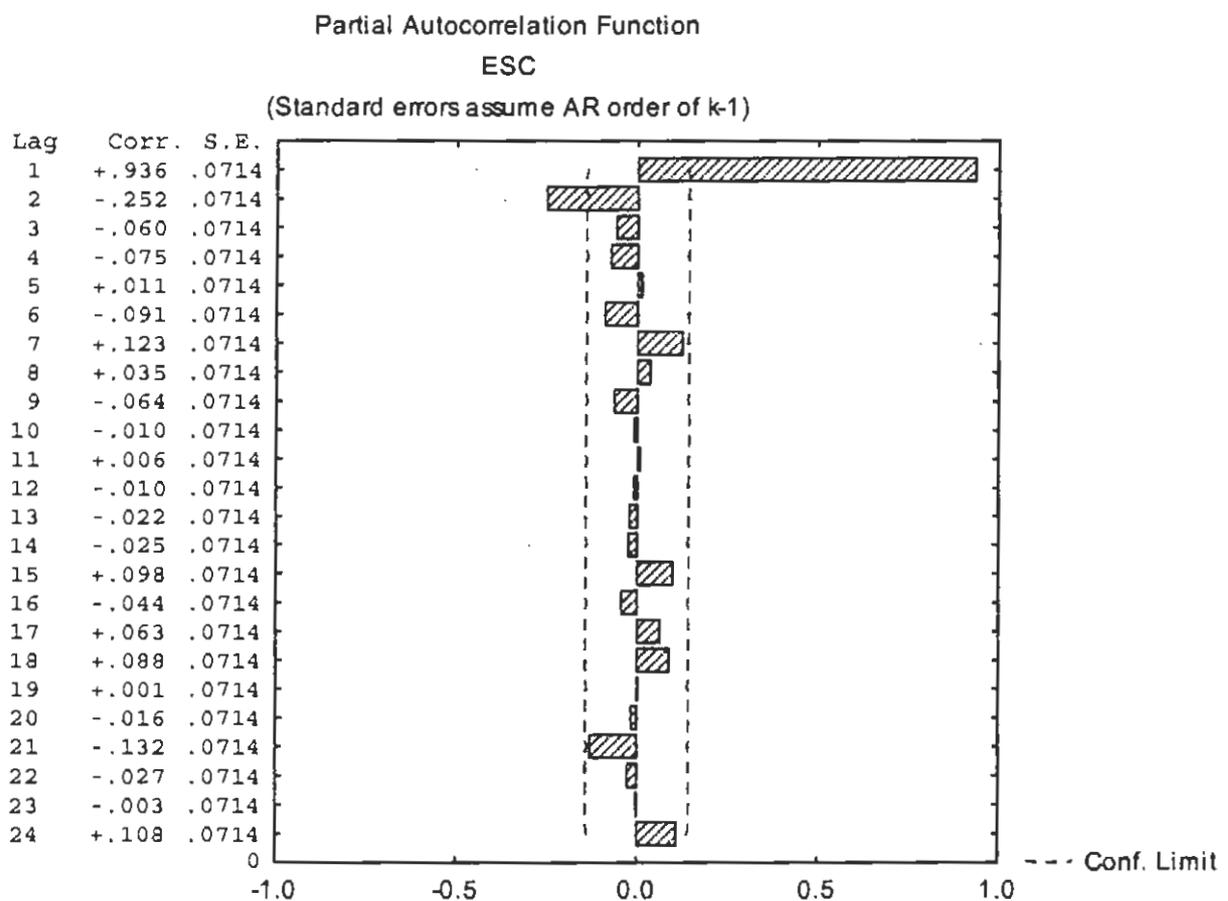


From the graph above, it can be seen that there is a spike at lag 1 and another spike at lag 2. After that, there is only one more spike at lag 4. However, it is possible to conclude from the graph above (BA) that the SPAC seems to cut off after lag 2.

From the graph below, again it can be seen that there is a spike at lag 1 and another spike at lag 2. After that, however, there are no more spikes crossing the dotted lines over the 24 lags plotted. Thus, it is possible to conclude from the graph below (Esc) that the SPAC cuts off after lag 2.

The significance in each case of the SPAC cutting off after lag 2 suggests that these models may be tentatively identified as autoregressive models of order 2 or AR(2) models. Such models are described next.

**Graph 6.6. STATISTICA output of the SPAC for the original Esc values**



### 6.3.1.2. Nonseasonal Autoregressive Models

According to Bowerman and O'Connell (1993:457), once an original time series  $y_1, y_2, \dots, y_n$  has been transformed into stationary time series values  $z_b, z_{b+1}, \dots, z_n$ , the SAC and SPAC are used to "identify a Box-Jenkins model describing the stationary time series values. Two useful types of Box-Jenkins models are *autoregressive models* and *moving average models*".

Bowerman and O'Connell (1993:469) go on to explain that the model

$$z_t = \delta + \phi_1 z_{t-1} + \phi_2 z_{t-2} + \dots + \phi_p z_{t-p} + a_t$$

is called "the *nonseasonal autoregressive model of order p*" and that the term "autoregressive" refers to the fact that "this model expresses the current time series value  $z_t$  as a function of past time series values  $z_{t-1}, z_{t-2}, \dots, z_{t-p}$ ".

$\phi_1, \phi_2, \dots, \phi_p$  are unknown parameters relating  $z_t$  to  $z_{t-1}, z_{t-2}, \dots, z_{t-p}$ .

$a_t$  is a random shock<sup>92</sup>

$$\delta = \mu(1 - \phi_1 - \phi_2 - \dots - \phi_p)$$

For this type of model, certain conditions for the Theoretical Autocorrelation Function (TAC) and Theoretical Partial Autocorrelation Function (TPAC) hold true and if for the time series values  $z_b, z_{b+1}, \dots, z_n$

1. the SAC *dies down* and
  2. the SPAC has spikes at lags 1, 2, ...,  $p$  and *cuts off* after lag  $p$ , then
- it should be tentatively concluded that "the time series values are described by the nonseasonal autoregressive model of order  $p$ " (Bowerman & O'Connell, 1993:469).

This is the case for the BA time series as well as the Esc time series. In each instance, the SPAC has spikes at lags 1 and 2 and cuts off after lag 2. Thus, the models may be tentatively identified as autoregressive models of order 2.

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<sup>92</sup> The random shock  $a_t$  is, as Bowerman and O'Connell (1993:457) explain, a value that is "assumed to have been randomly selected from a *normal distribution* that has *mean zero* and a *variance* that is the *same* for each and every time period  $t$ ". In addition, the random shocks  $a_1, a_2, a_3, \dots$  in different time periods "are assumed to be *statistically independent* of each other" (Bowerman & O'Connell, 1993:458).

Bowman and O'Connell (1993:489) identify the three conditions for stationarity<sup>93</sup> for

a second-order Autoregressive Model  $z_t = \delta + \phi_1 z_{t-1} + \phi_2 z_{t-2} + a_t$

They are:

$$\phi_1 + \phi_2 < 1$$

$$\phi_2 - \phi_1 < 1$$

$$|\phi_2| < 1$$

The parameter estimates calculated in STATISTICA are both **significant** (indicated in red when computed in the program) for both the BA as well as the Esc time series.

Below they are indicated in bold:

Variable: BA			
Transformations:			
Model: (2,0,0)			
No. of obs.:197 Initial SS=37307. Final SS=57.495 (.1541%) MS=.29636			
Parameters (p/Ps-Autoregressive, q/Qs-Moving aver.); highlight: p<.05			
	Const.	p(1)	p(2)
Estimate:	13.192	<b>1.3758</b>	<b>-0.4032</b>
Std.Err.:	1.2823	.06540	.06553

(a)

Variable: ESC			
Transformations:			
Model: (2,0,0)			
No. of obs.:196 Initial SS=45809. Final SS=41.390 (.0904%) MS=.21445			
Parameters (p/Ps-Autoregressive, q/Qs-Moving aver.); highlight: p<.05			
	Const.	p(1)	p(2)
Estimate:	15.255	<b>1.2782</b>	<b>-0.3377</b>
Std.Err.:	.52676	.06778	.06861

(b)

**Output 6.1. Output given in STATISTICA showing how both parameter estimates are significant in both the (a) BA and (b) Esc time series.**

In each case, the following can be shown:

BA		Esc	
p(1)	1.3758	p(1)	1.2782
p(2)	-0.4032	p(2)	-0.3377
1	1.3758 + (-0.4032) = 0.9726 which is <1	1	1.2782 + (-0.3377) = 0.9405 which is <1
2	(-0.4032) - 1.3758 = -1.779 which is <1	2	(-0.3377) - 1.2782 = -1.6159 which is <1
3	-0.4032  = 0.4032 which is <1	3	-0.3377  = 0.3377 which is <1

(a)

(b)

**Table 6.1. Table showing how the three conditions for stationarity are met for (a) BA time series and (b) Esc time series, using output from STATISTICA.**

<sup>93</sup> According to Bowman and O'Connell (1993:488), the Box-Jenkins methodology "requires that the model to be used in describing and forecasting a time series be both *stationary* and *invertible*". There are no conditions for invertibility for this model.

The tables above indicate that in each case, the models adhere to the conditions for stationarity for this type of model (an AR(2) model), that is, the three conditions are satisfied. Thus, it may be said that both the time series are stationary.

### 6.3.1.3. Forecasting with Nonseasonal Autoregressive Models

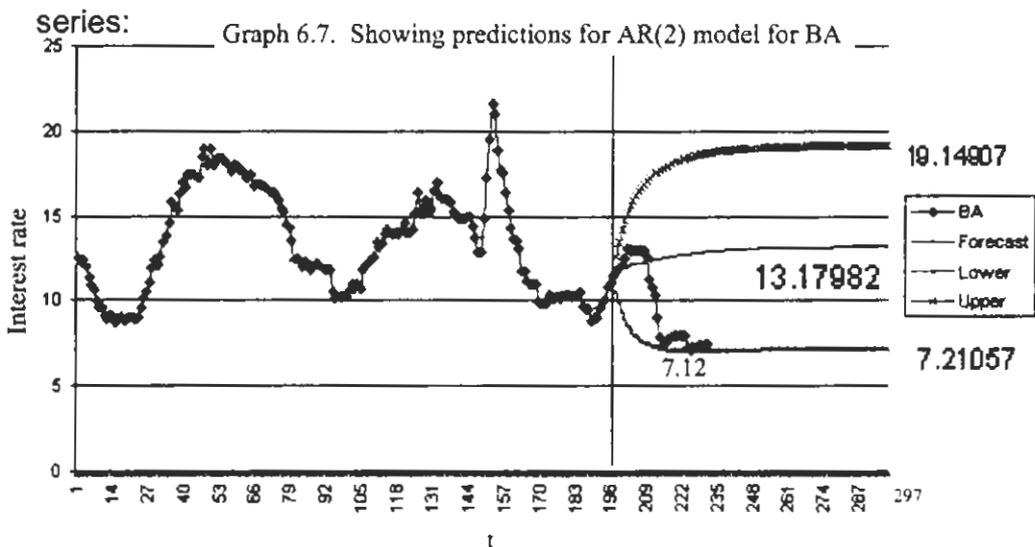
Univariate Box-Jenkins models or UBJ models are, as Pankratz (1983:5) mentions, often referred to as ARIMA models. "Univariate", "one variable" or single-series means that forecasts "are based *only on past values of the variable being forecast*" (Pankratz, 1983:5) and not on any other data series. In addition, an ARIMA model "is an algebraic statement telling how observations on a variable are statistically related to past observation on the same variable" (Pankratz, 1983:5).

#### a. Forecasting with AR Models: AR(2) Models

Having tentatively identified the models for the BA and Esc time series as second-order autoregressive models, forecasts<sup>94</sup> may now be made using the data, STATISTICA and

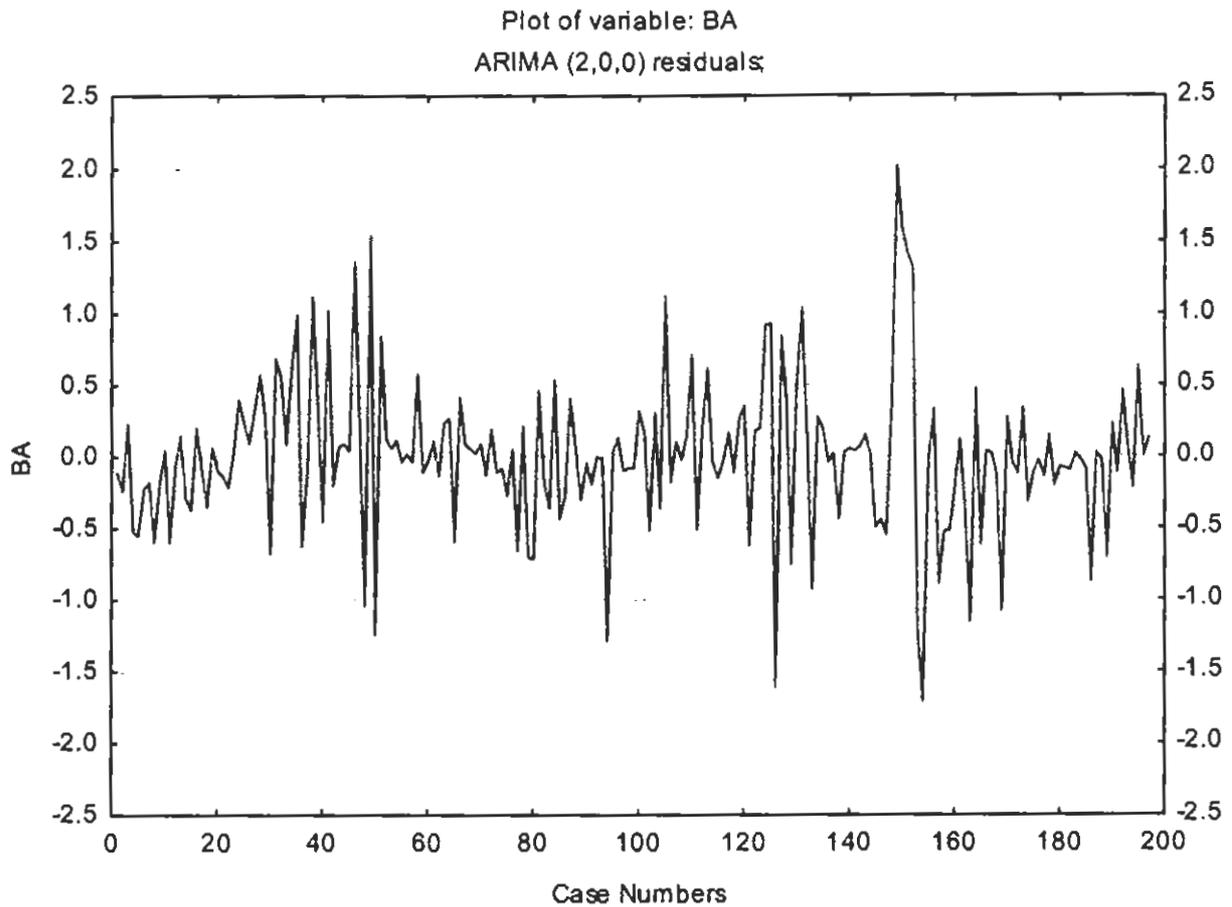
$$z_t = \delta + \phi_1 z_{t-1} + \phi_2 z_{t-2} + a_t \quad (\text{Eq. 1})$$

Forecasts were made, firstly, for the original BA and Esc time series. The next 100 values from the previously last known data point were predicted in each case. The prediction graphs are shown below, along with graphs of the residuals for each time

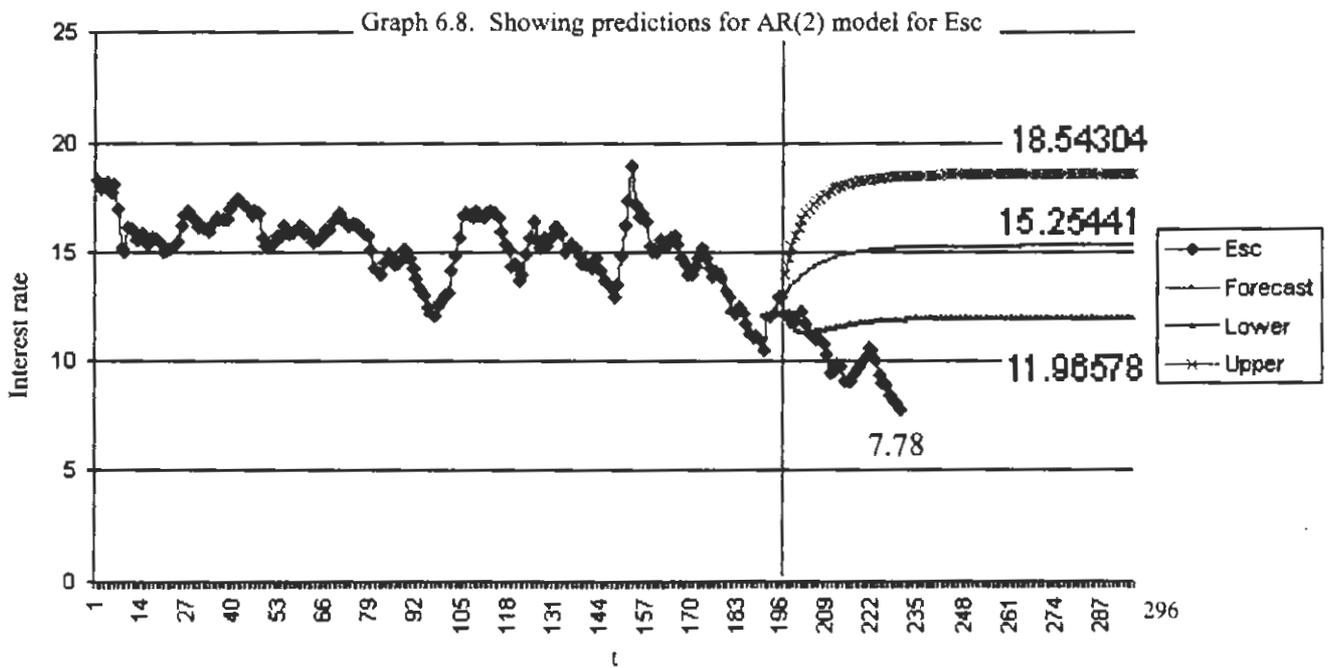


<sup>94</sup> Bowerman and O'Connell (1993:3) state that "predictions of future events and conditions are called forecasts, and the act of making such predictions is called forecasting".

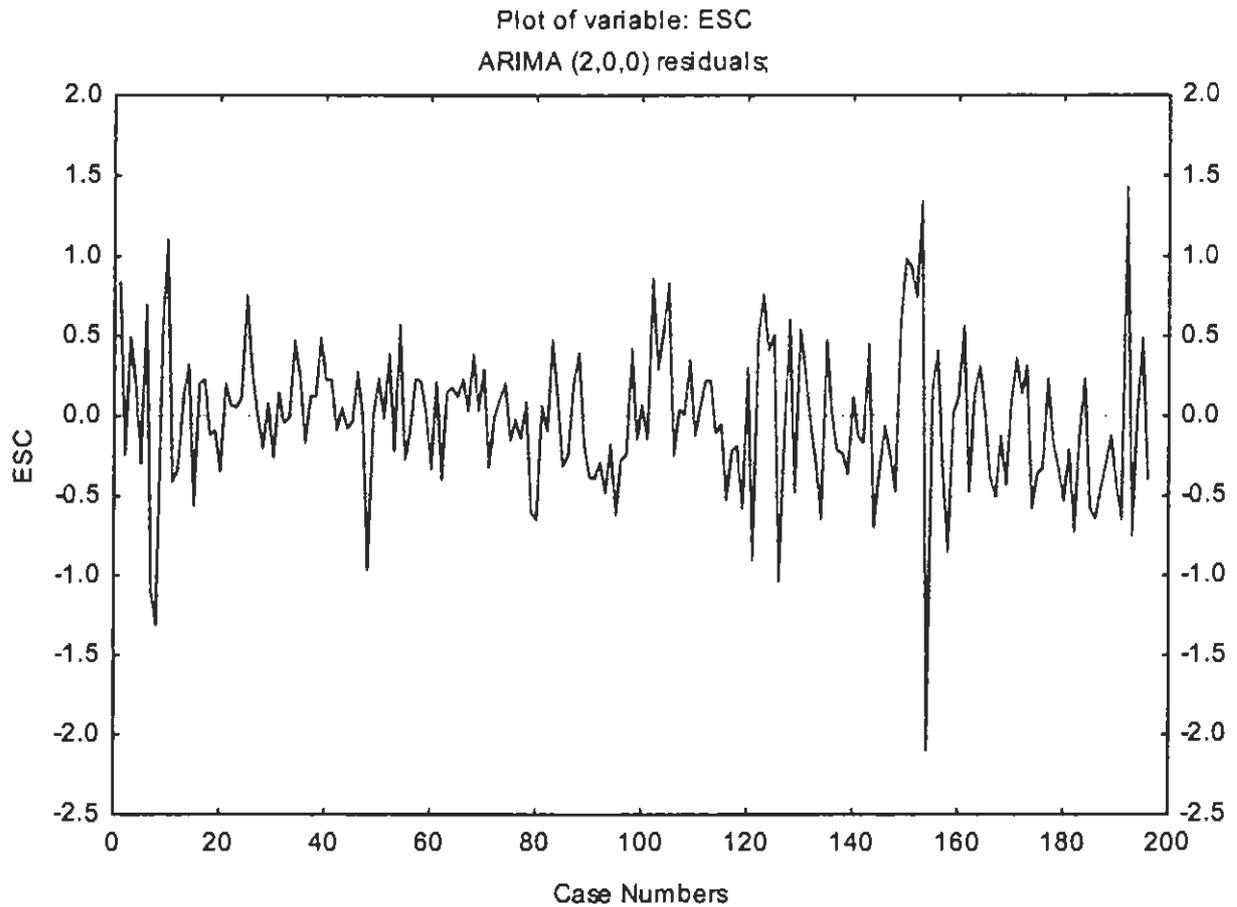
**Output 6.2. STATISTICA output – graph of the residuals for the original BA time series**



In each case, analyses may be performed on these residuals.



**Output 6.3. STATISTICA output – graph of the residuals for the original Esc time series**



In addition, a short table showing some of the predictions is presented below:

Forecasts; Model:(2,0,0) Input: BA Start of origin: 1 End of origin: 197					Forecasts; Model:(2,0,0) Input: Esc Start of origin: 1 End of origin: 196				
CaseNo.	Forecast	Lower 95.00%	Upper 95.00%	Std.Err.	CaseNo.	Forecast	Lower 95.00%	Upper 95.00%	Std.Err.
198	11.58211	10.50842	12.6558	0.544393	197	13.07448	12.16111	13.98785	0.463091
199	11.69961	9.87342	13.5258	0.925934	198	13.24975	11.76747	14.73203	0.751536
200	11.78784	9.36023	14.21546	1.230875	199	13.42835	11.53143	15.32527	0.961766
...	...	...	...	...	...	...	...	...	...
295	13.17855	7.20935	19.14776	3.02657	294	15.25438	11.96575	18.54301	1.667381
296	13.1792	7.20997	19.14843	3.026581	295	15.2544	11.96577	18.54302	1.667381
297	13.17982	7.21057	19.14907	3.026592	296	15.25441	11.96578	18.54304	1.667381

(a) (b)

**Table 6.2. Table showing some of the values (to where the intervals level off) predicted in STATISTICA for an AR(2) model using (a) BA time series and (b) Esc time series.**

From the forecasting graphs, it can be seen that the model is able to predict an interval for the BA time series wherein (for the most part) the future values are most

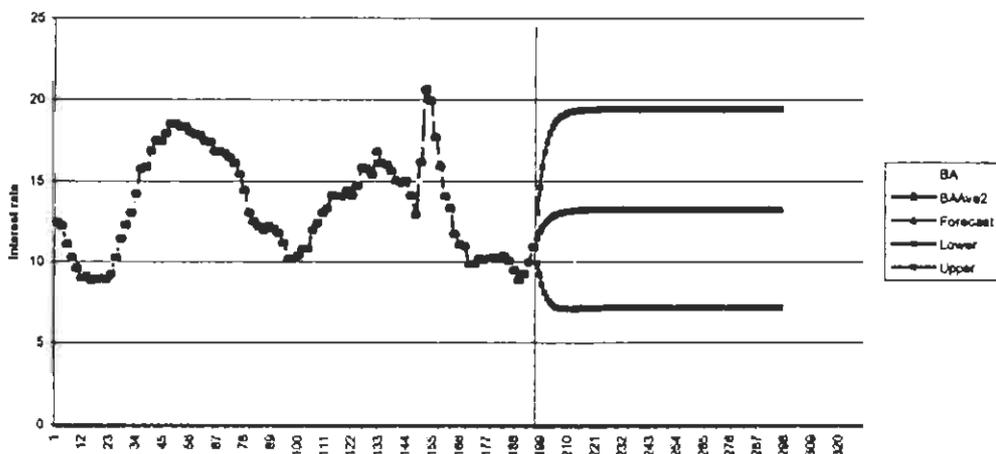
likely to lie. However, should the rates go any lower, it may be that the interval (the lower 95% limit) is too narrow. As for the Esc time series, the interval that is predicted is initially correct. However, after about only six predictions, the interval no longer contains the future interest rate values and is in a region far above that of the actual data, especially (as it looks from the newly acquired data) if the rates go any lower.

b. Forecasting Averages with AR Models

It was decided that, since these models should provide long-term predictions for the data, it would be interesting to see what type of intervals would be produced if averages of two, three and other consecutive data values were taken and AR(2) models applied to them<sup>95</sup>. Thus, for each data series, in turn, the same procedure was followed.

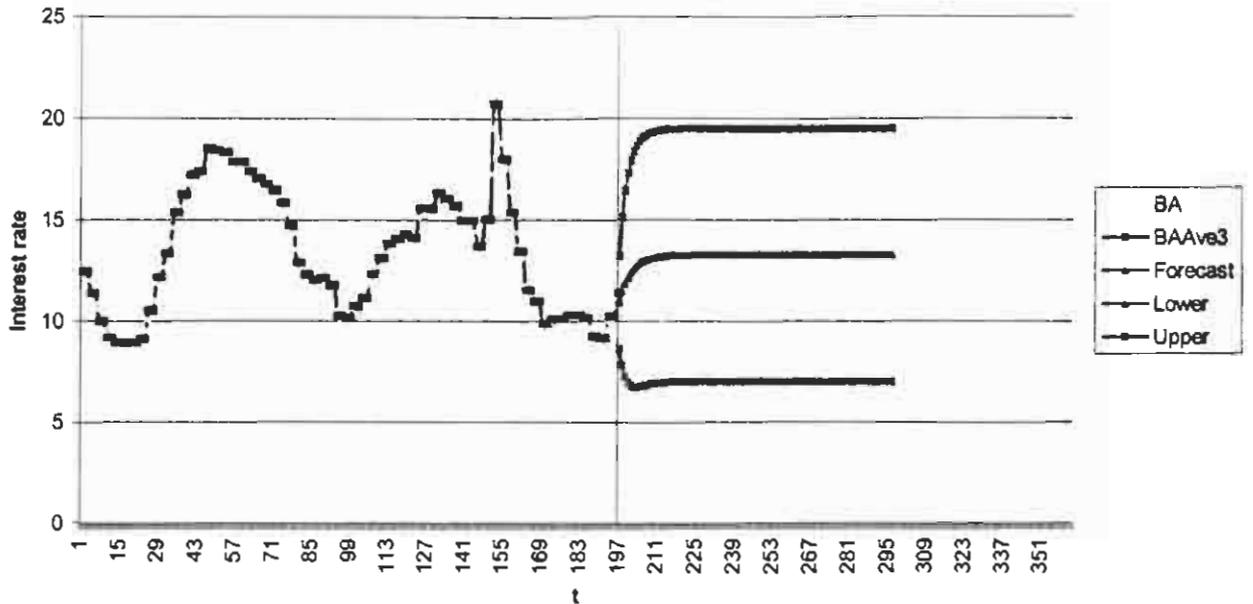
Examining the SAC and SPAC as well as the parameter estimates is essential. However, the point of this exercise was primarily to determine whether this averages technique would produce models that would be able to predict intervals that would capture the real data. Therefore, although the administrative part was done, only graphs showing the required information are provided below:

Graph 6.9. Showing predictions for AR(2) model for BAAve2

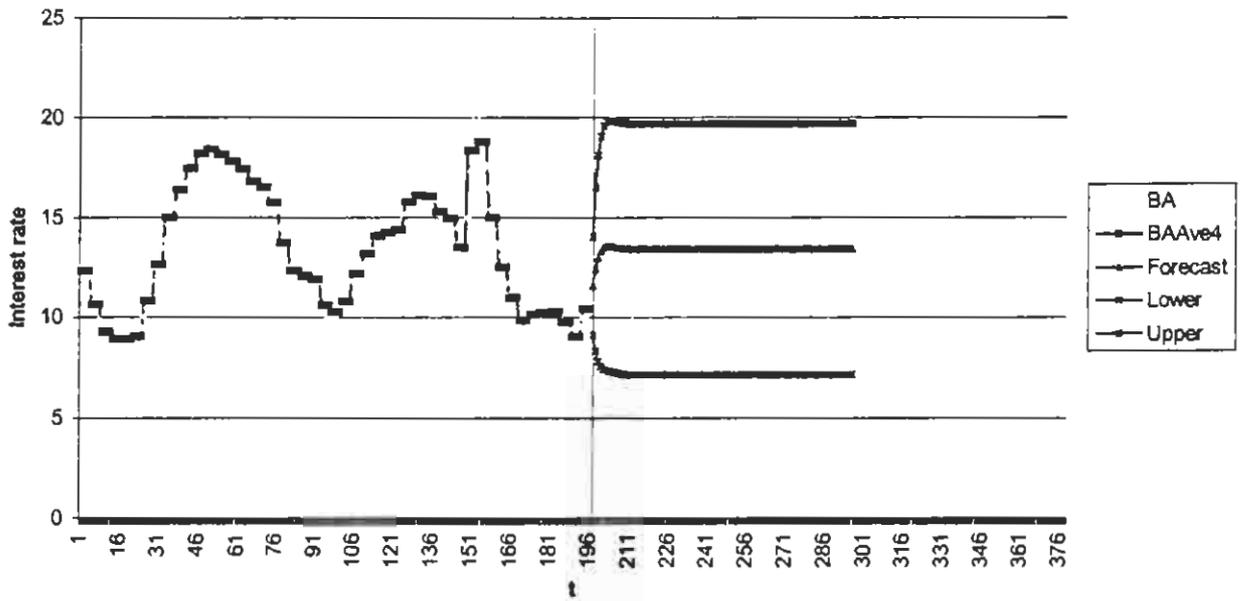


<sup>95</sup> Pankratz (1983:11) states that "building an ARIMA model requires an adequate sample size" and goes on to say that Box and Jenkins suggest that approximately 50 observations is the minimum required number. Thus, only averages until five were done since for Ave2 98 values were obtained and used, for Ave3 65, for Ave4 49 and for Ave5 39. However, it would be interesting to see what kind of results the averages of six and twelve values would produce.

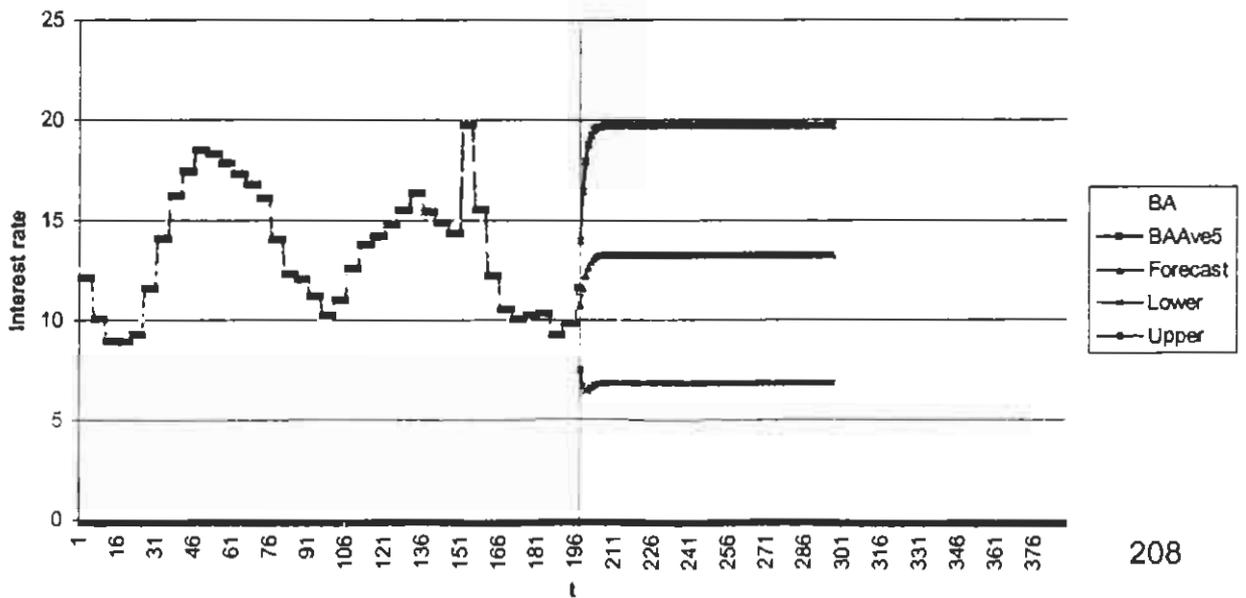
Graph 6.10. Showing predictions for AR(2) model for BAAve3



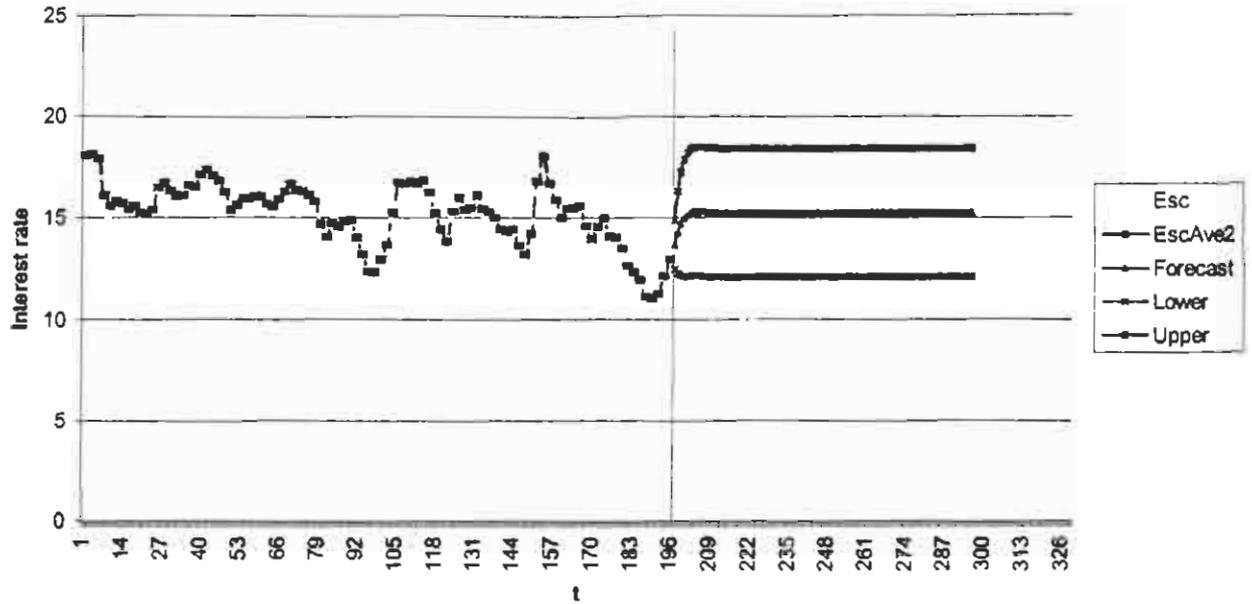
Graph 6.11. Showing predictions for AR(2) model for BAAve4



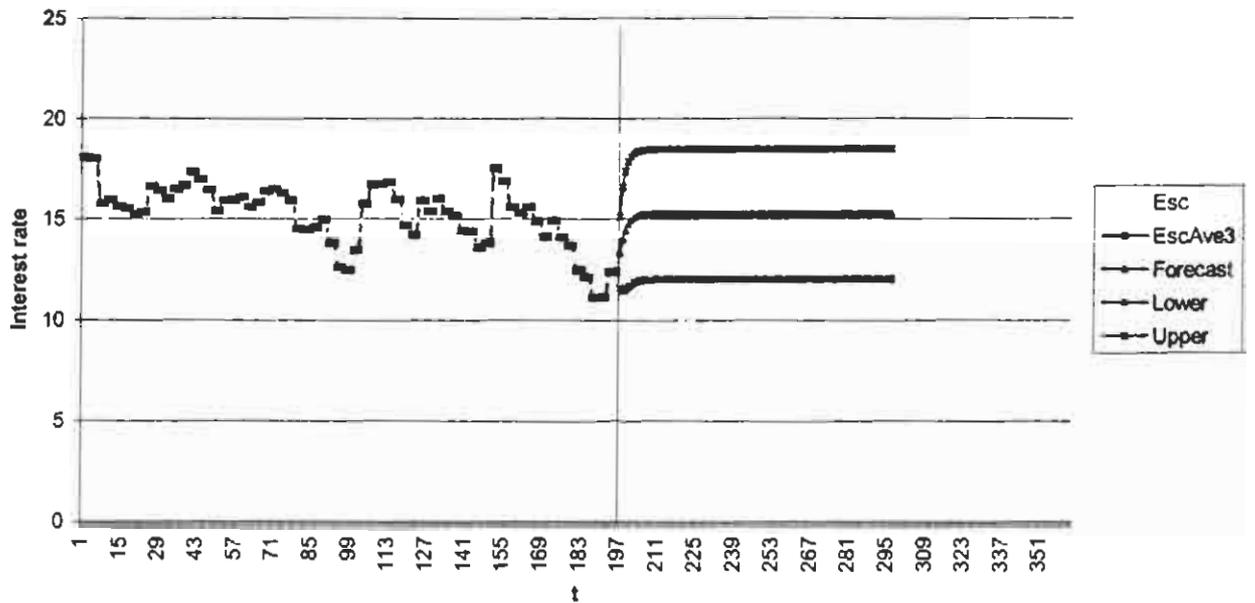
Graph 6.12. Showing predictions for AR(2) model for BAAve5



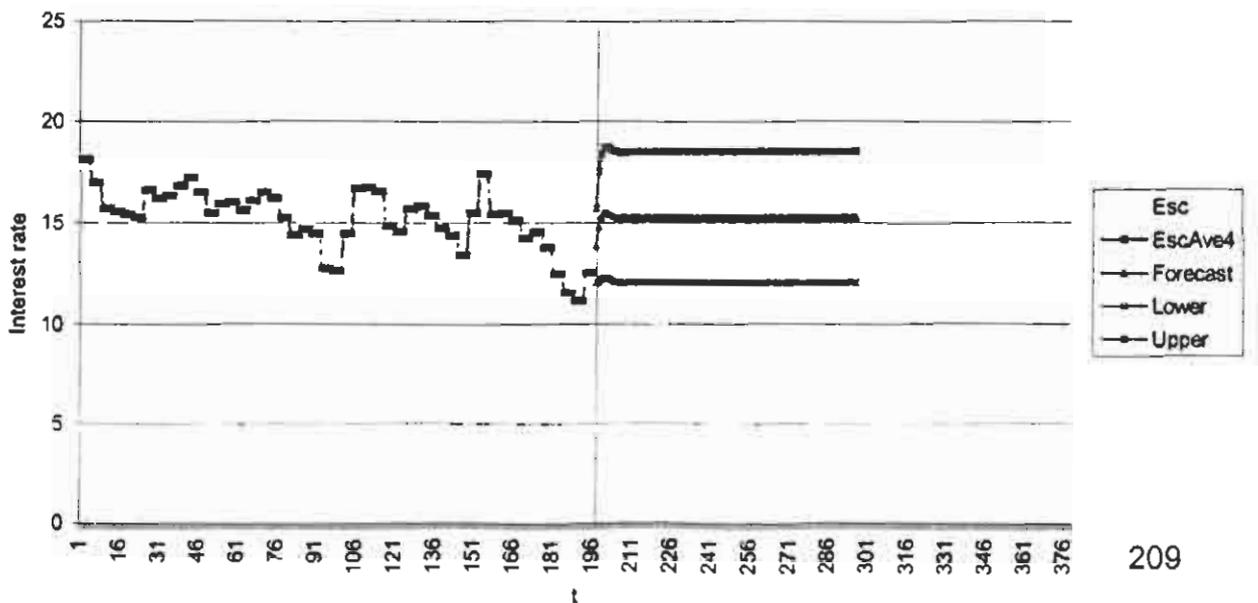
Graph 6.13. Showing predictions for AR(2) model for EscAve2



Graph 6.14. Showing predictions for AR(2) model for EscAve3



Graph 6.15. Showing predictions for AR(2) model for EscAve4



Graph 6.16. Showing predictions for AR(2) model for EscAve5

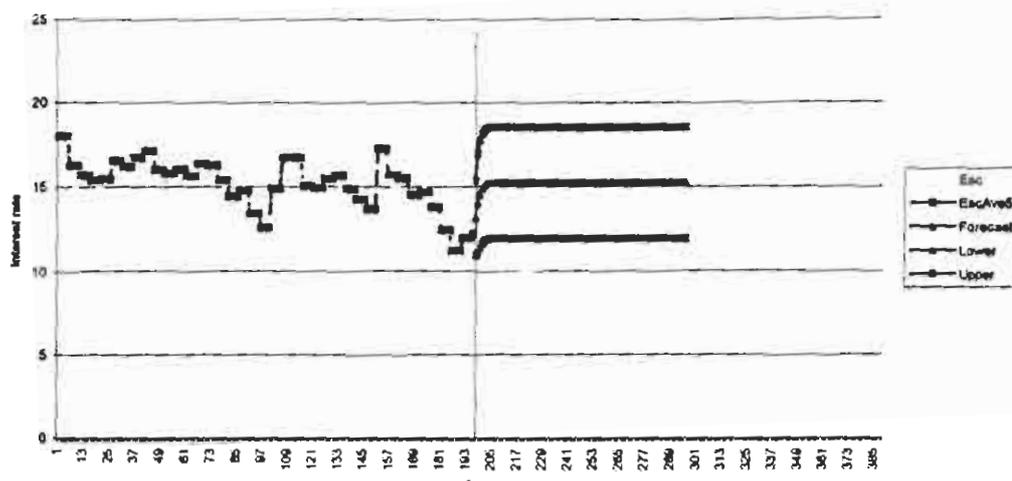


Table 6.3 below shows the last prediction values for each model, that are reflected in the graphs<sup>96</sup> above:

	t	Forecast	Lower 95.00%	Upper 95.00%	Std.Err.
<b>BA</b>	<b>297</b>	<b>13.17982</b>	<b>7.21057</b>	<b>19.14907</b>	<b>3.026592</b>
<b>Ave2</b>	<b>198</b>	<b>13.28155</b>	<b>7.156807</b>	<b>19.4063</b>	<b>3.085125</b>
<b>Ave3</b>	<b>165</b>	<b>13.25401</b>	<b>7.010769</b>	<b>19.49726</b>	<b>3.123229</b>
<b>Ave4</b>	<b>149</b>	<b>13.41759</b>	<b>7.132212</b>	<b>19.70298</b>	<b>3.122557</b>
<b>Ave5</b>	<b>139</b>	<b>13.27738</b>	<b>6.839614</b>	<b>19.71515</b>	<b>3.174295</b>

(a)

	t	Forecast	Lower 95.00%	Upper 95.00%	Std.Err.
<b>Esc</b>	<b>296</b>	<b>15.25441</b>	<b>11.96578</b>	<b>18.54304</b>	<b>1.667381</b>
<b>Ave2</b>	<b>198</b>	<b>15.24784</b>	<b>12.07146</b>	<b>18.42422</b>	<b>1.599988</b>
<b>Ave3</b>	<b>165</b>	<b>15.24179</b>	<b>12.01383</b>	<b>18.46976</b>	<b>1.614812</b>
<b>Ave4</b>	<b>149</b>	<b>15.27594</b>	<b>12.04955</b>	<b>18.50233</b>	<b>1.602862</b>
<b>Ave5</b>	<b>139</b>	<b>15.23595</b>	<b>11.91058</b>	<b>18.56132</b>	<b>1.639651</b>

(b)

**Table 6.3. Table showing the last values predicted each time for the different models, corresponding to the graphs above, for (a) BA time series and (b) Esc time series.**

From the graphs and table above, the following is evident:

For the BA time series, the values predicted are similar for the different models. Although in each case they are not able to predict an interval that catches the peak of the Asian Crisis, the interval each time is able to include most of the other values.

<sup>96</sup> In the graphs, the Averages are shown as follows (for example, BA):

Actual Data	Ave2	Ave3
12.55	12.43	12.43
12.3	12.43	12.43
12.45	12.23	12.43
12	12.23	11.38
11.3	11.08	11.38
10.85	11.08	11.38

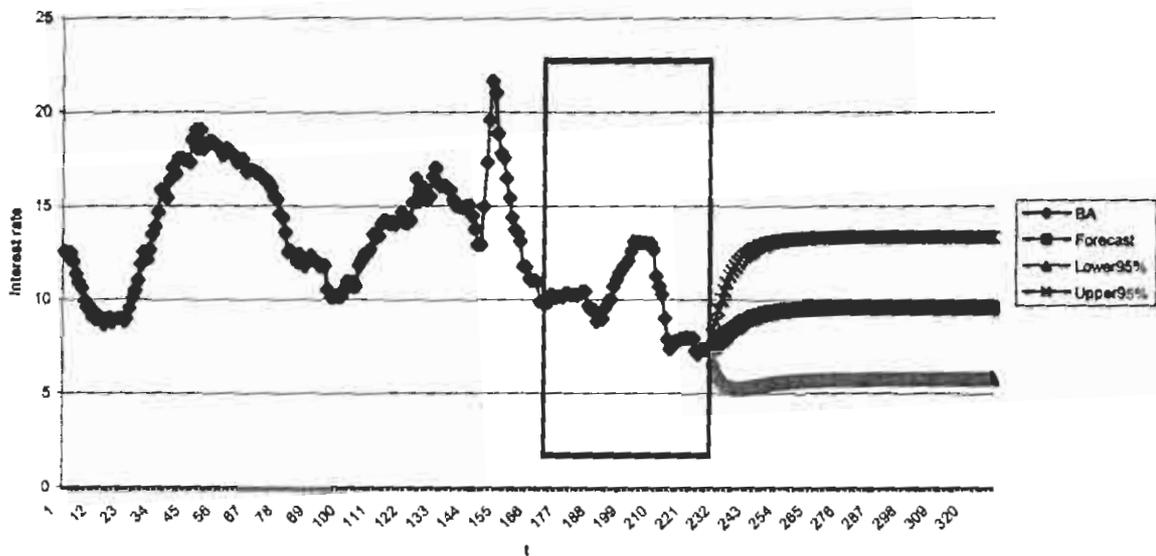
7.12 is the lowest interest rate for the BA data set. Therefore, only Ave3 and Ave5 would be able to include it in their intervals. Another interesting point is that the lower limit for Ave5 seems to end slightly lower than the others.

As for the Esc time series, again, the values predicted are similar for the different models. In each case the interval is not able to include the peak at the Asian Crisis. Also, all the models seem to miss the newly acquired data completely.

c. Forecasting with AR Models: Predictions for the Future

In addition to the above, it was decided to take the last 60 values of all the known data for each data set and make predictions for the future. The resultant graphs are shown below, along with a summary table of the predictions at which they end:

Graph 6.17. BA: AR(2) Predictions Now



Forecasts; Model:(2,0,0); BA				
CaseNo.	Forecast	Lower 95.00%	Upper 95.00%	Std.Err.
62	7.43232	6.74995	8.11468	0.34089
63	7.55410	6.30826	8.79994	0.62239
...	...	...	...	...
160	9.54852	5.77974	13.31730	1.88277
161	9.54853	5.77975	13.31730	1.88277

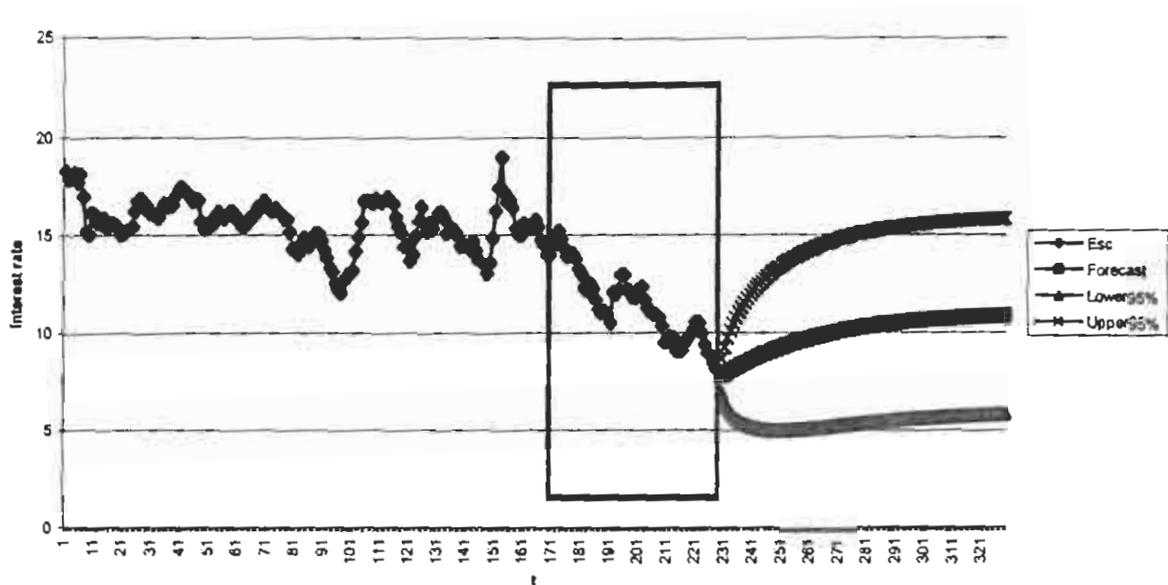
(a)

Forecasts; Model:(2,0,0); Esc				
CaseNo.	Forecast	Lower 95.00%	Upper 95.00%	Std.Err.
62	7.77528	6.92087	8.62969	0.42684
63	7.83970	6.46451	9.21489	0.68701
...	...	...	...	...
160	10.82272	5.80873	15.83670	2.50484
161	10.82819	5.81373	15.84265	2.50508

(b)

Table 6.4. Table showing some of the last predictions made with the AR(2) model, using the last known 60 (a) BA values and (b) Esc values.

Graph 6.18. Esc: AR(2) Predictions Now



Having tried these models, it was decided to experiment with other models that produce intervals where the volatilities are estimated by the absolute values of the first differences.

#### 6.4. Volatility Model

Having an outline for this section of the work makes it easier to understand, thus:

##### 6.4.1. Outline for Section

The aims of this section of Chapter 6, briefly, are the following:

Using the absolute value of the maximum errors obtained from each data set

1. Knowing the future – that is, using all the data up to point 196 (and then back casting at points 74 and 148<sup>97</sup>);

<sup>97</sup> These points were selected because in this study, an analysis is not done on every point. Instead, only three points are considered, namely:

1. Point 74 (February 1992) – just before there appears to be a downward trend;
2. Point 148 (April 1998) – before the Asian crisis (an extreme high);
3. Point 196 (April 2002) – the previously last known interest rate (for the sake of simplicity and for comparison purposes, the last known point for the BA data set is chosen also as point 196).

2. Not knowing the future – that is, using only past data (which brings up the question of how much past data is needed to predict how accurate in the future). In this study, only the last 60 interest rate values or five years' worth of data prior to each point are used.

Create intervals of:

3. 99% = MAX99<sup>98</sup>: estimate 99% volatility by the 99<sup>th</sup> percentile of absolute value first differences;
4. 95% = MAX95: estimate 95% volatility by the 95<sup>th</sup> percentile of absolute value first differences;
5. 90% = MAX90: estimate 90% volatility by the 90<sup>th</sup> percentile of absolute value first differences.

and in each instance make predictions using:

6. Extreme volatility – using n – adding n volatility estimates for n future periods:

$$\text{Upper Limit: } Y_{t+n} = Y_t + n * \text{MAX P} \quad \text{where P can be 99, 95 or 90}$$

$$\text{Lower Limit: } Y_{t+n} = Y_t - n * \text{MAX P} \quad \text{where P can be 99, 95 or 90;}$$

7. Normal volatility – using square root of n ( $\sqrt{n}$ ):

$$\text{Upper Limit: } Y_{t+n} = Y_t + \sqrt{n} * \text{MAX P} \quad \text{where P can be 99, 95 or 90}$$

$$\text{Lower Limit: } Y_{t+n} = Y_t - \sqrt{n} * \text{MAX P} \quad \text{where P can be 99, 95 or 90.}$$

To find:

8. A base case, where the upper and lower interval limits that are found continue outwards without any restrictions or limits;
9. A restricted case, where limits are put on the base case. The limits based on  $\bar{x} \pm z \times s$ , where the standard deviation<sup>99</sup> (s) is found with the calculation

$$\text{formula } s = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}}, \text{ are used. NOTE: } x \text{ and } \bar{x} \text{ are } y \text{ and } \bar{y} \text{ in the study.}$$

In each case test the results.

<sup>98</sup> MAX99 is an overall estimate of volatility by the 99% percentile of the absolute first differences that are used.

<sup>99</sup> Since the variance is, as Scheaffer and McClave (1995:311) explain:

$$s^2 = \frac{1}{n-1} \left[ \sum_{i=1}^n x_i^2 - \frac{1}{n} \left( \sum_{i=1}^n x_i \right)^2 \right]$$

A short explanation from where these numbers and formulas are derived is in order. Naïve model 1.1 is on which the volatility model is based. This is how it is done:

$\epsilon_t \sim N(0, \sigma_\epsilon^2)$  That is, the  $\epsilon_t$  's are assumed to be identically and independently<sup>100</sup> distributed (iid) with a normal distribution<sup>101</sup> with expected value 0 and variance  $\sigma_\epsilon^2$ .

Using Model 1.1, it then follows:

[The random drift model or ARIMA(0,1,0) where the first differences are independently distributed]

$$Y_{t+1} = Y_t + \epsilon_{t+1}$$

$$\begin{aligned} Y_{t+2} &= Y_{t+1} + \epsilon_{t+2} \\ &= Y_t + \epsilon_{t+1} + \epsilon_{t+2} \end{aligned}$$

$$\begin{aligned} Y_{t+3} &= Y_{t+2} + \epsilon_{t+3} \\ &= Y_t + \epsilon_{t+1} + \epsilon_{t+2} + \epsilon_{t+3} \end{aligned}$$

Thus, assuming  $Y_t$  and  $Y_{t-1}$  are independent, the variance is

$$\begin{aligned} \text{Var}Y_{t+3} &= \text{Var}Y_t + \text{Var} \epsilon_{t+1} + \text{Var} \epsilon_{t+2} + \text{Var} \epsilon_{t+3} \\ &= 0 + \sigma_\epsilon^2 + \sigma_\epsilon^2 + \sigma_\epsilon^2 \\ &= 3\sigma_\epsilon^2 \end{aligned}$$

$$\therefore \text{Var}Y_{t+n} = n\sigma_\epsilon^2$$

Since the standard deviation is the square root of the variance, the volatility of  $Y_{t-n}$  is

$$\begin{aligned} \text{Std}Y_{t+n} &= \sqrt{\text{Var}Y_{t+n}} \\ &= \sqrt{n} \cdot \sigma_\epsilon \end{aligned}$$

<sup>100</sup> Independence is the second inference assumption given by Bowerman and O'Connell (1993:94). It states that: Any one value of the dependent variable  $y$  is *statistically independent* of any other value of  $y$ . Said equivalently, any one value of the error term  $\epsilon$  is *statistically independent* of any other value of  $\epsilon$ .

<sup>101</sup> According to Steyn, *et al.* (1994:344), the normal distribution (also known as the Gauss distribution) is the most important continuous distribution and was studied by the French mathematician A. de Moivre as far back as 1733. The normal distributions "are described by bell-shaped, symmetric unimodal density curves" (Moore & McCabe, 1999:85). The density function of the normal distribution with mean  $\mu$  and standard deviation  $\sigma$  is defined in Steyn, *et al.* (1994:345) and represented by the function

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}, \quad -\infty < x < +\infty$$

From the definition, it can be seen that the two parameters of the mean  $\mu$  and variance  $\sigma^2$  determine the distribution. It is customary to refer to this distribution as the  $n(\mu, \sigma^2)$  distribution.

Prediction interval at time t

$$Y_{t+n} = Y_t \pm z \times \sqrt{n} \cdot \sigma$$

$$= Y_t \pm \sqrt{n} \cdot z\sigma$$

To estimate  $z_p \sigma_D$ , where D = Differences, we use MAXP:  $MAXP \approx z \hat{\sigma}_D$

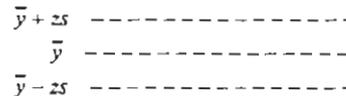
The variance of the first differences is  $\sigma_D^2 = \text{Var}(Y_t - Y_{t-1})$   
and assuming the average is zero,  $E Y_t = E Y_{t-1}$ ,

$$\sigma_D^2 \text{ is estimated by } \hat{\sigma}_D^2 = \frac{\sum(Y_t - Y_{t-1})^2}{n} \text{ and } \hat{\sigma}_D = \sqrt{\hat{\sigma}_D^2}$$

BA			Esc			BA VarD	Esc VarD
Differences	MAXP $\approx z_{0.05} \cdot \hat{\sigma}_D$		Differences	MAXP $\approx z_{0.05} \cdot \hat{\sigma}_D$			
	P = 99	z = 2.576		P = 99	z = 2.576		
196 at 196	2.170	0.896	196 at 196	1.600	0.615	0.348	0.239
60 at 74	1.200	0.593	60 at 74	0.790	0.216	0.230	0.084
60 at 148	1.250	0.603	60 at 148	1.010	0.553	0.234	0.215
60 at 196	2.250	1.581	60 at 196	1.600	0.915	0.614	0.355
BA			Esc			BA VarD	Esc VarD
Differences	MAXP $\approx z_{0.05} \cdot \hat{\sigma}_D$		Differences	MAXP $\approx z_{0.05} \cdot \hat{\sigma}_D$			
	P = 95	z = 1.960		P = 95	z = 1.960		
196 at 196	1.200	0.681	196 at 196	1.070	0.468	0.348	0.239
60 at 74	1.000	0.452	60 at 74	0.500	0.164	0.230	0.084
60 at 148	1.100	0.459	60 at 148	0.860	0.420	0.234	0.215
60 at 196	2.050	1.203	60 at 196	1.380	0.697	0.614	0.355
BA			Esc			BA VarD	Esc VarD
Differences	MAXP $\approx z_{0.05} \cdot \hat{\sigma}_D$		Differences	MAXP $\approx z_{0.05} \cdot \hat{\sigma}_D$			
	P = 90	z = 1.645		P = 90	z = 1.645		
196 at 196	1.000	0.572	196 at 196	0.750	0.393	0.348	0.239
60 at 74	0.850	0.379	60 at 74	0.420	0.138	0.230	0.084
60 at 148	0.850	0.385	60 at 148	0.780	0.353	0.234	0.215
60 at 196	1.100	1.010	60 at 196	1.050	0.585	0.614	0.355

In the table above, it can be seen that the limits based on MAXP are larger than what they would have been, had the z-values been used. This is because MAXP is based on percentiles which are more extreme than the normal distribution.

$$[ARIMA(0,0,0)]; Y_t = \mu + \epsilon_t; \epsilon_t \sim N(0, \sigma^2); m = 60$$



### 6.4.2. Empirical Work

Using other conventional methods, it is possible to make predictions at each data point. It was decided, however, in this study, to start with the previously last known interest rate (point 196 or April 2002 for both data sets) and determine what the model would predict (short- and long-term) if one were to stand at that data point 'not

knowing the future' (the newly acquired data). Thereafter, using all past data, make predictions and set intervals (as well as limits later on) and then use the latest data to test the results.

Obtaining a base case at data point 196 (April 2002) in this way, would allow for a type of back casting at other points. Two other points in particular were chosen for back casting:

1. Point 74 (February 1992) – just before there appears to be a downward trend;
2. Point 148 (April 1998) – before the Asian crisis (an extreme high).

Thus, for both data sets in turn, all the previously known data were selected and first differences were taken. Subsequently, the absolute values of these differences were found (see Table 6.1 (a)).

Then, the original data and corresponding absolute value first differences were sorted according to the differences, in descending order (see Table 6.1 (b)). The point of doing this is to be able to identify:

- The 99 percentile – the largest 1% (2 values) of the absolute value of differences that need to be omitted for a 99% interval
- The 95 percentile – the largest 5% (10 values) of the differences that need to be removed for a 95% interval and
- The 90 percentile – the largest 10% (20 values) of the differences that must be excluded for a 90% interval

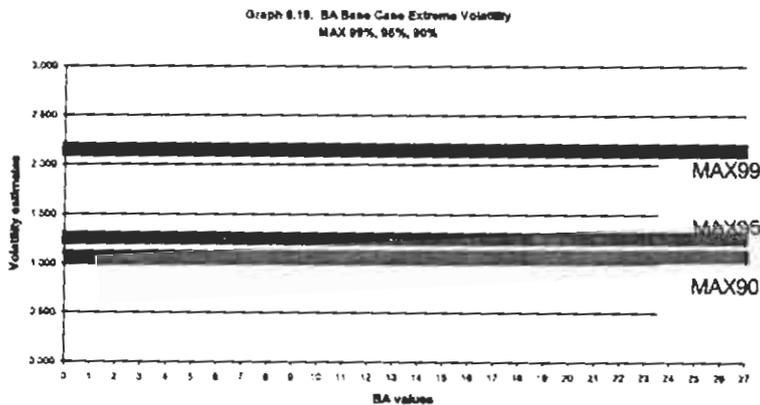
Once identified, the values were removed. The new data and corresponding absolute value first differences (now excluding the largest percentages) were then divided into groups of ten (forming, in this case, 20 groups) by sorting the BA values. In each group, a maximum absolute value first difference was identified.

These absolute first differences in BA values (volatility estimates) are plotted on a graph against the BA values and the maximum absolute value point for each interval is found. These maximum points are used as the volatility estimates (VE).

BA data	ABS(1 <sup>st</sup> diff)		BA data	ABS(1 <sup>st</sup> diff)	
12.55	0.250		14.95	2.350	
12.30	0.150		17.30	2.250	=> MAX99
12.45	0.450		21.00	2.170	
12.00	0.700		19.55	2.050	
11.30	0.450		12.92	2.030	
10.85	0.300		13.08	1.340	
10.55	0.650		15.15	1.250	
9.90	0.350		14.60	1.250	
9.55	0.000		11.75	1.250	
9.55	0.500		17.30	1.200	=> MAX95
9.05	0.150		16.40	1.200	
8.90	0.200		17.55	1.100	
...	...		...	...	

(a) → (b)

**Table 6.5.** Tables showing for the BA data set: (a) the first twelve values of original data with corresponding absolute value first differences; (b) the first twelve values after the whole of table (a) is sorted in descending order according to the differences, showing the values that need to be omitted for MAX99 and MAX95.



From the graph it can be seen that: for the 99% interval, the maximum absolute value first difference is 2.170; for the 95% interval it is 1.200; and for the 90% interval it is 1.000. These values are used further.

#### 6.4.3. ARIMA(0,1,0) Possible Models

From the empirical work conducted above, the following models are possible:

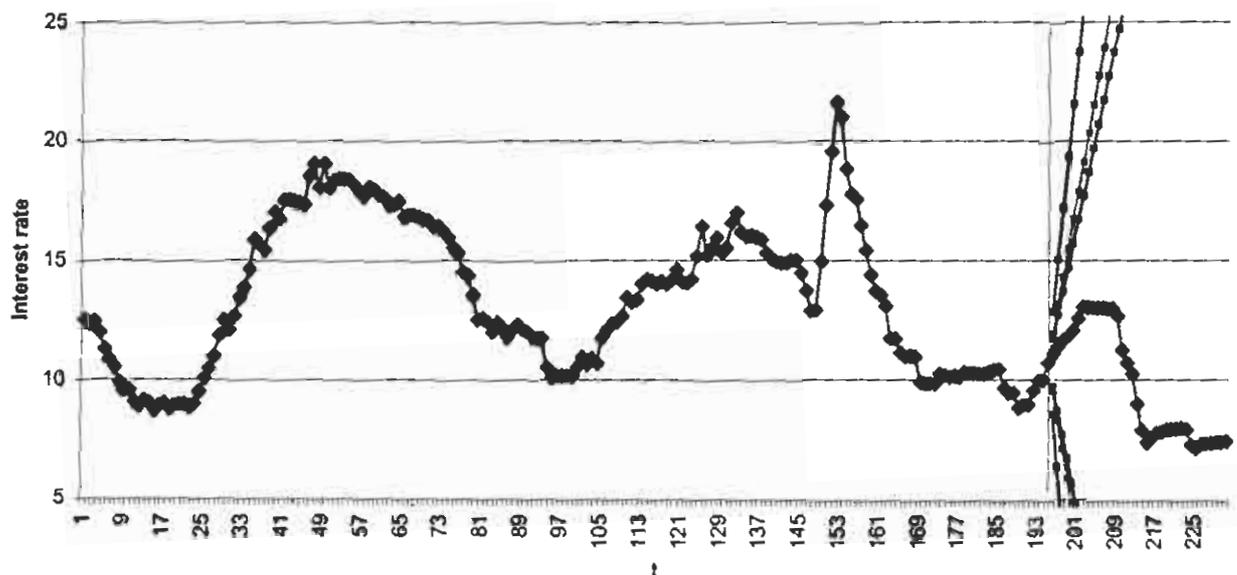
##### 6.4.3.1. Base Case Model for Extreme Volatility

Extreme volatility refers to when a period of great volatility is suspected or expected for a certain amount of time. In these cases, it makes more sense to use this type of model, which allows for a quicker rise (steeper intervals).

The **base case model for extreme volatility** for each interval (99%, 95% and 90%) consists of forming:

- A lower interval limit that starts at the intended point (74, 148 or 196) and goes down by the respective maximum amount (volatility estimate) for each interval, for each subsequent prediction
- An upper interval limit that starts at the intended point and goes up by the respective maximum amount (volatility estimate), for each subsequent prediction

Graph 6.20. Base Case Model for Extreme Volatility  
BA MAX99%, 95%, 90%

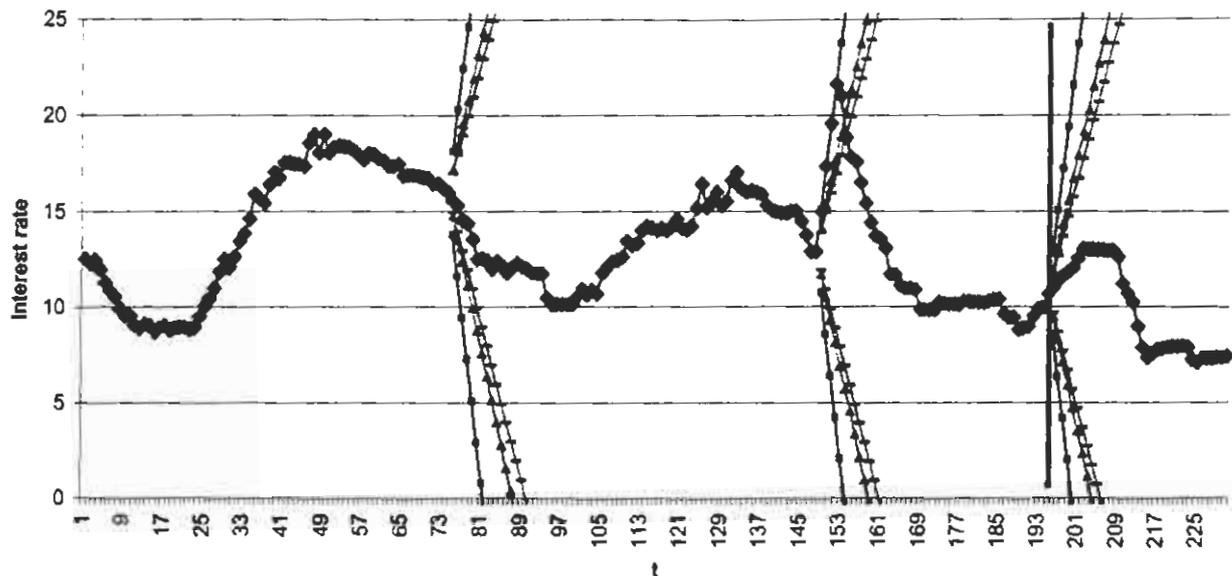


#### 6.4.3.2. Back Casting Models for Extreme Volatility

Once a base case has been found, it is possible to do back casting at the two other points selected earlier (74 and 148). This was done and may be seen in the graph below. For comparison purposes, the predictions at point 196 are also shown:

A conclusion that may be drawn from this graph is that, although at point 196 this type of prediction looks too extreme (too wide intervals), the Asian Crisis can be predicted using Extreme Volatility.

Graph 6.21. Back Casting Model for Extreme Volatility  
BA MAX99%, 95%, 90%



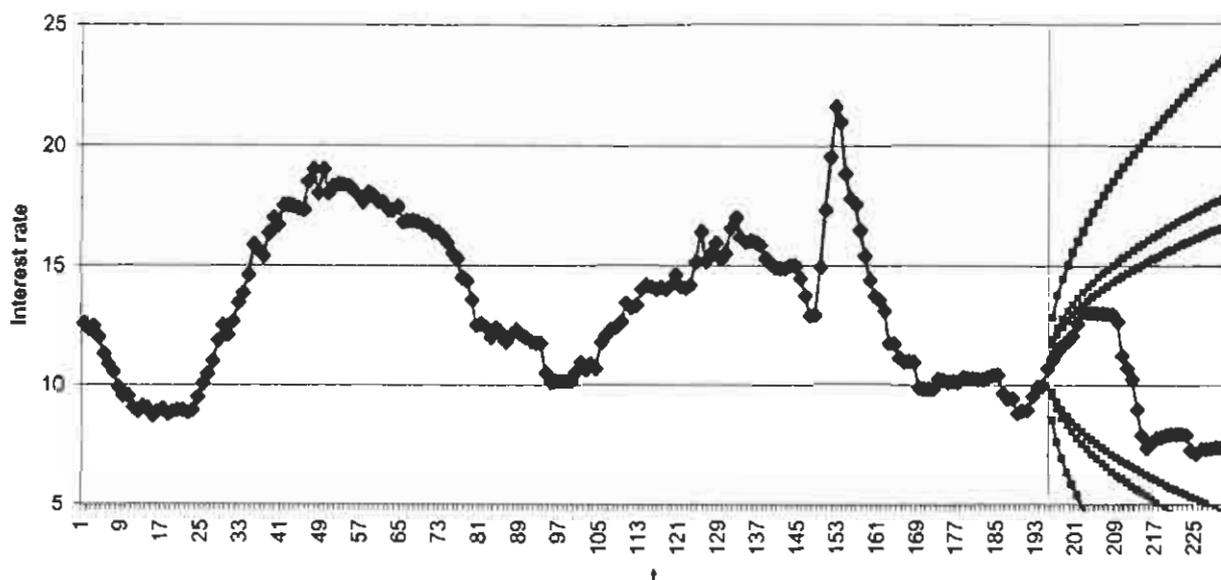
#### 6.4.3.3. Base Case Model for Normal Volatility

Normal volatility refers to when a period where the suspected or expected volatility for a certain amount of time is not so great. In these cases, it makes more sense to use this type of model, which makes use of square root of  $n$  (where  $n$  is the number of predictions) in order to create interval limits that fan out more slowly than the extreme volatility models.

The **base case model for normal volatility** for each interval (99%, 95% and 90%) consists of forming:

- A lower interval limit that starts at the intended point (74, 148 or 196) and goes down by the volatility estimate for each interval divided by the square root of  $n$  (where  $n$  is the number of predictions, starting at 1 for the first prediction), for each subsequent prediction
- An upper interval limit that starts at the intended point and goes up by the respective volatility estimate divided by the square root of  $n$ , for each subsequent prediction

Graph 6.22. Base Case Model for Normal Volatility  
BA MAX99%, 95%, 90%

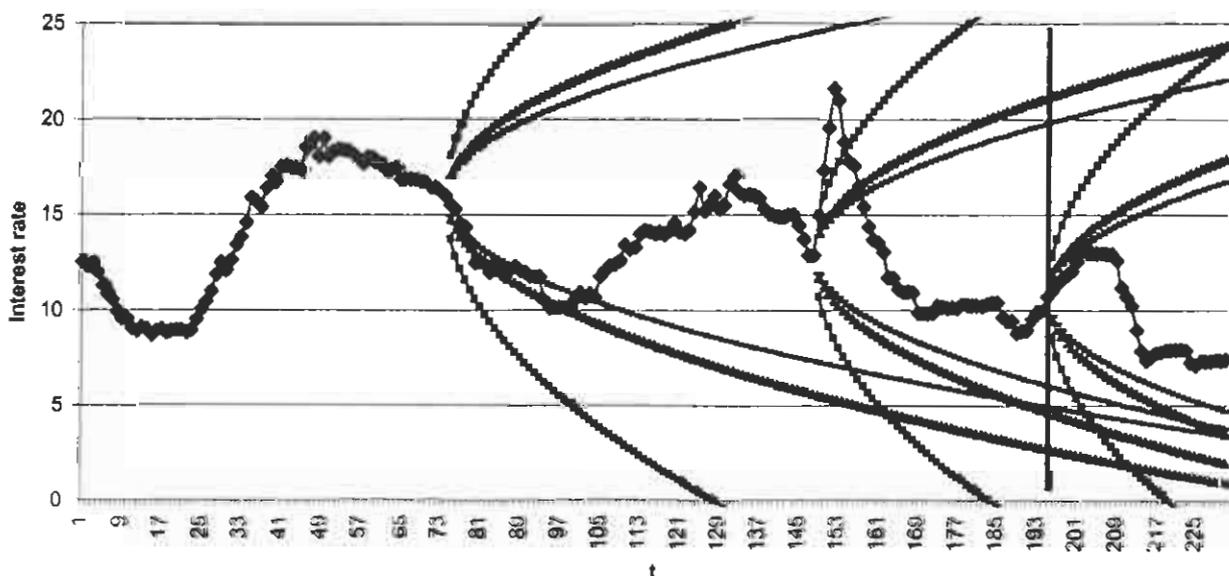


As can be seen in the graphs, these models take longer to move outward. They do not move out as quickly as the extreme volatility models.

#### 6.4.3.4. Back Casting Models for Normal Volatility

Again, once a base case has been found, it is possible to do back casting at points 74 and 148 (February 1992 and April 1998, respectively). A graph hereof is shown below, along with the predictions made at point 196:

Graph 6.23. Back Casting Model for Normal Volatility  
BA MAX99%, 95%, 90%



However, inevitably these predictions (for most models above) become unusable in the far future. Therefore, models that fan out initially but then reach a limit at which they remain in the long term, were produced. These are discussed next.

#### 6.4.3.5. Models with Limits Based on a Stationary Normal Distribution

Since the intervals of the predictions for the base case and back casting models become too wide and therefore, unusable, new models must be developed that have intervals that reach an acceptable limit wherein the future interest rates are likely to lie. One solution is to make volatility a function of the level of the time series.

Consequently, each of the volatility models described above were modified to level off at limits based on

$$\bar{x} \pm z \times s \quad (\text{Eq. 2})$$

where  $\bar{x}$  is the average or mean of the data being used<sup>102</sup>

$z$  is a critical value read from Table B.3 in Steyn, Smit, du Toit, and Strasheim (1994:683) each time, using:

For a 99% interval, the value of 2.576

For a 95% interval, the value of 1.960

For a 90% interval, the value of 1.645

and  $s$  is the standard deviation<sup>103</sup> (which can be estimated in various ways, creating different models) obtained using the calculation formula given in Steyn, *et al.* (1994:131):

<sup>102</sup> The arithmetic mean (or average) of a set of observations  $x_1, x_2, \dots, x_n$  is defined in Steyn, *et al.* (1994:99) by:

$$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n}$$

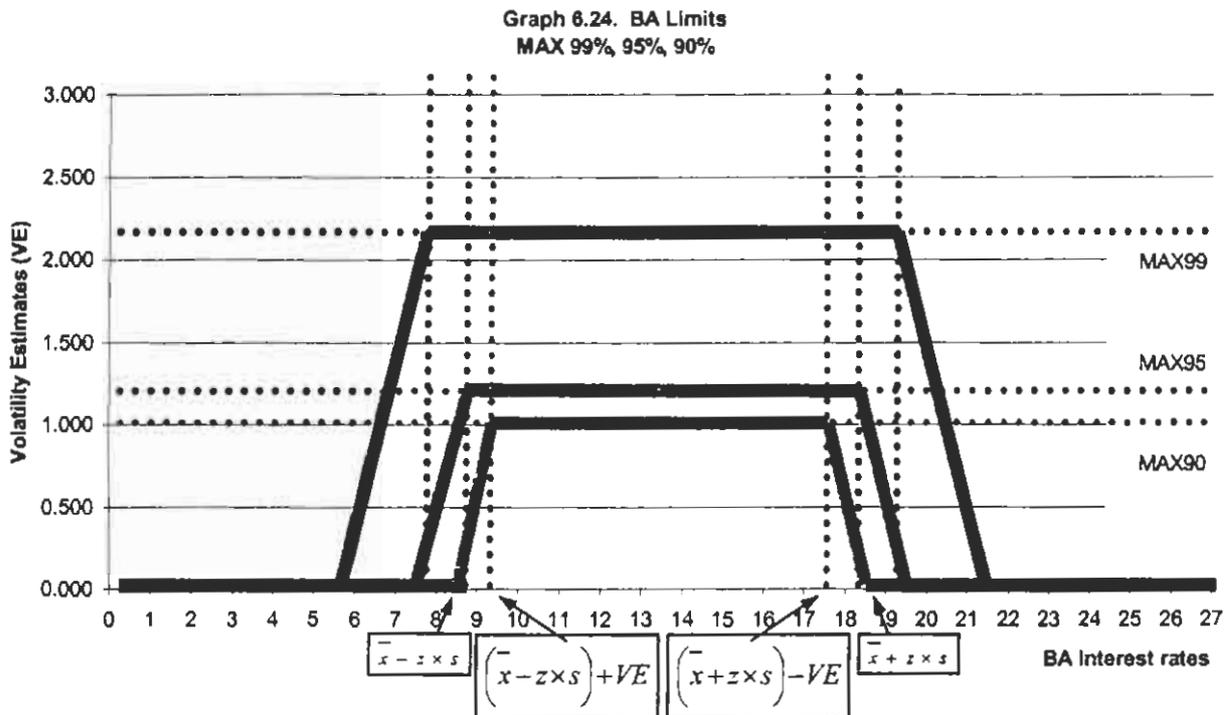
$$= \frac{\sum x}{n}$$

<sup>103</sup> The standard deviation of  $x_1, x_2, \dots, x_n$  is defined in Steyn, *et al.* (1994:130) by:

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

$$s = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}}$$

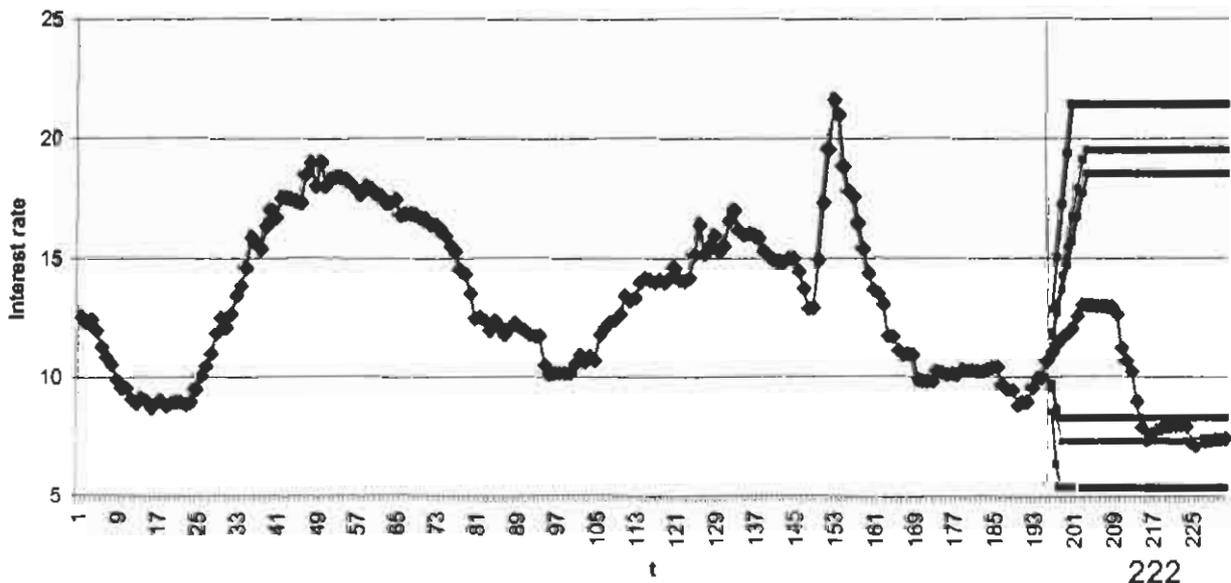
The new illustrative graph showing the limits for the BA data set is:



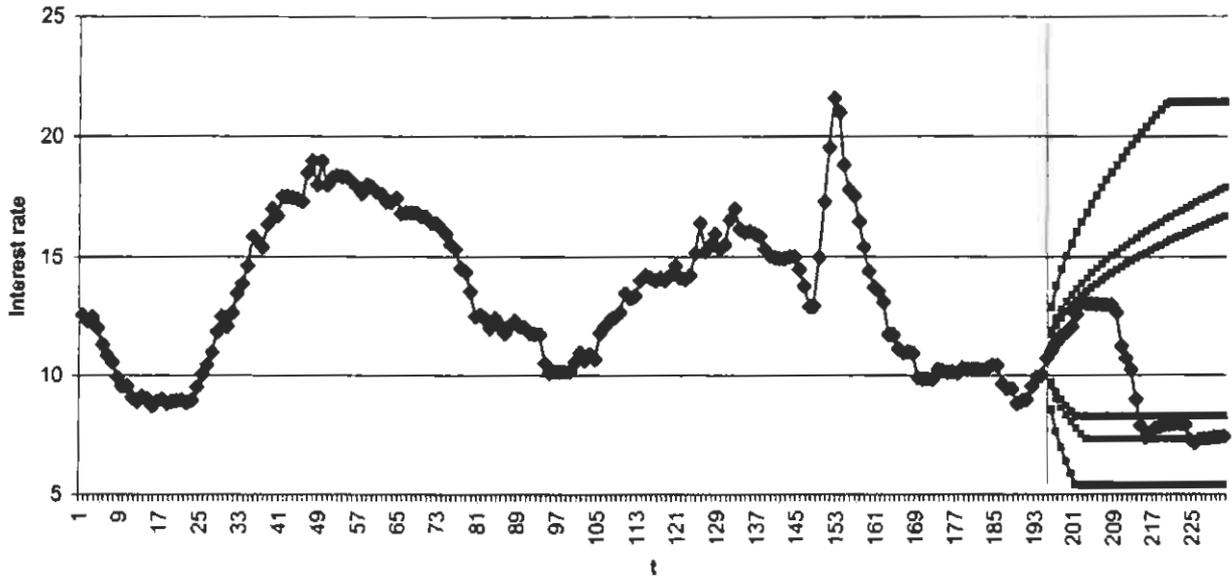
In the graph above (and for all graphs of this kind), the limits are set at  $\bar{x} \pm z \times s$  for each of the three intervals. In order for the predictions not to exceed these limits, a Volatility Estimate (VE) is added to each of the corresponding lower limits so that as from those points, the predictions can start to be such that they do not exceed the limits. At the other end, a VE is subtracted from each of the corresponding upper limits in order to achieve the same result (not to allow the predictions past the limits).

Thus, for the extreme and normal volatility models above, the graphs with limits are shown below:

**Graph 8.25. Extreme Volatility Model with Limits**  
BA MAX99%, 95%, 90%

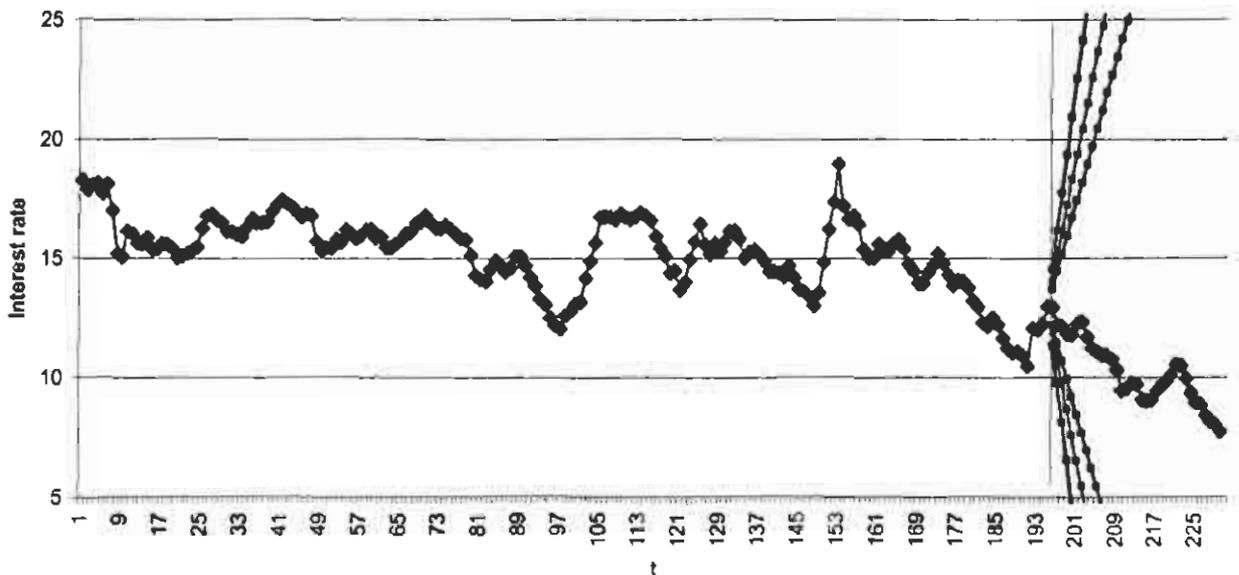


Graph 6.26. Normal Volatility Model with Limits  
BA MAX99%, 95%, 90%

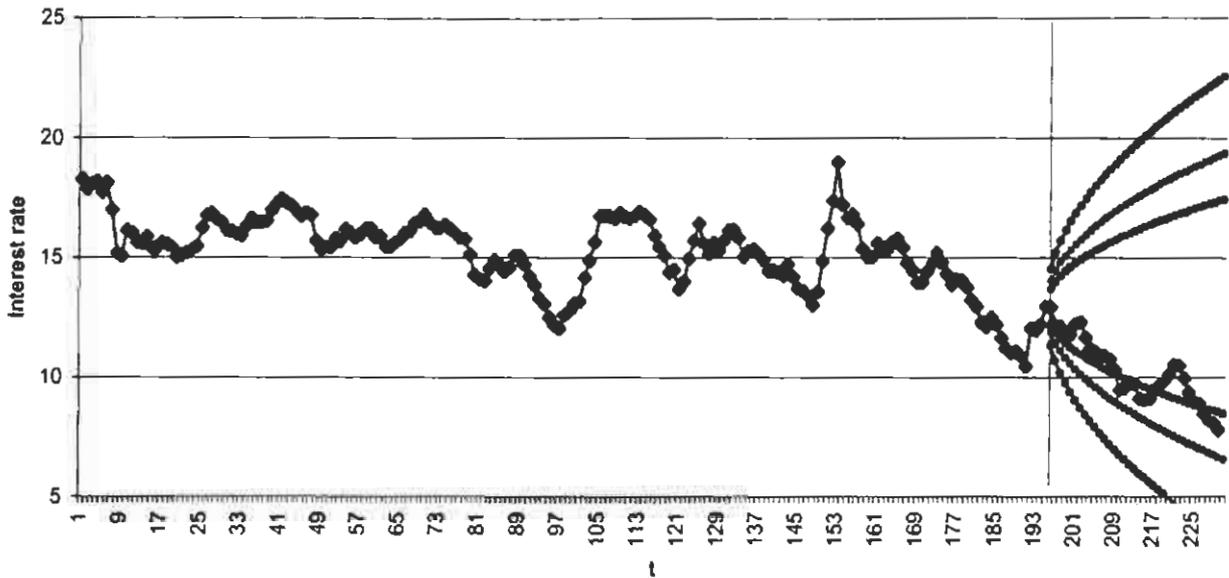


The same procedure was followed for the Esc data set. The graphs may be seen below:

Graph 6.27. Base Case Model for Extreme Volatility  
Esc MAX99%, 95%, 90%

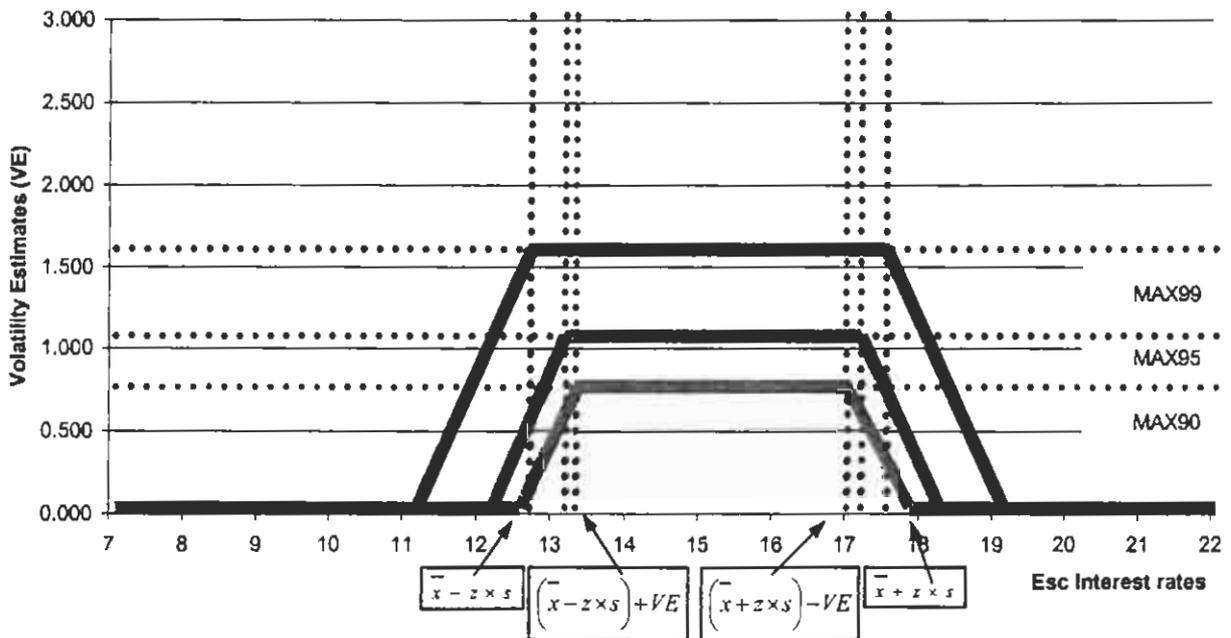


Graph 6.28. Base Case Model for Normal Volatility  
Esc MAX99%, 95%, 90%



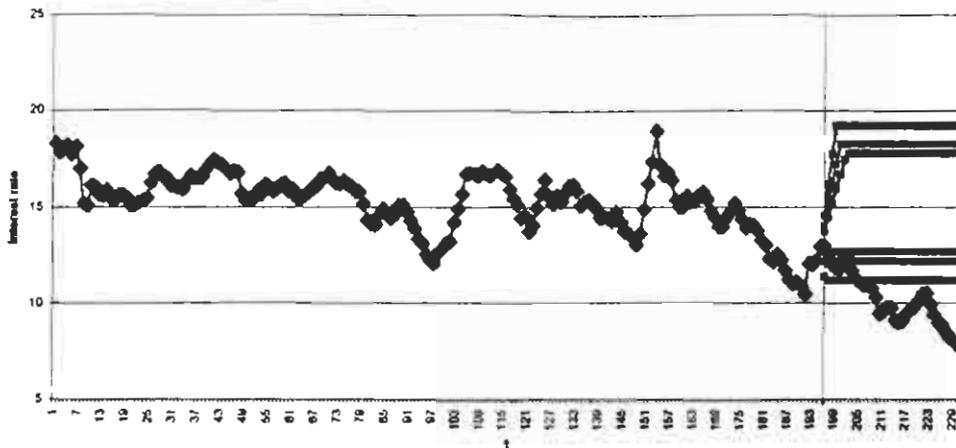
Incorporating the following limits into the models:

Graph 6.29. Esc Limits  
MAX 99%, 95%, 90%

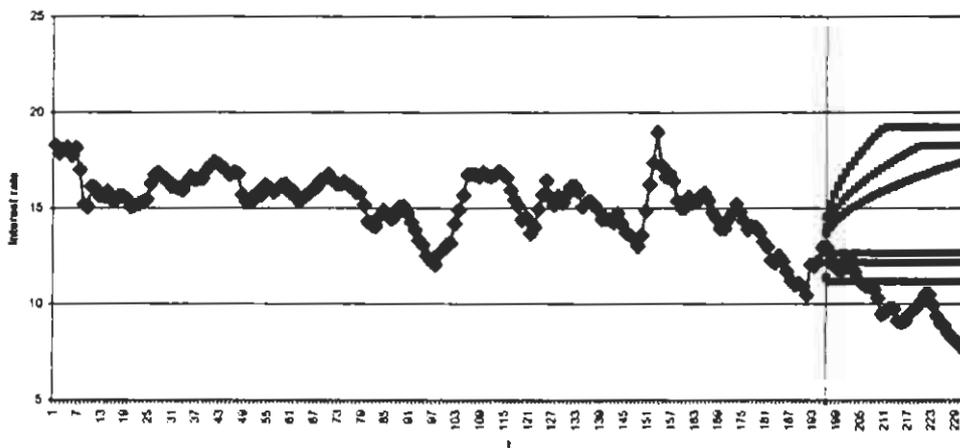


yields the graphs below:

Graph 6.30. Extreme Volatility Model with Limits  
Esc MAX99%, 95%, 90%



Graph 6.31. Normal Volatility Model with Limits  
Esc MAX99%, 95%, 90%



For each of the intervals, it is possible to determine whether the actual data remains within the interval set out at each prediction point. In addition, it is possible to verify whether the actual data remains within the limits or if these are too restrictive (or narrow) and cause future predictions to be incorrect.

#### 6.4.4. Meaningful Models

Having developed the models above, the question of how much data is needed in order to make a good prediction still remains. Using 196 interest rate data points requires having access to over 16 years' worth of data, which in some instances may be difficult to acquire. It may be worth the trouble to get that information, especially to see the "bigger picture" in the long run. However, going too far back into the past and working with too much data may cause a distorted view of the future, not only because the future is more dependent on the immediate past, but also, because necessitating so much data is impractical.

The actual data (the type of data) being forecasted needs to be taken into consideration as well as the techniques that are going to be used on that data to make predictions for the future<sup>104</sup>. However, banks tend to favour working with data of five to ten years. Therefore, it was decided to go back to each point (74, 148 and 196) for both data sets individually and determine what the forecasts would look like, if only the 60 data values immediately prior to each of those points were used to make the predictions.

Thus, the same procedure as before was followed each time but using only the 60 values (five years' worth of data) before each point<sup>105</sup>. The results obtained consisted of base case models for extreme as well as normal volatility (that become unusable fairly quickly) and more importantly, models that tend to limits set by using the conventional equation explained above (Eq. 2). These graphs<sup>106</sup> may be seen over the next few pages.

The summary table below identifies the limits for each model at the different points:

BA	Point		Lower Limit	Upper Limit	Size of Interval
197	196	99%	5.38	21.43	16.05
		95%	7.30	19.51	12.21
		90%	8.28	18.53	10.25
60	74	99%	5.83	24.09	18.26
		95%	8.01	21.91	13.89
		90%	9.13	20.79	11.66
	148	99%	8.43	18.65	10.23
		95%	9.65	17.43	7.78
		90%	10.27	16.80	6.53
	196	99%	4.32	21.06	16.74
		95%	6.32	19.06	12.74
		90%	7.35	18.04	10.69

(a)

Esc	Point		Lower Limit	Upper Limit	Size of Interval
196	196	99%	11.17	19.24	8.07
		95%	12.14	18.28	6.14
		90%	12.63	17.78	5.15
60	74	99%	14.58	17.65	3.07
		95%	14.95	17.28	2.33
		90%	15.14	17.09	1.96
	148	99%	11.51	18.32	6.81
		95%	12.32	17.50	5.18
		90%	12.74	17.09	4.35
	196	99%	9.68	18.62	8.94
		95%	10.75	17.55	6.80
		90%	11.29	17.00	5.71

(b)

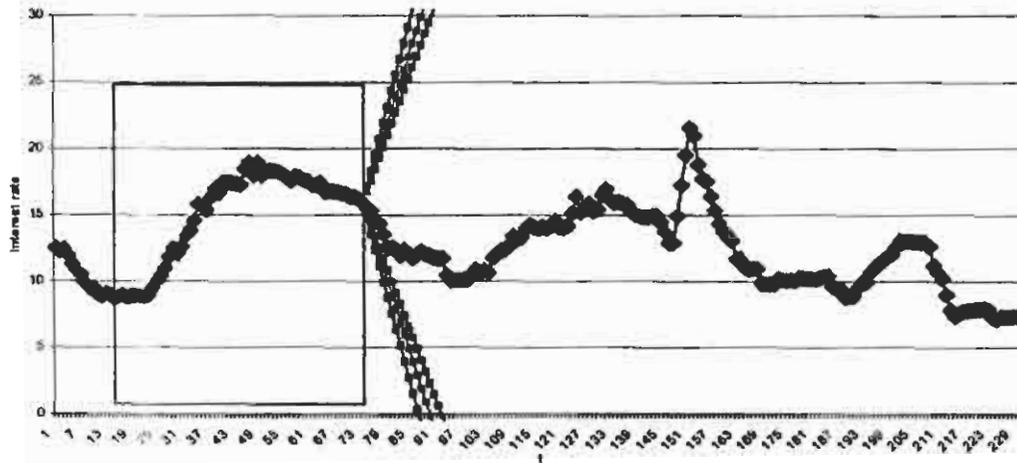
**Table 6.6. Summary table showing the limits that were used for each model at the various points for (a) the BA time series and (b) the Esc time series.**

<sup>104</sup> See, for example, H. Levenbach and J.P. Cleary, *The modern forecaster: The forecasting process through data analysis* (1984:27).

<sup>105</sup> First differences were obtained and the top 1%, 5% and 10% removed. The data and corresponding absolute value first differences were then divided into groups of ten (forming, in this case, 6 groups). In each group, a minimum, average and maximum absolute value first difference was identified. The maximum values were plotted on a graph and the maximum absolute value point in each interval was found.

<sup>106</sup> Please note that in the graphs, MAX99%, 95%, 90% refers to MAX99%, MAX95% and MAX90%.

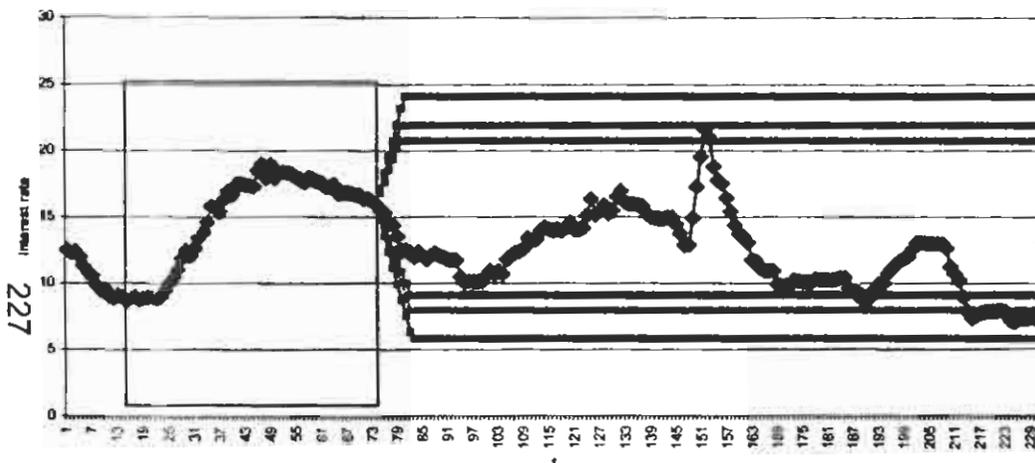
**Graph 6.32. Base Case Model for Extreme Volatility**  
60 values before point 74 BA MAX99%, 95%, 90% 74



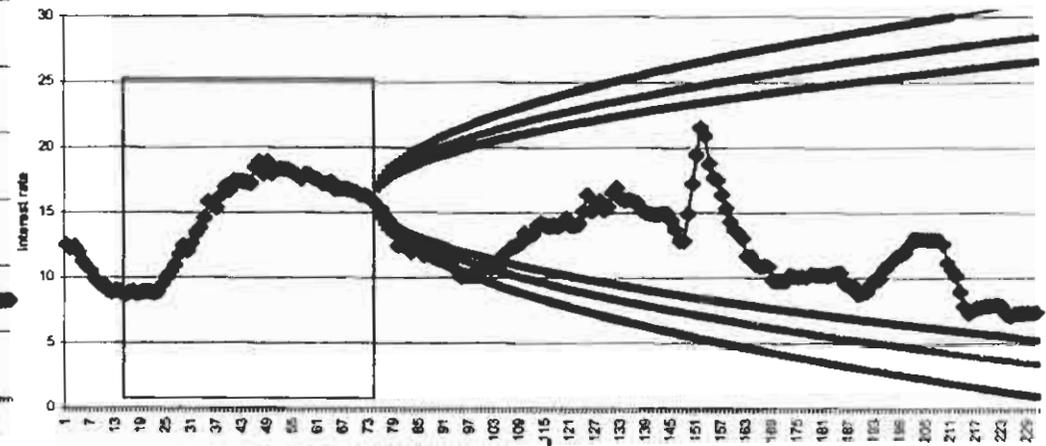
The graph above shows how, in anticipation of extreme volatility conditions, the model would be able to create an interval that would encompass all the future data. However, although this is desirable, the limits in the long-term are much too wide to be of use. The space is too open.

The graph below has reasonably good limits for the medium-term which makes it a better graph than the one above, although there are still open spaces where the intervals and limits should be narrower. However, for the long-term, they are too narrow (especially the lower limit at 90%).

**Graph 6.34. Extreme Volatility Model with Limits**  
60 values before point 74 BA MAX99%, 95%, 90% 74



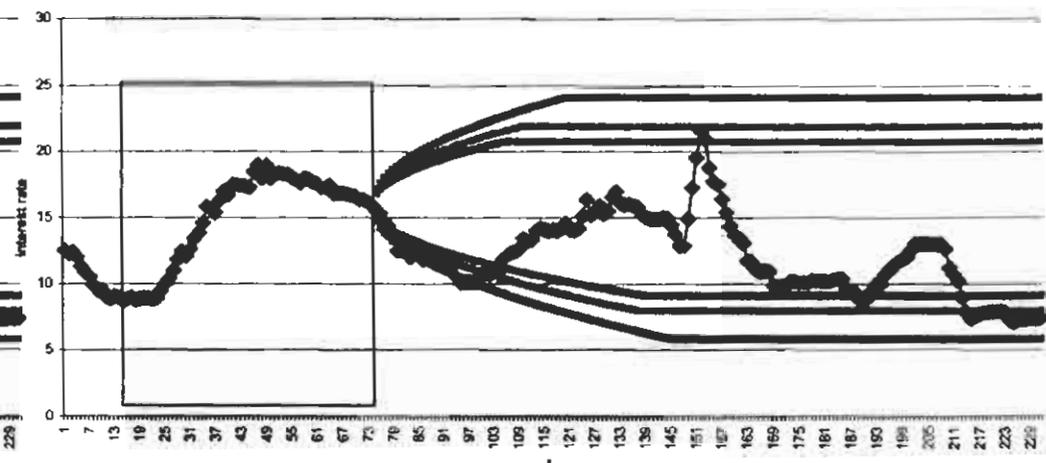
**Graph 6.33. Base Case Model for Normal Volatility**  
60 values before point 74 BA MAX99%, 95%, 90% 74



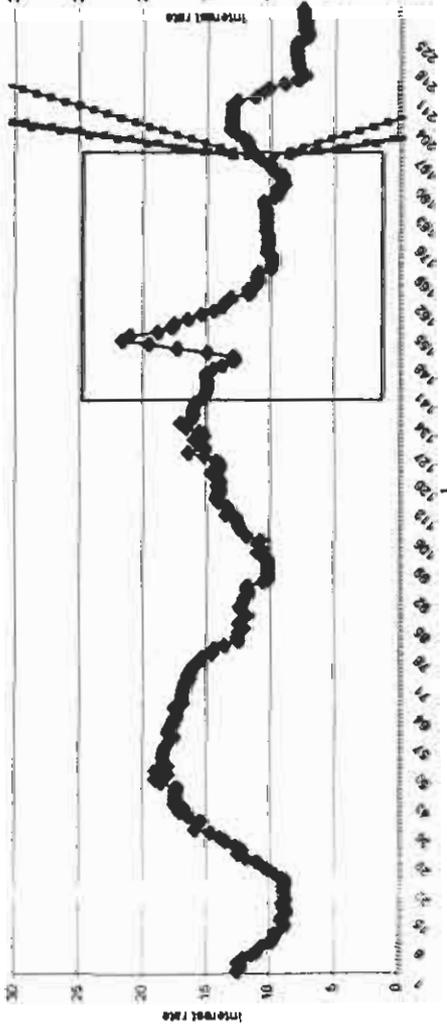
The graph above shows an improvement on the first one in that it is able to predict much better intervals, especially for the long-term. In the short- and medium-terms the data lies slightly outside of the intervals at times but these are much closer intervals to the data than before.

The graph below shows how this model, used for short- and medium-term predictions, produces intervals that are close to the original data (although some values do lie outside of the intervals). However, in the long-term, especially some of the lower limits are a bit restrictive.

**Graph 6.35. Normal Volatility Model with Limits**  
60 values before point 74 BA MAX99%, 95%, 90% 74



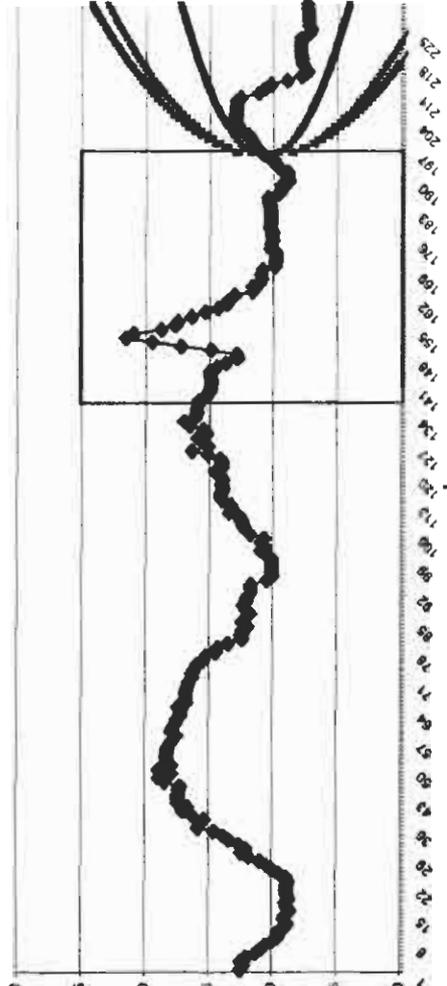
Graph 6.40. Base Case Model for Extreme Volatility  
60 values before point 196 BA MAX99%, 95%, 90% 196



Using just the 60 values before point 196 to make predictions using an extreme volatility model without restrictions, the graph above shows that, although the intervals are able to capture all the future available data, they are of no use in the long-term because they are simply too wide.

The model below is good in the sense that it produces intervals that include all the real available data in the short- and medium-terms. The limits that are set on the intervals for the long-term are reasonable in including the downward movement of the interest rates (except at lower 90%).

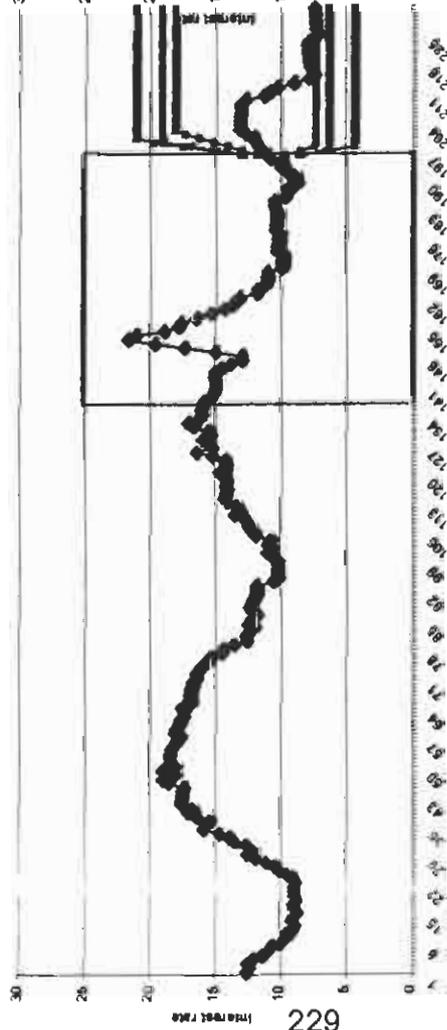
Graph 6.41. Base Case Model for Normal Volatility  
60 values before point 196 BA MAX99%, 95%, 90% 196



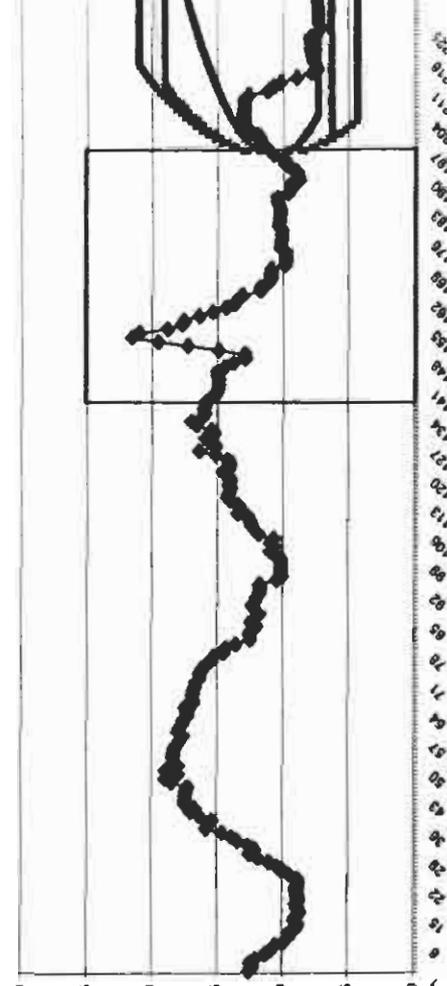
The graph above is an improvement on the first one in that it shows that the intervals produced by this model are much closer to the actual data than before. Even though in the long-term the intervals are still a bit wide, they are much better than in the first graph (extreme conditions).

The model used in the graph below (perhaps the best one of the four) appears to be good in that it is able to produce intervals that are close to the actual data in the short- and medium-terms and reasonable limits in the long-term (though not much data is available), except at lower 90%.

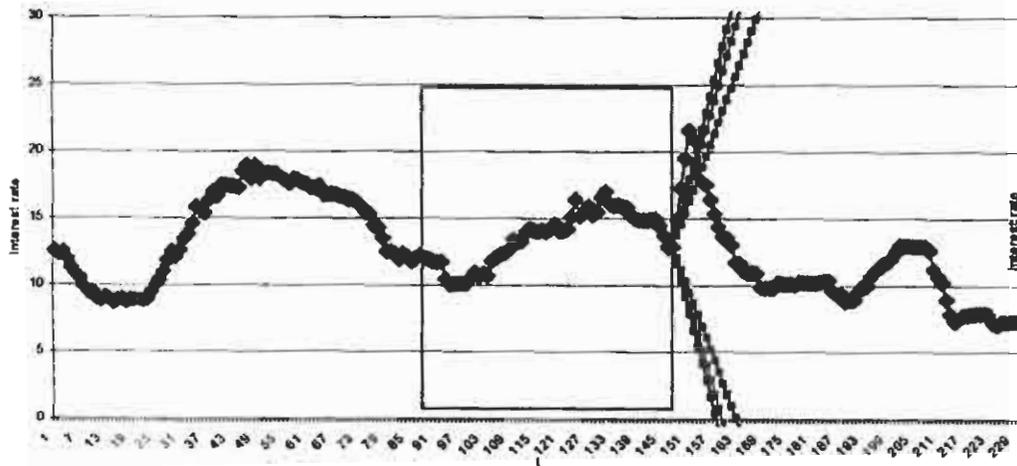
Graph 6.42. Extreme Volatility Model with Limits  
60 values before point 196 BA MAX99%, 95%, 90% 196



Graph 6.43. Normal Volatility Model with Limits  
60 values before point 196 BA MAX99%, 95%, 90% 196



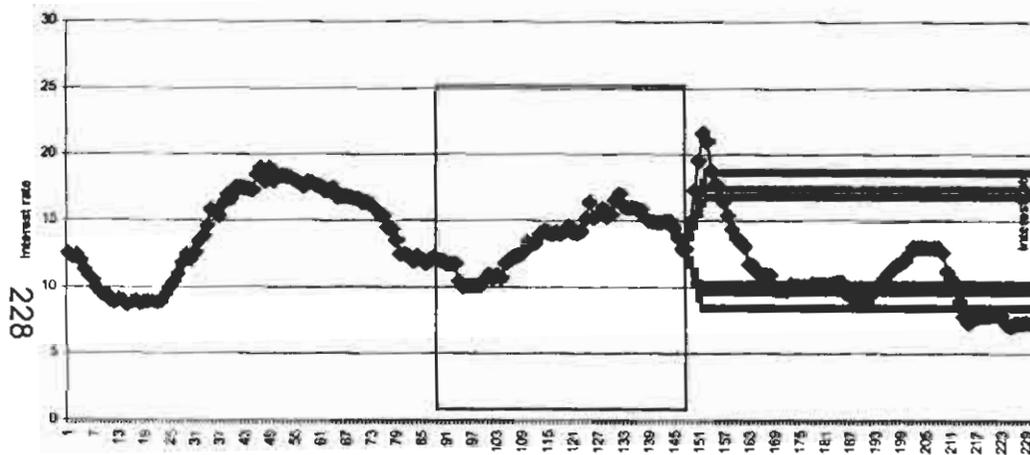
Graph 6.36. Base Case Model for Extreme Volatility  
60 values before point 148 BA MAX99%, 95%, 90% 148



The graph above shows how, even with the extreme volatility models, the upward movement of the Asian Crisis does not lie between the predicted intervals. Nevertheless, this model seems to be the one that is able to predict this extreme movement and reach the peak, the best.

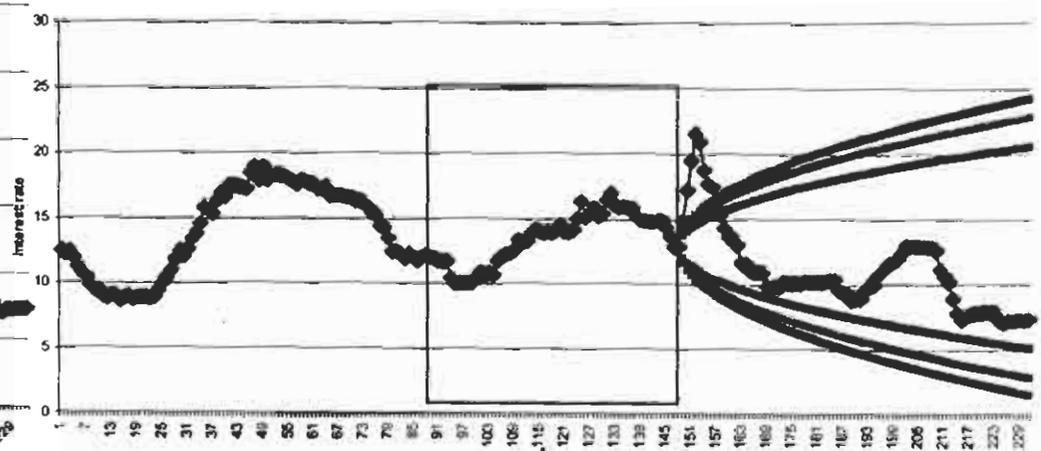
The intervals in the graph below start off close to the actual data of the Asian Crisis peak. However, the limits that are set on the intervals are too conservative, both in predicting the peak of the crisis and also in including the downward movement in the long-term.

Graph 6.38. Extreme Volatility Model with Limits  
60 values before point 148 BA MAX99%, 95%, 90% 148



228

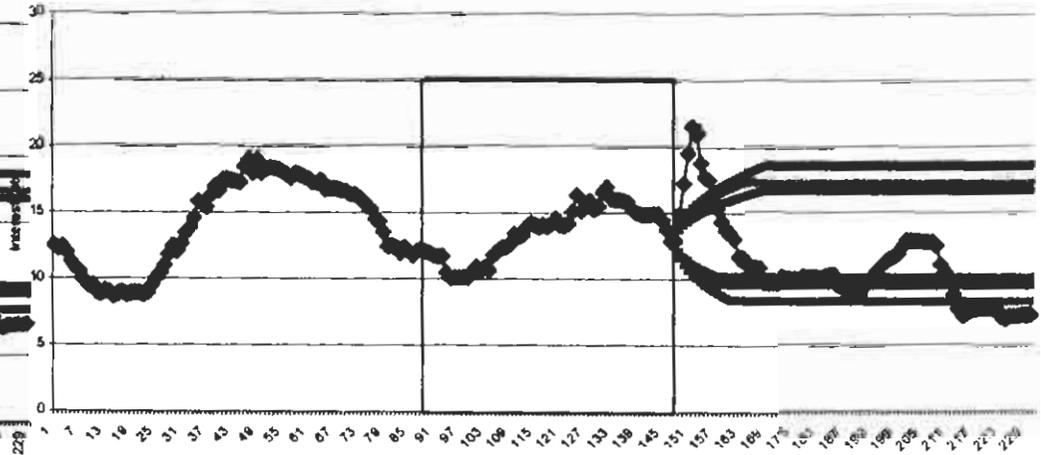
Graph 6.37. Base Case Model for Normal Volatility  
60 values before point 148 BA MAX99%, 95%, 90% 148

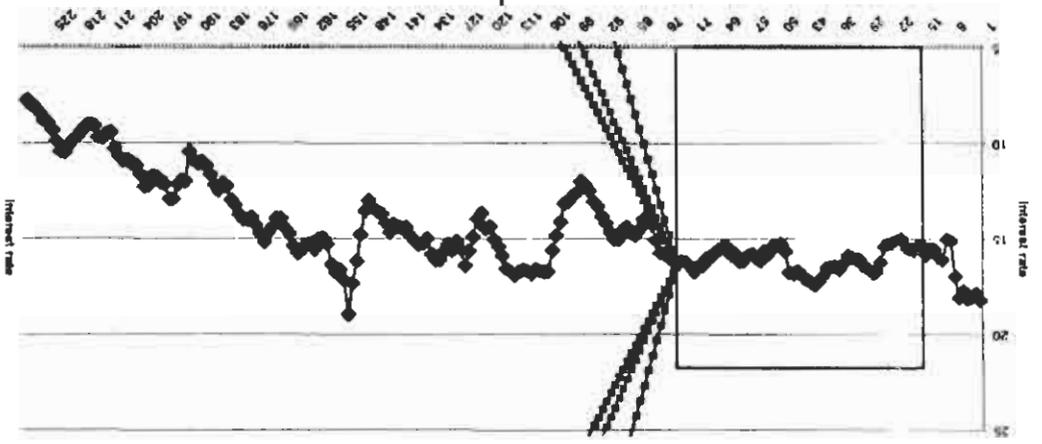


Although the graph above has reasonably good intervals for the lower limits in the long-term, it is not able in the short- and medium-terms to predict the extreme upward movement of the Asian Crisis at all.

The graph below shows that the model that is used is not able to predict the extreme upward movement accurately in the medium-term, nor is it able to include the downward movement in the long-term because of the limits restricting the intervals too much.

Graph 6.39. Normal Volatility Model with Limits  
60 values before point 148 BA MAX99%, 95%, 90% 148

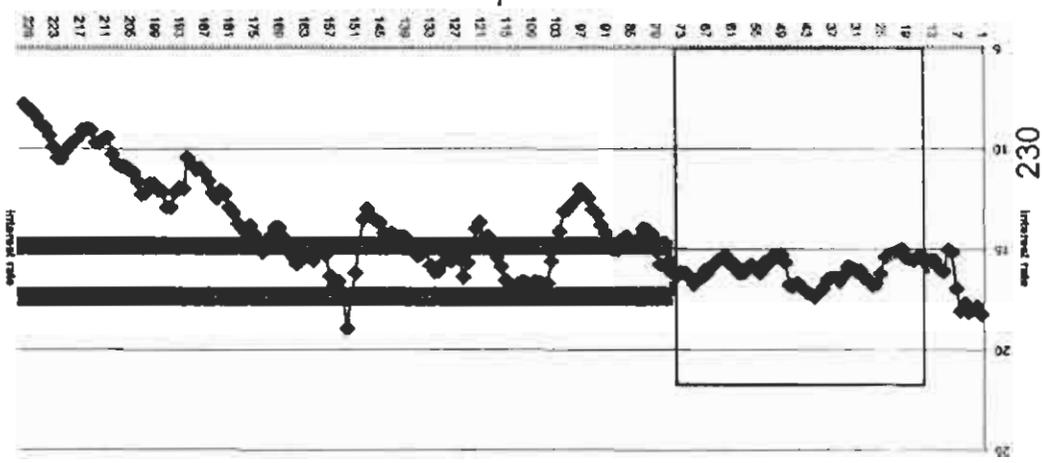




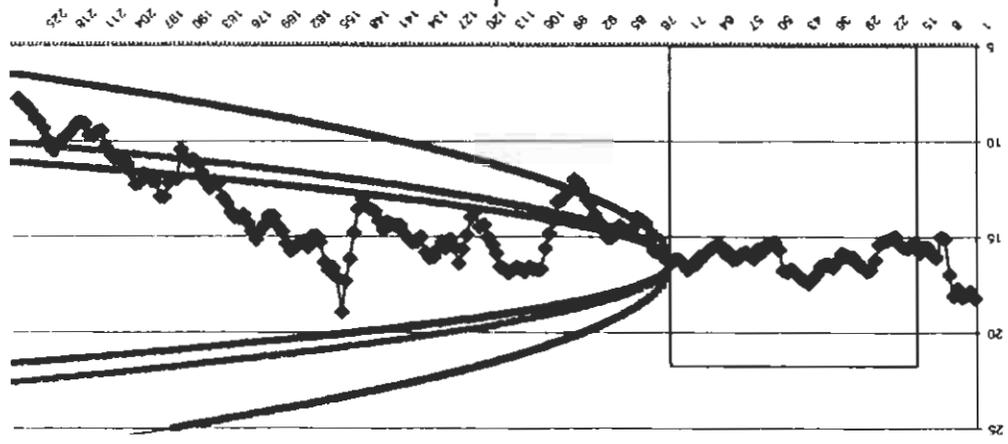
Graph 6.44. Base Case Model for Extreme Volatility  
60 values before point 74 Esc MAX99%, 95%, 90% 74

The graph above shows that the model is able to make good predictions in the short-term since the intervals include the actual data. However, the intervals start becoming wide already in the medium-term and although they include all the future available data, are too wide long-term.

The graph below illustrates how the restricted extreme volatility model that is used on this data produces limits that are much too conservative. It is not able to capture most of the data in the medium- and long-terms. The data is non-stationary since it goes out of the intervals at the end.



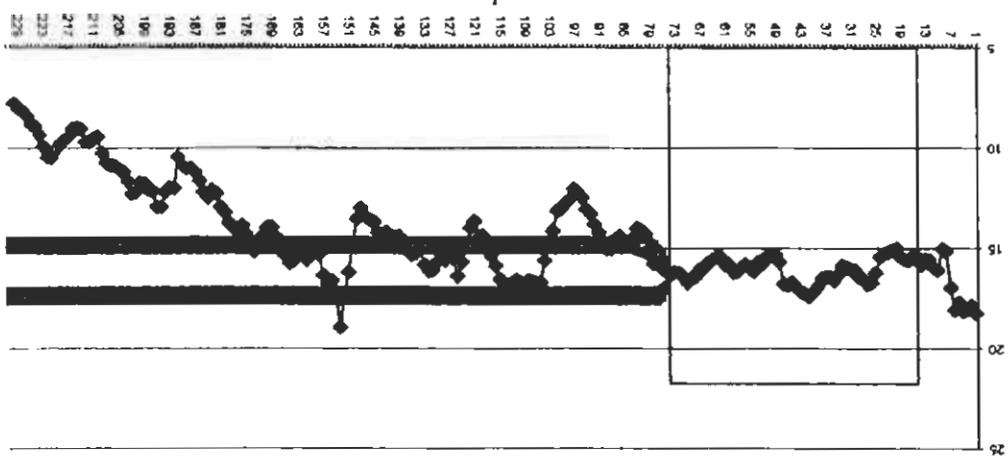
Graph 6.46. Extreme Volatility Model with Limits  
60 values before point 74 Esc MAX99%, 95%, 90% 74



Graph 6.45. Base Case Model for Normal Volatility  
60 values before point 74 Esc MAX99%, 95%, 90% 74

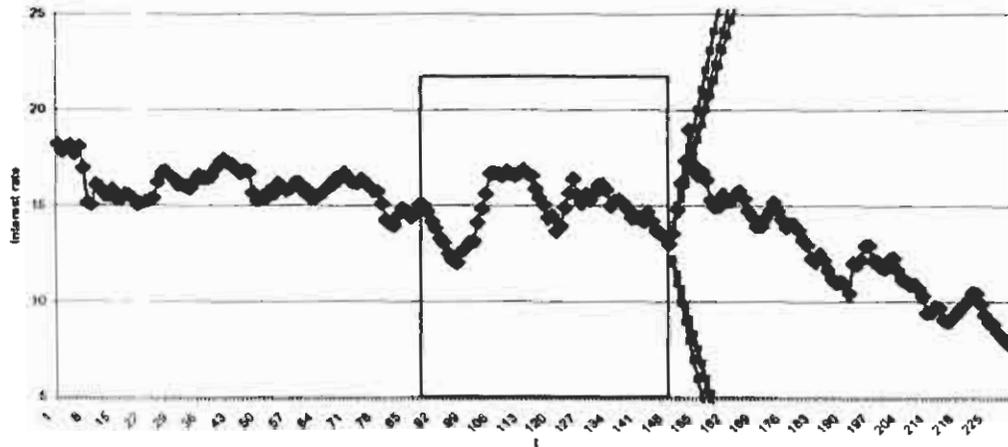
The graph above appears to be the best one of these four. The unrestricted normal volatility model produces intervals that seem to be quite close to the actual data, not only in the short- and medium-terms but also in the long-term, although some data lies outside the intervals at times.

The graph below shows how the restricted normal volatility model also produces limits that are much too narrow. Only a few actual data points lie within the intervals in the medium-term and then for most of the medium- and long-terms, the data lies outside of the intervals.



Graph 6.47. Normal Volatility Model with Limits  
60 values before point 74 Esc MAX99%, 95%, 90% 74

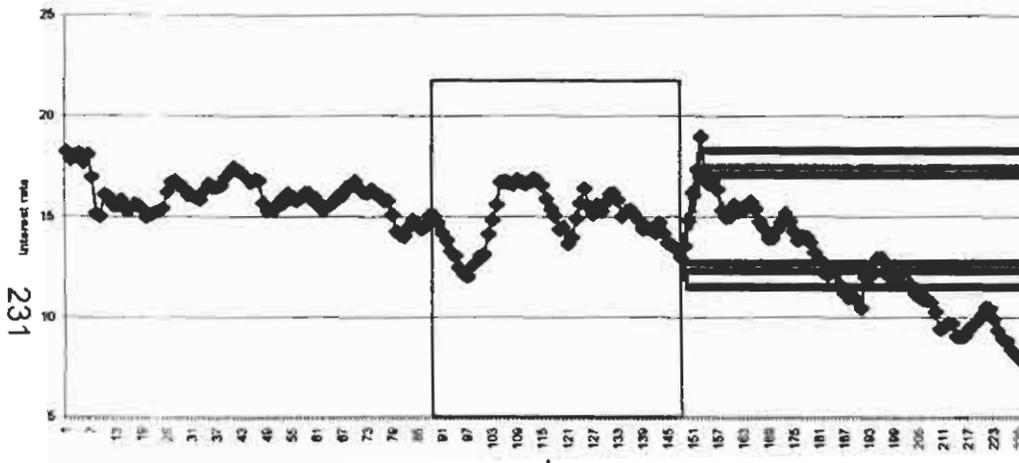
**Graph 6.48. Base Case Model for Extreme Volatility**  
60 values before point 148 Esc MAX99%, 95%, 90% 148



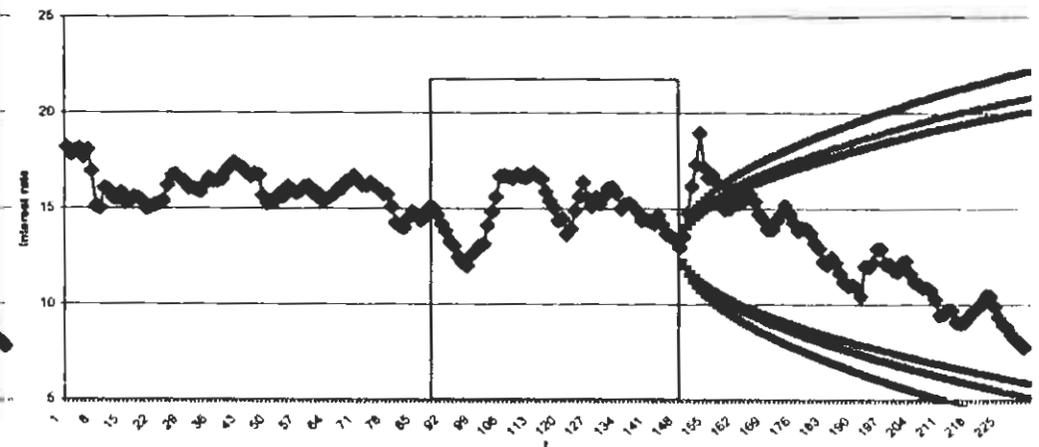
The graph above illustrates that this model is the only one of these four that is able to predict up and above the peak of the Asian Crisis. For the short-term, this is a good model but for the medium- and long-terms, it produces intervals that include all the data but that are too wide.

The model in the graph below is able to make good predictions in the short- and medium-terms, (with the exception of not including the peak of the Asian Crisis) where the data lies within the intervals. However, the data lies far below the lower limit in the long-term.

**Graph 6.50. Extreme Volatility Model with Limits**  
60 values before point 148 Esc MAX99%, 95%, 90% 148



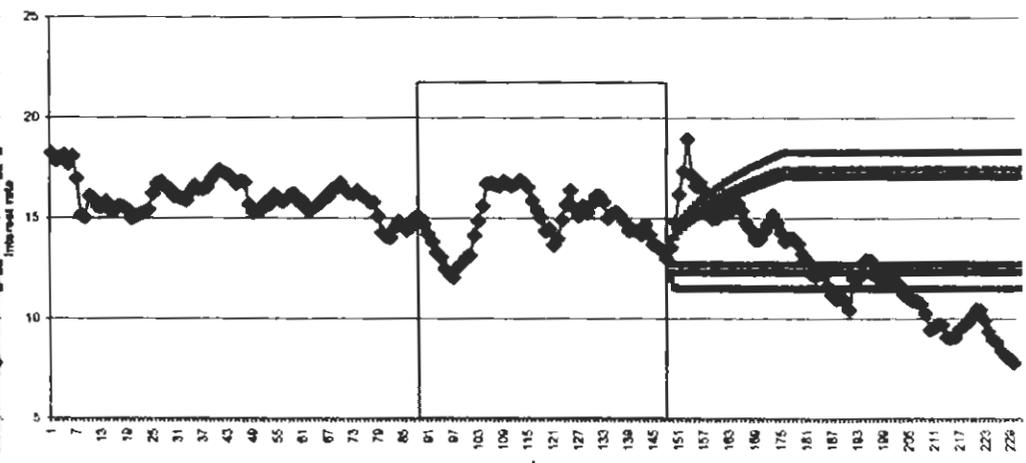
**Graph 6.49. Base Case Model for Normal Volatility**  
60 values before point 148 Esc MAX99%, 95%, 90% 148



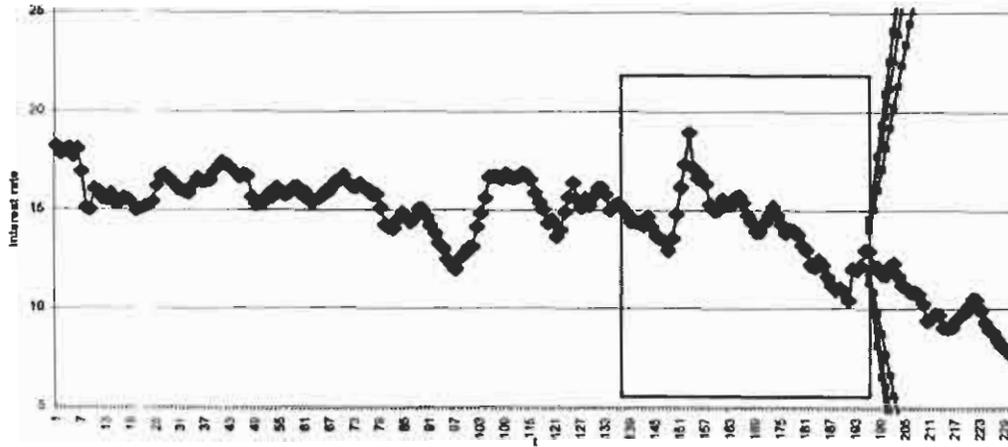
The unrestricted normal volatility model shown in the graph above is not able to make accurate predictions in the medium-term at the crisis, since it is not within the predicted intervals. Apart from that and in the long-term, the intervals do include the actual data (downward movement).

The graph below shows how the normal volatility model with limits does not make accurate interval predictions at the crisis in the medium-term nor for the long-term (neither the peak nor the downward movements are included in the intervals and limits).

**Graph 6.51. Normal Volatility Model with Limits**  
60 values before point 148 Esc MAX99%, 95%, 90% 148



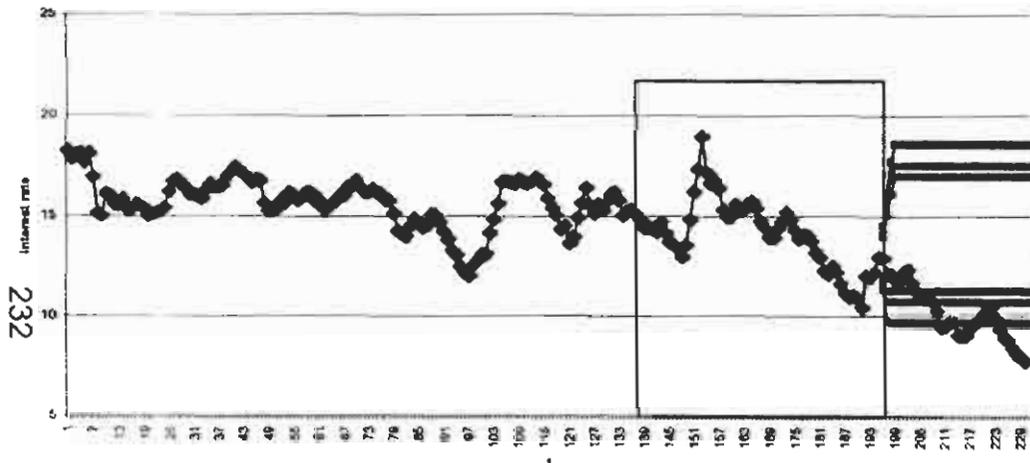
**Graph 6.52. Base Case Model for Extreme Volatility**  
60 values before point 196 Esc MAX99%, 95%, 90% 196



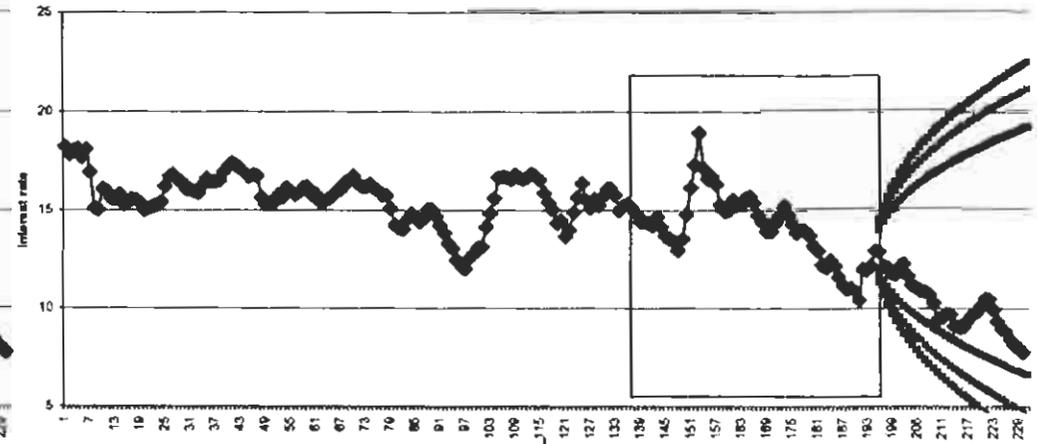
The unrestricted extreme volatility model that makes the graph above, produces intervals that include all the data. However, in the medium- and long-terms, the intervals seem too extreme, even considering the downward movement (suggests non stationary). There are open spaces.

The graph below indicates that the limits set on the intervals of this model do not allow the data to be included. The upper limits are too high up and the lower limits are too restrictive for the medium and long-terms (the latter for which there is not much data available).

**Graph 6.54. Extreme Volatility Model with Limits**  
60 values before point 196 Esc MAX99%, 95%, 90% 196



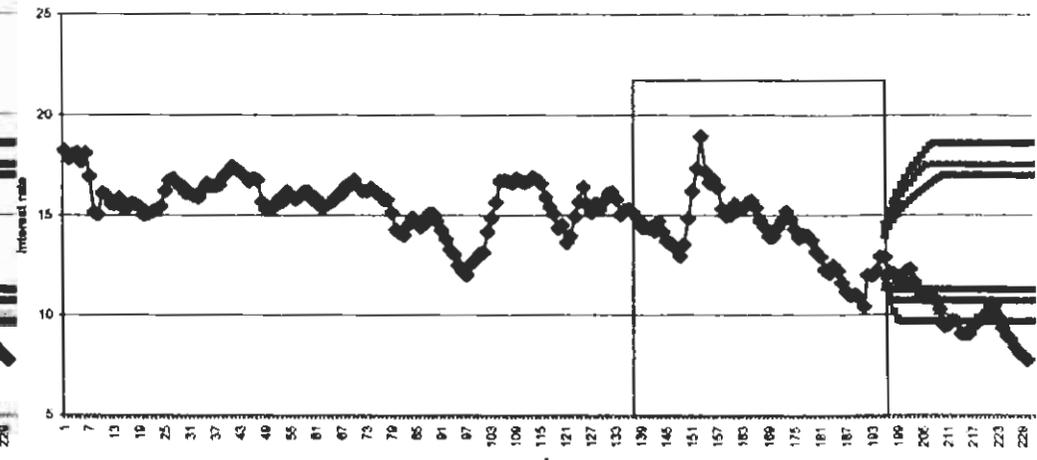
**Graph 6.53. Base Case Model for Normal Volatility**  
60 values before point 196 Esc MAX99%, 95%, 90% 196



The graph above seems like the best one of the four because the intervals contain all the data in the short-, medium- and long-terms and are able to capture the downward movement in the negative space of the interval (the area south of the imaginary horizontal no-volatility line).

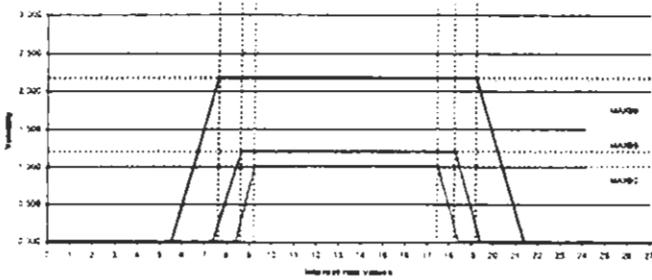
The data that is lying below the (lower) limits in the graph below suggests non stationarity. The normal volatility model produces intervals that are too restrictive for the lower limits and too wide in the upper limits (medium- and long-terms).

**Graph 6.55. Normal Volatility Model with Limits**  
60 values before point 196 Esc MAX99%, 95%, 90% 196

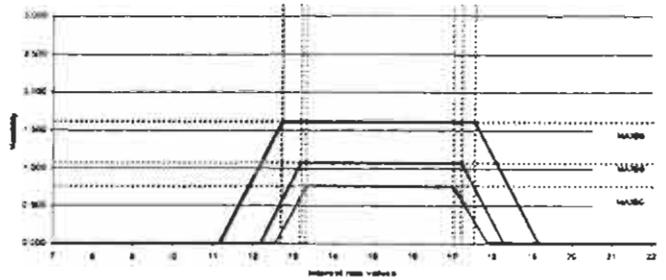


The graphs of volatility showing the limits obtained in each case are given below:

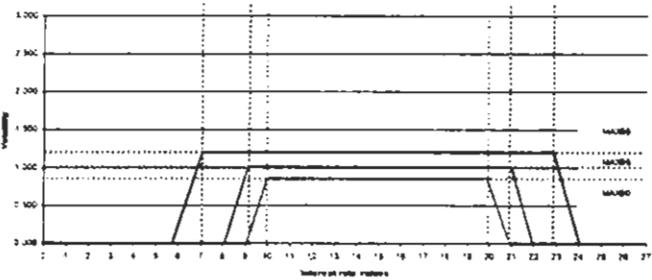
Graph 6.26. BA Limits  
MAX 90%, 95%, 99%



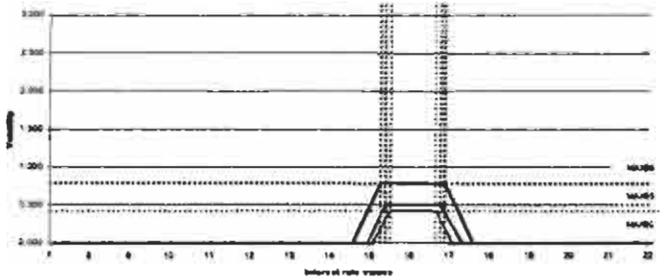
Graph 6.27. Lev Limits  
MAX 90%, 95%, 99%



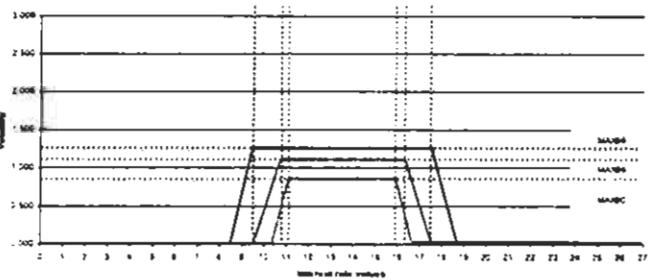
Graph 6.28. BA Limits  
90 values before point 74 MAX 90%, 95%, 99%



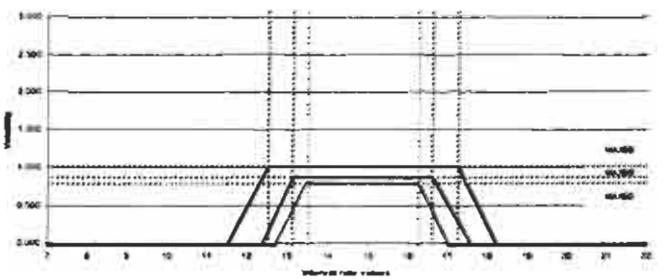
Graph 6.27. Lev Limits  
90 values before point 74 MAX 90%, 95%, 99%



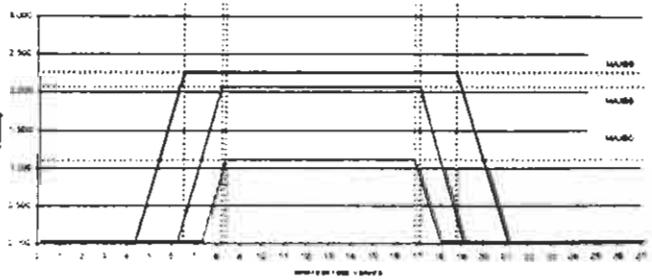
Graph 6.28. BA Limits  
90 values before point 148 MAX 90%, 95%, 99%



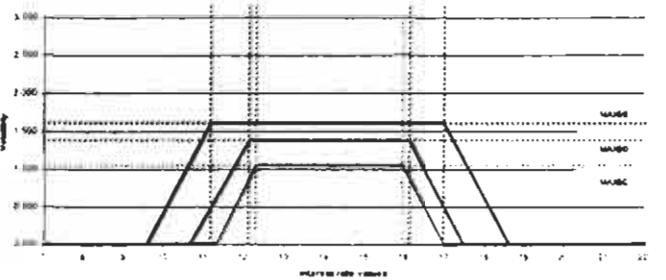
Graph 6.27. Lev Limits  
90 values before point 148 MAX 90%, 95%, 99%



Graph 6.28. BA Limits  
90 values before point 198 MAX 90%, 95%, 99%



Graph 6.27. Lev Limits  
90 values before point 198 MAX 90%, 95%, 99%



Summary tables showing how much percentage inside of the interval the actual data lies, are provided below:

Point 74		99%		95%		90%	
Percentage Inside Interval		Extreme Volatility	Normal Volatility	Extreme Volatility	Normal Volatility	Extreme Volatility	Normal Volatility
BA	Using	156 / 156 = 100%	156 / 156 = 100%	158 / 156 = 100%	148 / 156 = 95%	156 / 156 = 100%	138 / 156 = 88%
	Limits (Back casting) 196 values	155 / 156 = 99%	155 / 156 = 99%	151 / 156 = 97%	143 / 156 = 92%	135 / 156 = 87%	117 / 156 = 75%
Etc	Base case 60 values	156 / 156 = 100%	148 / 156 = 95%	156 / 156 = 100%	138 / 156 = 88%	156 / 156 = 100%	130 / 156 = 83%
	Limits 60 values	156 / 156 = 100%	148 / 156 = 95%	139 / 156 = 89%	121 / 156 = 78%	133 / 156 = 85%	107 / 156 = 69%
Etc	Base case (Back casting) 196 values	156 / 156 = 100%	156 / 156 = 100%	156 / 156 = 100%	156 / 156 = 100%	156 / 156 = 100%	149 / 156 = 96%
	Limits (Back casting) 196 values	126 / 156 = 81%	126 / 156 = 81%	114 / 156 = 73%	114 / 156 = 73%	104 / 156 = 67%	101 / 156 = 65%
Etc	Base case 60 values	156 / 156 = 100%	150 / 156 = 96%	156 / 156 = 100%	115 / 156 = 74%	156 / 156 = 100%	103 / 156 = 66%
	Limits 60 values	64 / 156 = 41%	64 / 156 = 41%	51 / 156 = 33%	50 / 156 = 32%	44 / 156 = 28%	43 / 156 = 28%

Point 148		99%		95%		90%	
Percentage Inside Interval		Extreme Volatility	Normal Volatility	Extreme Volatility	Normal Volatility	Extreme Volatility	Normal Volatility
BA	Using	80 / 82 = 98%	77 / 82 = 94%	77 / 82 = 94%	74 / 82 = 90%	77 / 82 = 94%	73 / 82 = 89%
	Limits (Back casting) 196 values	79 / 82 = 96%	77 / 82 = 94%	75 / 82 = 91%	72 / 82 = 88%	69 / 82 = 84%	56 / 82 = 68%
Etc	Base case 60 values	77 / 82 = 94%	74 / 82 = 90%	77 / 82 = 94%	73 / 82 = 89%	76 / 82 = 93%	72 / 82 = 89%
	Limits 60 values	59 / 82 = 72%	57 / 82 = 70%	49 / 82 = 60%	48 / 82 = 59%	33 / 82 = 40%	32 / 82 = 39%
Etc	Base case (Back casting) 196 values	82 / 82 = 100%	78 / 82 = 95%	79 / 82 = 96%	74 / 82 = 90%	78 / 82 = 95%	74 / 82 = 90%
	Limits (Back casting) 196 values	52 / 82 = 63%	48 / 82 = 59%	39 / 82 = 48%	34 / 82 = 41%	31 / 82 = 38%	27 / 82 = 33%
Etc	Base case 60 values	79 / 82 = 96%	74 / 82 = 90%	78 / 82 = 95%	74 / 82 = 90%	78 / 82 = 95%	74 / 82 = 90%
	Limits 60 values	47 / 82 = 57%	42 / 82 = 51%	32 / 82 = 39%	28 / 82 = 34%	30 / 82 = 37%	27 / 82 = 33%

Point 196		99%		95%		90%	
Percentage Inside Interval		Extreme Volatility	Normal Volatility	Extreme Volatility	Normal Volatility	Extreme Volatility	Normal Volatility
BA	Using	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%
	Limits 196 values	35 / 35 = 100%	35 / 35 = 100%	33 / 35 = 94%	33 / 35 = 94%	18 / 35 = 51%	18 / 35 = 51%
Etc	Base case 60 values	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	30 / 35 = 86%
	Limits 60 values	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	30 / 35 = 86%	24 / 35 = 69%
Etc	Base case 196 values	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%
	Limits 196 values	9 / 35 = 26%	9 / 35 = 26%	4 / 35 = 11%	4 / 35 = 11%	1 / 35 = 3%	1 / 35 = 3%
Etc	Base case 60 values	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%	35 / 35 = 100%
	Limits 60 values	21 / 35 = 60%	21 / 35 = 60%	13 / 35 = 37%	13 / 35 = 37%	8 / 35 = 23%	8 / 35 = 23%

Table 6.7. Summary tables showing the percentage of predictions that lie inside the set intervals and limits, at each forecasted point.

#### 6.4.5. Analysing the Results

From the graphs and tables above, amongst other things, the following may be seen:

For the BA time series:

- Standing at point 196 and using all past data to predict without limits (base case)
  - 1: (Graph 6.20) In anticipation of a period of extreme volatility, a wide interval is found that ensures that for 99%, 95% and 90%, all actual interest rates lie within it
  - 2: (Graph 6.22) In anticipation of a less volatile period, a smaller interval that goes out slower, is found. This narrower interval still contains all future interest rates, which makes it a better model
- Standing at point 196 and using all past data to predict with limits
  - 3: (Graph 6.25) In anticipation of a period of extreme volatility, initial predictions are the same as before (1). However, adding limits cuts the predictions so that they don't become too wide and therefore, unusable but in this case, causes the lower limit to be too narrow for 95% and 90%, which ensures that only 94% and 51% of actual interest rates, respectively, are captured
  - 4: (Graph 6.26) In anticipation of a less volatile period, initial predictions are the same as before (2) but since the limits are the same as in the case of extreme volatility (3), the same percentage results are obtained
- Standing at point 196 and using only the 60 values before it to predict without limits (base case)
  - 5: (Graph 6.40) In anticipation of a more volatile period, a wide interval is found that ensures that for 99%, 95% and 90%, all the actual interest rates lie within it
  - 6: (Graph 6.41) In anticipation of a 'normal' volatile period, a smaller interval that goes out slower and closer to the actual data, is found. This narrower interval still contains all future interest rates for 99%, 95% and 90%. The interval for 90% seems the best (closest to the real data)
- Standing at point 196 and using only the 60 values before it to predict with limits
  - 7: (Graph 6.42) In anticipation of a period of extreme volatility, initial predictions are as before (5). However, adding limits causes the lower

limit to be too narrow at 90% which accounts for having only 86% of actual interest rates lie within it

- 8: (Graph 6.43) In anticipation of a less volatile period, initial predictions are the same as before (6) but since the limits are the same as in the case of extreme volatility (7), the same percentage results are obtained. These results seem to be better than those obtained using all the data.

For the Esc time series:

- Standing at point 196 and using all past data to predict without limits (base case)
  - 1: (Graph 6.27) In anticipation of an extremely volatile period, a wide interval is found that ensures that for 99%, 95% and 90%, all actual interest rates lie within it
  - 2: (Graph 6.28) In anticipation of a period of less volatility, a smaller interval that goes out slower, is found. This narrower interval seems to be too conservative for 90%, where only 69% of actual interest rates lie within it
- Standing at point 196 and using all past data to predict with limits
  - 3: (Graph 6.30) In anticipation of a period of extreme volatility, initial predictions for the upper limit are the same as before (1) and after that, cause no difference to the percentage of the original data that lie inside the interval. However, adding a lower limit in this case, ensures that most of the data lies outside of the intervals, since only 26%, 11% and a mere 3% of the original data at 99%, 95% and 90%, respectively, lies within the limits
  - 4: (Graph 6.31) In anticipation of a less volatile period, initial predictions for the upper limit are the same as before (2). However, with the limits introduced in (3), the same percentage results as in the case of extreme volatility are obtained
- Standing at point 196 and using only the 60 values before it to predict without limits (base case)
  - 5: (Graph 6.52) In anticipation of an extremely volatile period, once again, a wide interval is found that ensures that all predictions at 99%, 95% and 90% lie within it
  - 6: (Graph 6.53) In anticipation of a less volatile period, again, a smaller interval that goes out slower, is found. In this case, though, the

narrower interval is able to contain all future interest rates for 99%, 95% and also 90%. The problem (that can be seen in the graph) is that the upper limits are relatively wide but the lower limits almost miss the data

- Standing at point 196 and using only the 60 values before it to predict with limits
  - 7: (Graph 6.54) When a period of extreme volatility is anticipated, initial predictions are the same as at (5), until the limits (especially the lower limits) start taking effect. Since the original data after the Asian Crisis appears to be heading lower (downward), the more recent 60 previous values are able to provide a slightly wider interval than the 196 values could. Although still not able to include all the data, these intervals for 99%, 95% and 90% are able to include substantially more data than before, namely: 60%, 37% and 23%, respectively.
  - 8: (Graph 6.55) When a period of less volatility is anticipated, initial predictions are the same as before (6) until the limits start to make a difference, in which case, a similar situation to (7) occurs and the same percentage results are obtained

The predictions that are made and the intervals that are set do not appear to be too good using only the 60 values before point 196. However, the limits that are set with these 60 values are better than those found using all the data before point 196, especially because they are lower, which is the direction in which the actual interest rates seem to be going.

As for the other points, it is difficult to compare forecasts made using the previous 60 values as opposed to those made by back casting. Since, standing at point 74, the future was not known, the predictions made with hindsight would not help anyone trying to predict at the time. Nevertheless, comparing the two predictions may be useful in providing some information and insight.

For the BA data series at point 74, for example, it is interesting to see that predictions for extreme volatility are all in but when normal volatility conditions are expected, the models are not able to predict correctly initially, although providing a good interval for the long-term. When limits are added, the peak at the Asian Crisis does not always

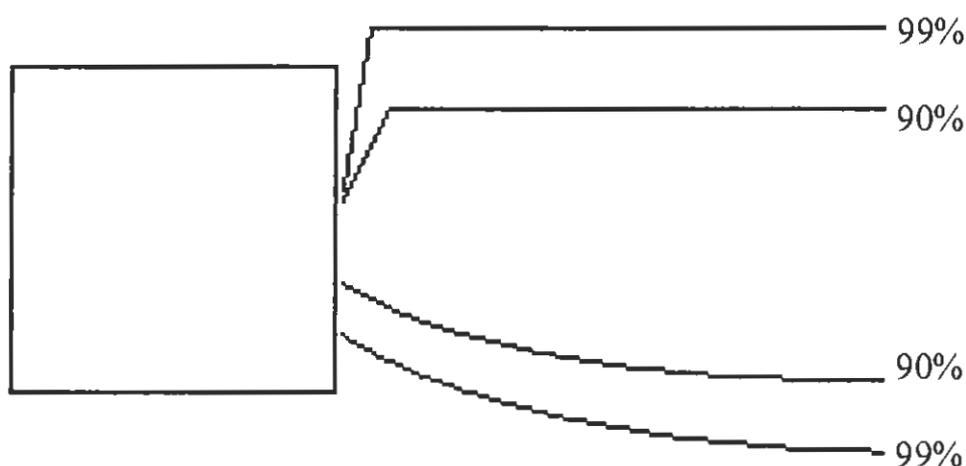
lie within the intervals. Also, using the 60 values before point 74 does not provide good limits for actual data happening around 2005.

For the Esc data set, the worst-looking limits are probably those found using the 60 values before point 74. They produce the smallest intervals<sup>107</sup> (due, especially, to the lower limits), even though the percentage of actual data inside the interval is higher than at some of the other points. This emphasises one of the pitfalls of considering only the percentage numbers and not the numbers and graphs as a whole – there is a difference in the number of predictions that are made. Less comparisons are made at point 196 (35), than at point 148 (82), than at point 74 (156). This also needs to be taken into consideration.

Another interesting thought is that, even anticipating extremely volatile conditions at point 148 (before the Asian Crisis), these models would not have been able to predict intervals that include the highest observed interest rates. The 60 values before point 148 are not able to provide a wide enough interval – the limits (especially the lower limits) are too small, or narrow, for what takes place in reality.

#### 6.4.6. Hybrid Volatility Model

Considering Graphs 6.32 to 6.55 of the previous section, a hybrid model can be developed. It looks something like this:



<sup>107</sup> That can be seen in Table 6.6.

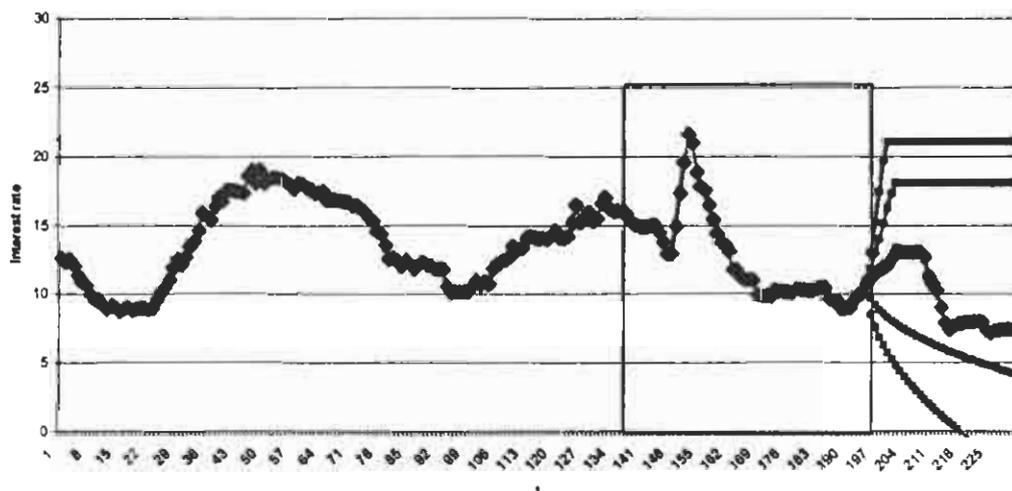
The hybrid model suggests that predictions should be made as follows:

1. Select the amount of data to use (for example, 60 values). Follow the procedures as above to find volatility estimates for MAX90% and MAX99%
2. Start making long-term forecasts with the extreme volatility model and make upper predictions for an interval of 90%. Then, for this upper interval only, find and set a limit according to Eq.2;
3. Make long-term forecasts using the normal volatility model making lower predictions for an interval of 90%;
4. Repeat Steps 2 and 3 for a 99% interval.

This new model can be used to predict intervals that should contain all the future data in the short-, medium- and long-terms. If any data lies outside of the 90% interval, then it should be covered by the 99% interval (see for example, the latest Esc data – the downward movement). If the data lies in any area above the 99% upper interval limit or below the 99% interval, then it is considered too extreme.

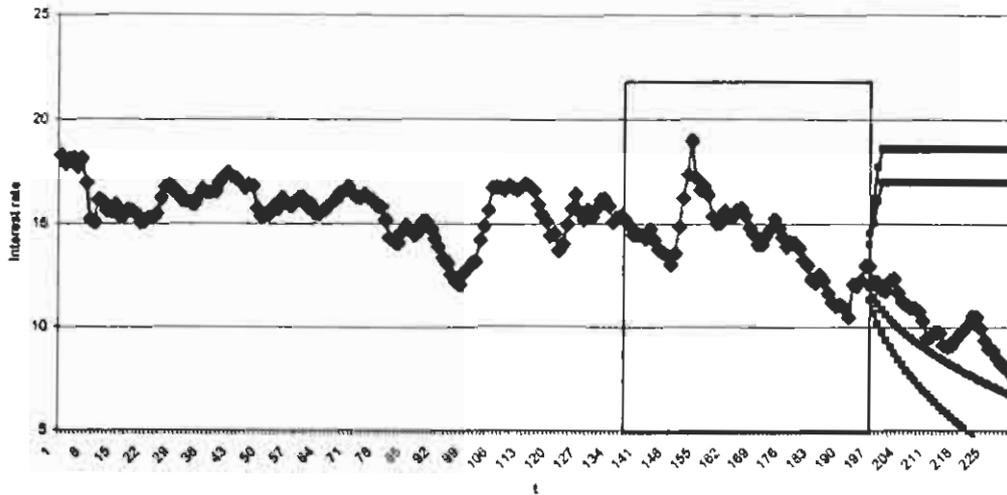
This hybrid model was tested out on the last 60 values before point 196 for the BA and Esc time series, in order to make a prediction for the future. The resulting graphs are shown below:

Graph 6.64. Hybrid Model  
60 values before point 196 BA MAX99%, 90% 196



In the graph above, All the available BA data lies within the intervals and limits set. This graph is an improvement on Graphs 6.40 and 6.42.

Graph 6.65. Hybrid Model  
60 values before point 196 Esc MAX99%, 90% 196



From the graph above it can be seen that all the available Esc data lies within the intervals and limits that were set with the hybrid model. It is an improvement on Graphs 6.52 (although there is still a lot of space between the upper limit and the actual data) and 6.54.

In order to ascertain whether correct predictions were made for the longer-term, more actual data is needed. This will be possible only once the data is available in reality. Yet, since all the data lies within the 90% intervals (and limits) for both time series, the hybrid model seems to be one that is able to make reasonably good predictions.

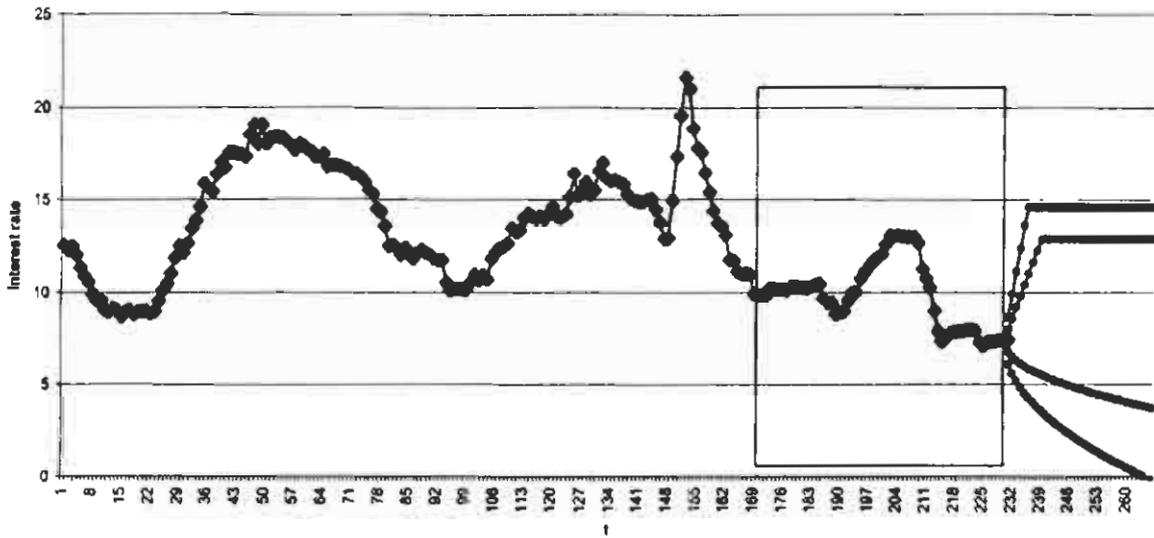
#### 6.4.6.1. Forecasting with the Hybrid Volatility Model: Predictions for the Future

As was done with the AR(2) model, in addition to the above, it was decided to take the last 60 values of all the known data for each data set and make predictions for the future when standing at this last known data point. The resultant graphs are shown below, as is a small table with the last predictions:

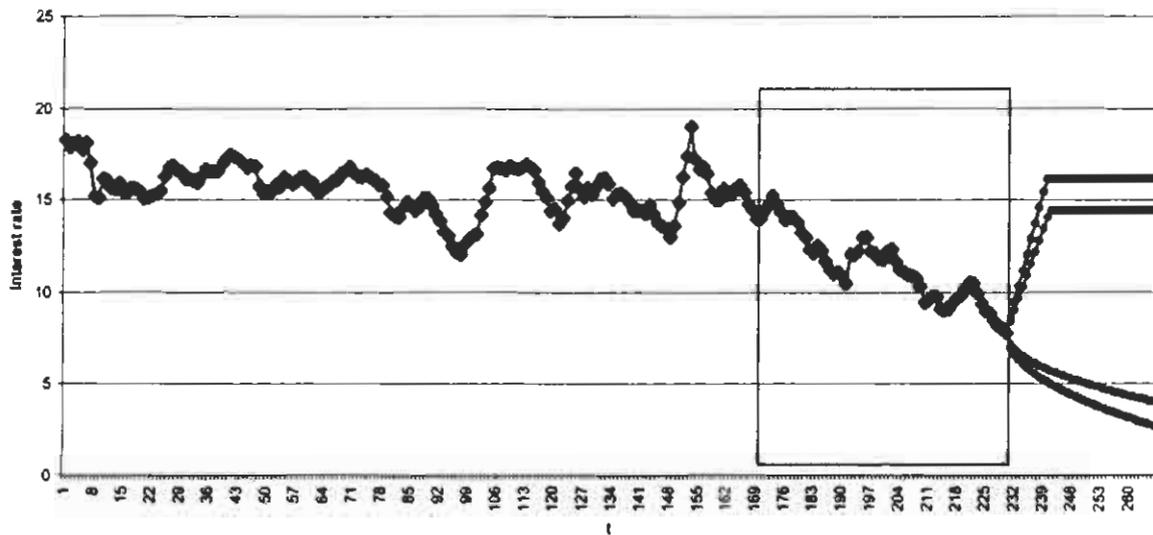
Hybrid	LL 90%	UL 90%	LL 99%	UL 99%	
BA	3.70	12.90	-0.20	14.58	36 predictions
Esc	4.00	14.42	2.68	16.13	36 predictions

*Table 6.8. Summary table showing the last predictions using the hybrid model.*

Graph 6.66. Hybrid Model  
60 values before point 230 BA MAX99%, 90% 230



Graph 6.67. Hybrid Model  
60 values before point 230 Esc MAX99%, 90% 230



A type of comparison of the AR(2) models and the hybrid models can be made.

Thus:

BA	LL 90%	UL 90%	LL 95%	UL 95%	LL 99%	UL 99%	
AR(2)			5.78	13.32			100 predictions
Hybrid	3.70	12.90			-0.20	14.58	36 predictions

Esc	LL 90%	UL 90%	LL 95%	UL 95%	LL 99%	UL 99%	
AR(2)			5.81	15.84			100 predictions
Hybrid	4.00	14.42			2.68	16.13	36 predictions

From the work done with the hybrid model, it appears to be the best model for making predictions over the different time horizons (short-, medium- and long-term). All the available data lies within the intervals and limits set with this model.

## 6.5. Conclusion

Forecasting is an essential part of our lives. From the clothes we wear the next day, to how much money we invest, making and receiving correct predictions affects our lives and our businesses<sup>108</sup>. Banks are amongst those affected the most. Indeed, they need to be able to forecast things (such as interest rates) that affect their survival in the economic market. Therefore, it is crucial that they are able to predict rates, for example, quickly and correctly.

In attempting to manage interest rate risk effectively by predicting interest rates for two data sets (BA and Esc), Chapter 4 focused on simple forecasting methods and techniques. Fundamentally, predictions for one-step ahead were looked at. In this chapter, the aim is to introduce more advanced models in the hopes of finding better long-term predictions for the two real time series (BA and Esc). The focus is now on using more advanced forecasting and volatility models in order to make longer-term forecasts for the two time series.

Making longer-term forecasts means working with intervals. It is important to find an interval that will contain the future actual data, or at least most of it. Being able to find a good interval with the least amount of past data is also important.

Before starting on the predictions, however, since the last known data points would be used, more data was collected (just under three years' worth of data for each time

<sup>108</sup> One of the examples given by Bowerman and O'Connell (1993:3) of situations in which business forecasts are needed, is in finance, where "interest rates must be predicted so that new capital acquisitions can be planned and financed. Financial planners must also forecast receipts and expenditures in order to predict cash flows and maintain company liquidity".

series). This actual data was used to determine how effective the models are in forecasting accurate prediction intervals that are able to include all the real data.

For this chapter, in particular, two broad areas of work were explored. These areas are distinguished by answering the questions: is a stationary time series or a non-stationary time series involved? If it's the latter, are they extreme or normal conditions?

For stationary time series, Box-Jenkins autoregressive models of order two were discussed. For non-stationary time series, new models were developed.

For the Box-Jenkins models<sup>109</sup>, a package called STATISTICA was used in addition to Excel. The conditions for stationarity were observed (which is a requirement for each of the time series for these models) and both time series were tentatively identified as AR(2) models. Predictions were then made.

The models were able to estimate an interval that contained most of the actual BA data. However, an interval much higher up than where the actual data really is, was predicted for the Esc time series.

Next, averages of the original data were taken. From averages of two values, to three, four and five. The same model was applied to each series individually and results were obtained and analysed.

The 60 values before the last known data points of each time series were then selected. These were used to make predictions for the future with the AR(2) model.

For the non-stationary times series, new models were developed. These new models create 99%, 95% and 90% intervals based on their respective volatility estimates (which are found with new work done using the maximum absolute value

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<sup>109</sup> As Pankratz (1983:47) explains, an ARIMA process "refers to the set of possible observations on a time-sequenced variable, along with an algebraic statement (a generating mechanism) describing how these observations are related".

first differences). Every time, intervals were created in anticipation of extreme volatility conditions and normal volatility conditions.

Described in greater detail: a base case was found for each time series, where all the previously known data values were used. From here, back casting was done at two other chosen points (74 and 148) that reflected a different direction in which the actual data was moving. Each time, two cases were examined – one in times when extreme volatility was expected and another, when a period of less, or normal, volatility was anticipated. Results were obtained.

Each interval was then restricted by adding volatility limits. Thus, limits based on  $\bar{x} \pm z \times s$  were considered for each interval in extreme and normal circumstances. These limits were obtained and the results analysed.

However, using so many past interest rates (196 values) to make predictions for such a short amount of time seemed excessive. Since indications were to use five to ten years' worth of data, models using only the 60 values before each point were developed.

Again, cases of extreme volatility (that makes use of  $n$ , where  $n$  is the number of periods of the predictions) and normal volatility (that make use of the squared root of  $n$ ) were explored. Results were summarised in graphs and tables and a short analysis of these was conducted. Amongst other things, it was found that adding limits is not always the best thing to do, as these may be too narrow, causing the actual data to lie outside of the intervals (which means or confirms that the data is non-stationary).

A hybrid model was also suggested. This model makes interval predictions for 90% and 99% and then applies only upper limits on these. Areas that are not covered by the model are considered extreme. The hybrid model was tested on both time series, using the 60 values before point 196. In each case positive results were achieved which suggest that the model (which appears to be the best one of all) is

able to make accurate predictions over the different time horizons for both time series.

A similar procedure to that done for the AR(2) models was followed for the hybrid volatility model. That is, predictions were made for the future when considering just the 60 values before the last known data points. Long-term results can be tested only once actual data is available.

The effectiveness of all the models described in this chapter can be compared. Given certain expectations, different models are recommended. The table below indicates whether a model is able to make correct and accurate predictions (√) or not (X) and whether it is recommended, over different time horizons:

- Short-term            one month
- Medium-term        one year
- Long-term            more than one year

BA MODEL	TIME HORIZON				Esc MODEL	TIME HORIZON			
	SHORT	MEDIUM		LONG		SHORT	MEDIUM		LONG
		Extreme	Normal				Extreme	Normal	
AR(2)	√	√	√	√	AR(2)	√	X	X	X
EVM	√	√	X	X	EVM	√	√	X	X
NVM	√	X	√	√	NVM	√	X	√	√
EVM with Limits	√	√	√	X	EVM with Limits	√	√	X	X
NVM with Limits	√	X	√	X	NVM with Limits	√	X	X	X
Hybrid	√	√	√	√	Hybrid	√	√	√	√

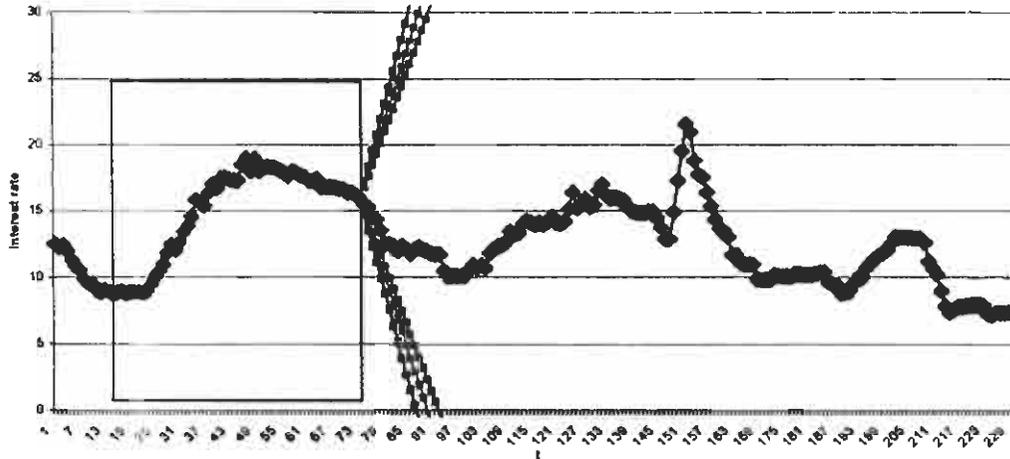
EVM = Extreme Volatility Model  
 NVM = Normal Volatility Model

EVM = Extreme Volatility Model  
 NVM = Normal Volatility Model

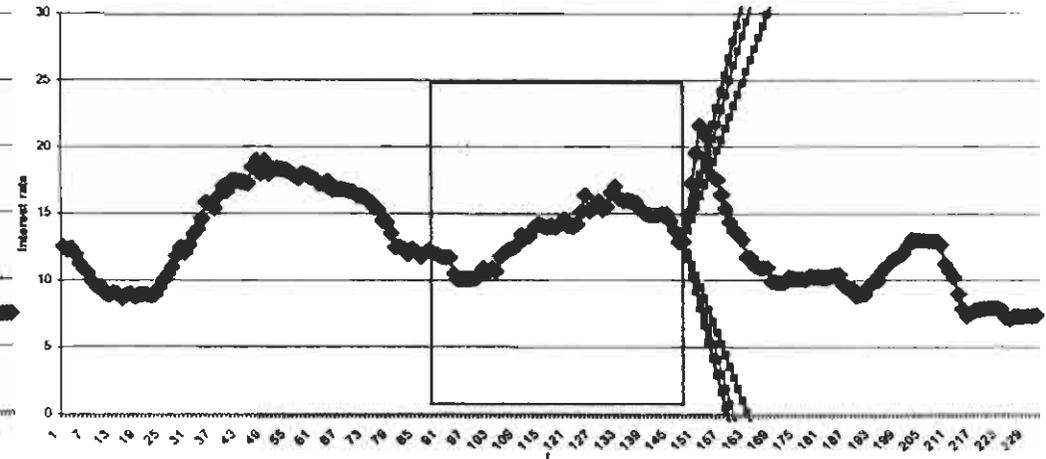
***Table 6.9. Summary table comparing how effective the different models are in predicting over different time horizons.***

The results given in the table above can be explained by considering Graphs 6.32 to 6.55 again. This time arranging and examining them in terms of each model at the different points.

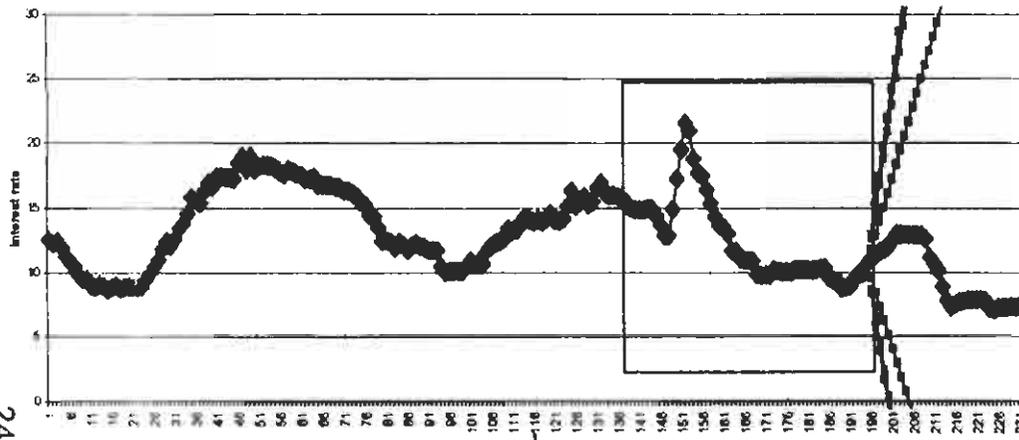
Graph 6.32. Base Case Model for Extreme Volatility  
60 values before point 74 BA MAX99%, 95%, 90% 74



Graph 6.36. Base Case Model for Extreme Volatility  
60 values before point 148 BA MAX99%, 95%, 90% 148



Graph 6.40. Base Case Model for Extreme Volatility  
60 values before point 196 BA MAX99%, 95%, 90% 196

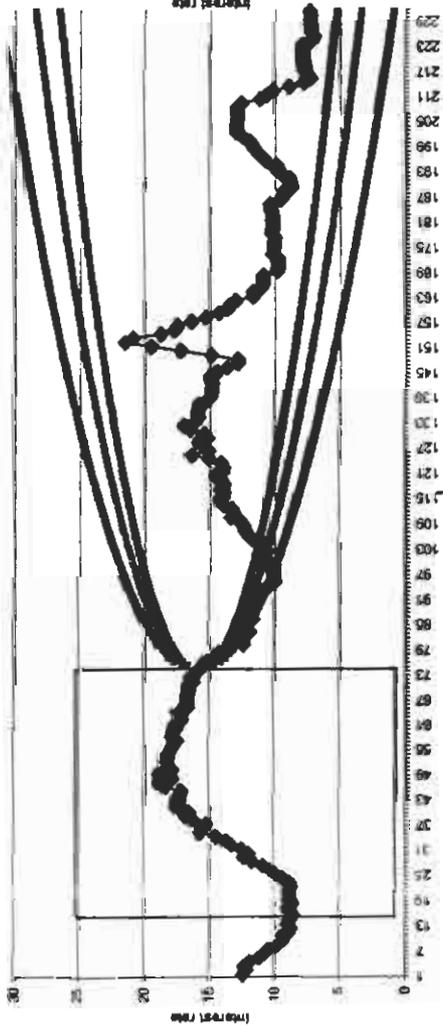


For the BA time series:

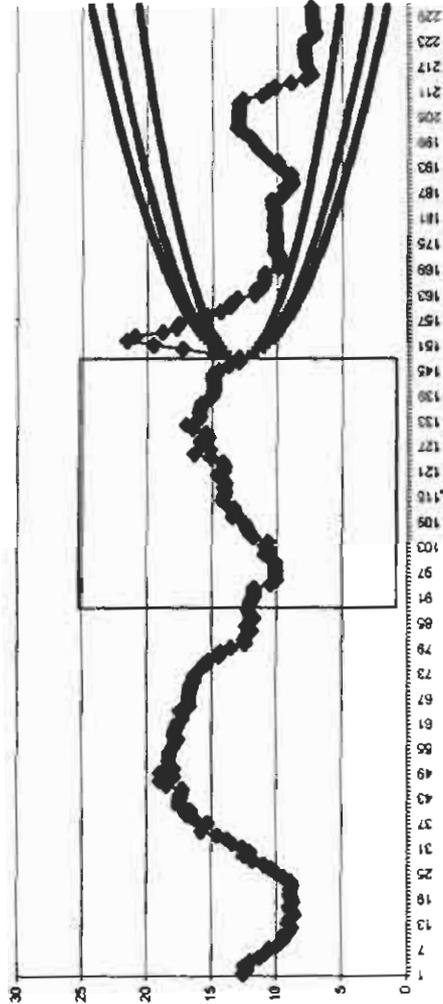
The graphs given here show the predictions of the extreme volatility model (EVM) at the different points (74, 148 and 196) using only the 60 values before each one.

- For the short-term, the extreme volatility model is able to make predictions that include, or are close to, the actual data.
- Already in the medium-term, this model starts to predict intervals that are quite wide and it is thus, not recommended to use this model at times other than in anticipation of extreme volatility, such as at the Asian Crisis (Graph 6.36) where, although it does not include all the actual data, it is the model that is able to make the closest predictions.
- Clearly, for the long-term, the intervals predicted using the EV model are much too wide and it is recommended not to use this model for making long-term predictions.

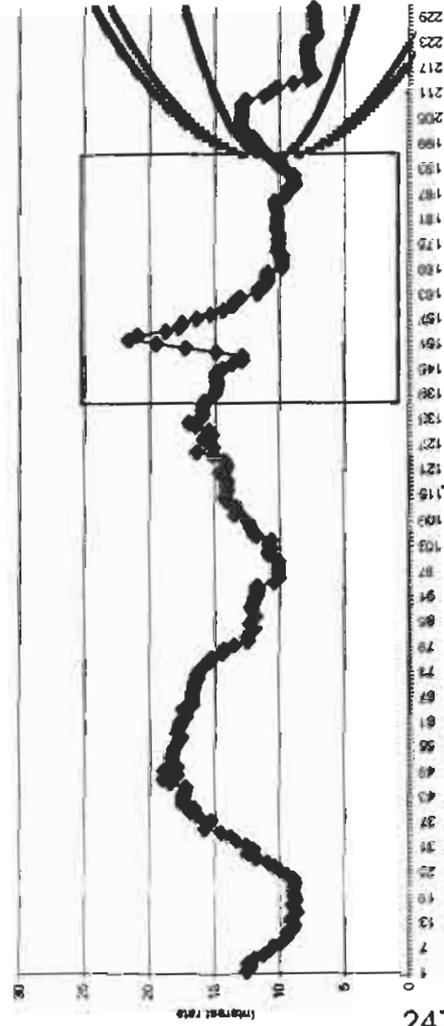
Graph 6.33. Base Case Model for Normal Volatility  
60 values before point 74 BA MAX99%, 95%, 90% 74



Graph 6.37. Base Case Model for Normal Volatility  
60 values before point 148 BA MAX99%, 95%, 90% 148



Graph 6.41. Base Case Model for Normal Volatility  
60 values before point 196 BA MAX99%, 95%, 90% 196

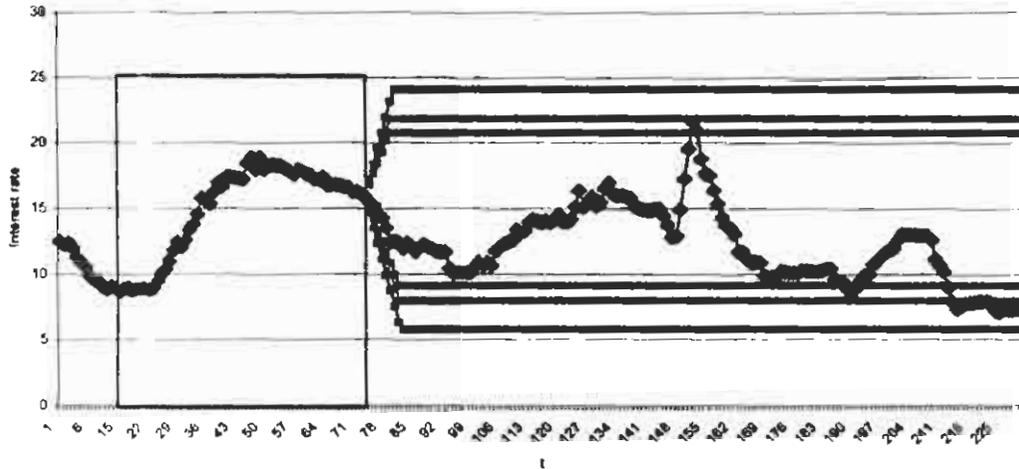


For the BA time series:

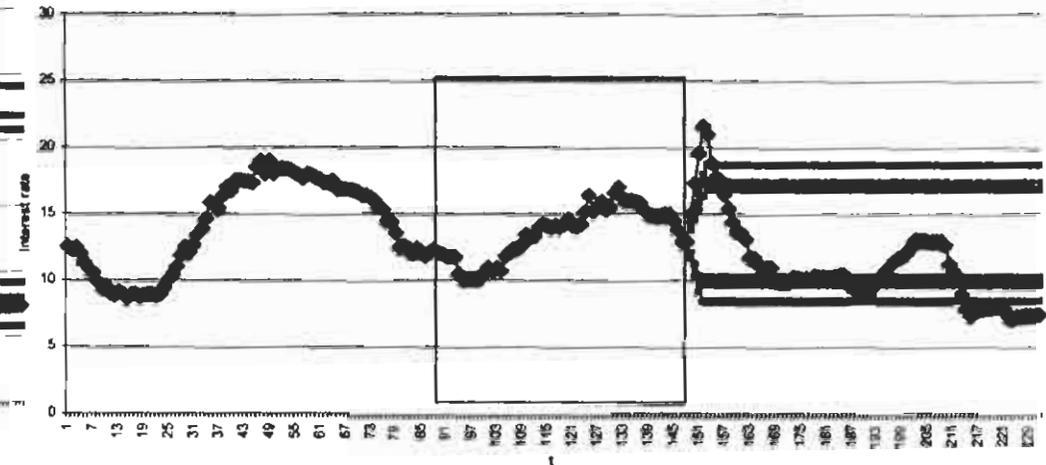
The graphs given here show the predictions of the normal volatility model (NVM) at the different points (74, 148 and 196) using only the 60 values before each one.

- For the short-term, the normal volatility model is able to make predictions that include, or are close to, the actual data.
- As indicated in Table 6.7, except in extreme conditions such as at the Asian Crisis (Graph 6.37), this model makes reasonably good interval predictions that are able to include, or are quite close to, the actual data.
- This model is recommended for making long-term predictions because the intervals predicted using the NV model are able to include all the actual data available.

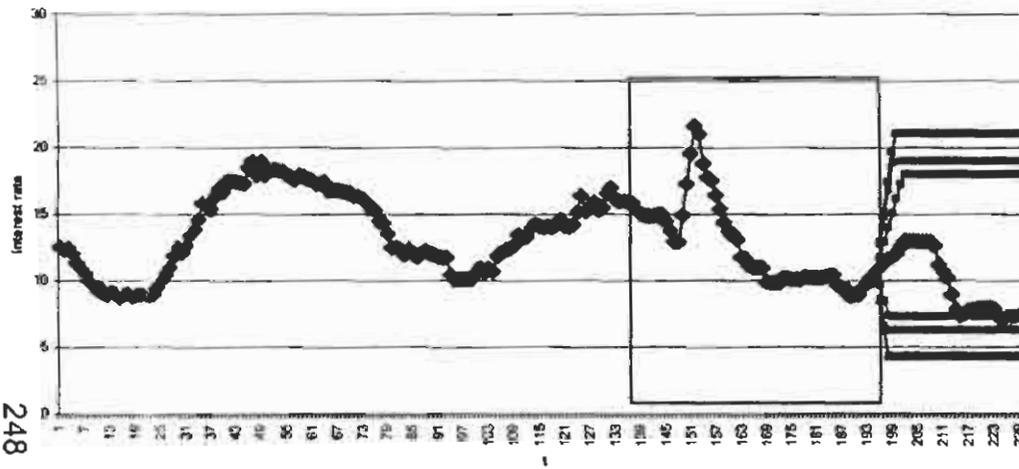
Graph 6.34. Extreme Volatility Model with Limits  
60 values before point 74 BA MAX99%, 95%, 90% 74



Graph 6.38. Extreme Volatility Model with Limits  
60 values before point 148 BA MAX99%, 95%, 90% 148



Graph 6.42. Extreme Volatility Model with Limits  
60 values before point 196 BA MAX99%, 95%, 90% 196

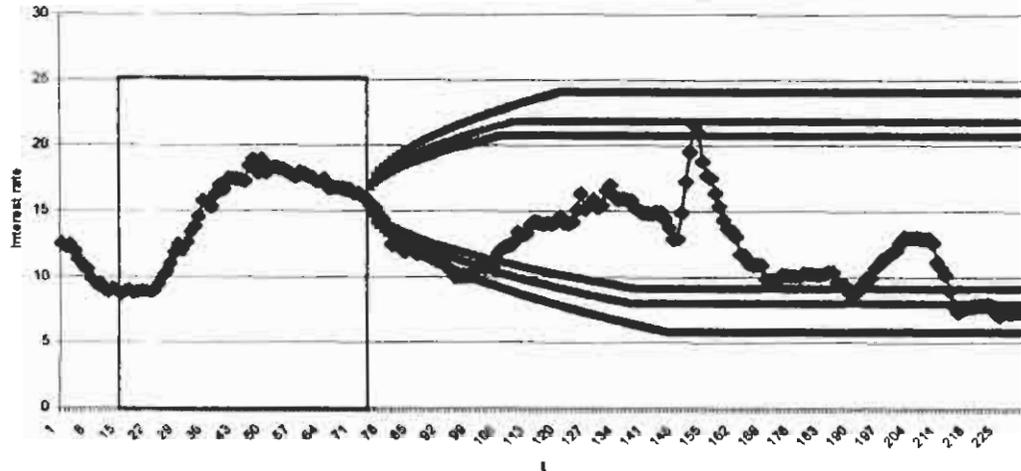


For the BA time series:

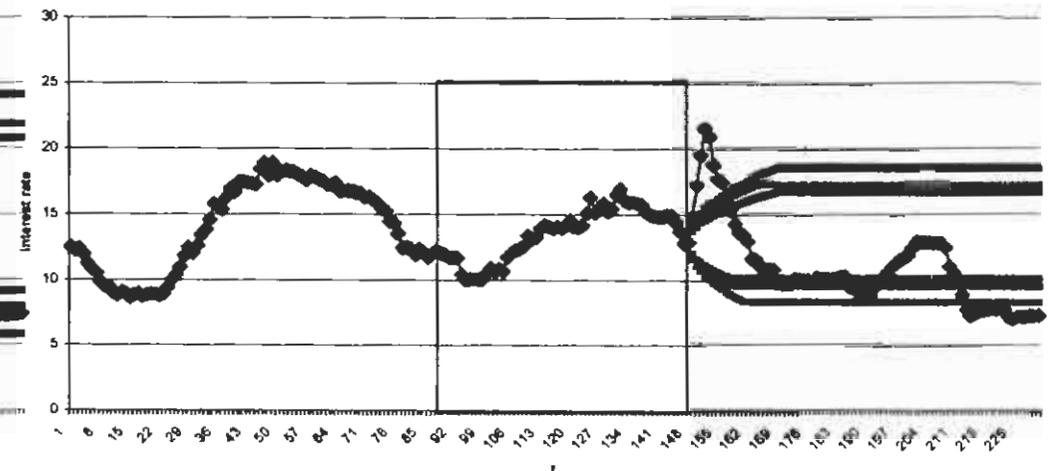
The graphs given here show the predictions made with the extreme volatility model (EVM), restricted by limits, at the different points (74, 148 and 196) using only the 60 values before each one.

- For the short-term, the extreme volatility model with limits is able to make predictions that include, or are close to, the actual data.
- With the exception at the Asian Crisis, the limits that restrict the fast outward movement of the EV model ensure that this model is able to make more reasonable medium-term predictions than before.
- The limits that restrict the predictions of the extreme volatility model are too conservative for the long-term and the intervals produced by this model are too narrow. Long-term predictions using this model are, therefore, not recommended.

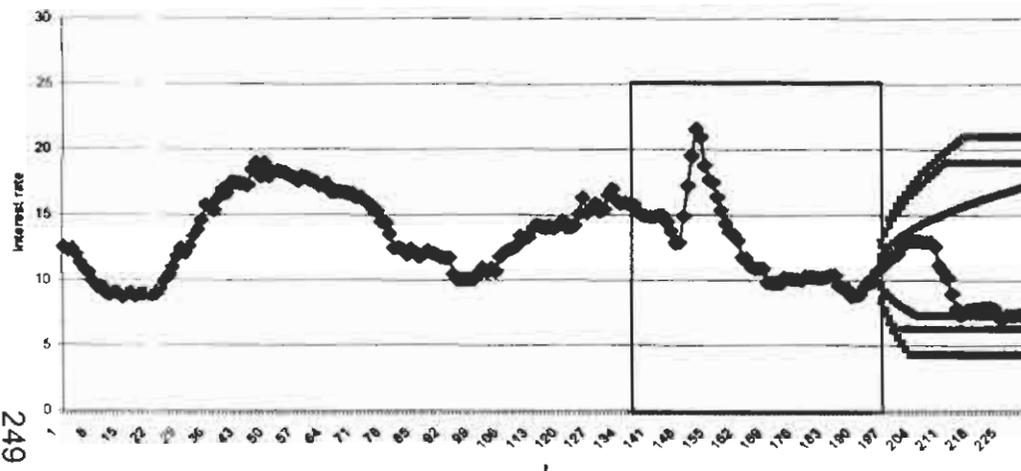
Graph 6.35. Normal Volatility Model with Limits  
60 values before point 74 BA MAX99%, 95%, 90% 74



Graph 6.39. Normal Volatility Model with Limits  
60 values before point 148 BA MAX99%, 95%, 90% 148



Graph 6.43. Normal Volatility Model with Limits  
60 values before point 196 BA MAX99%, 95%, 90% 196

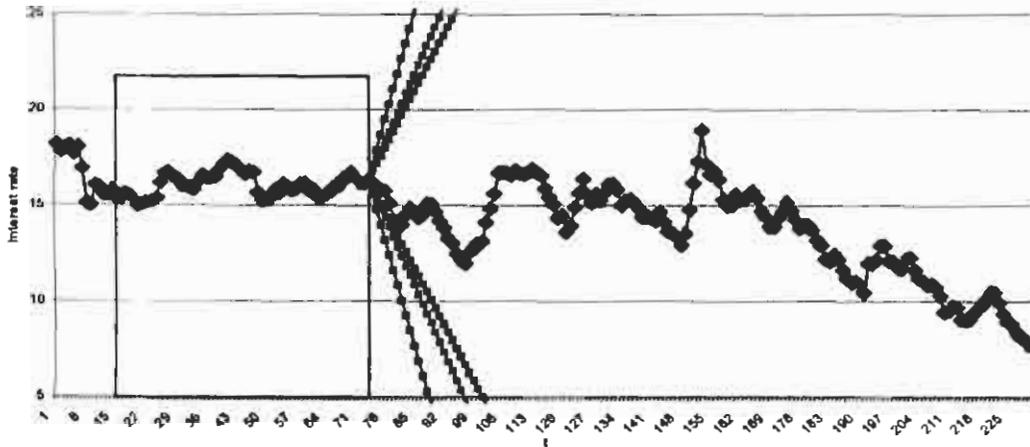


For the BA time series:

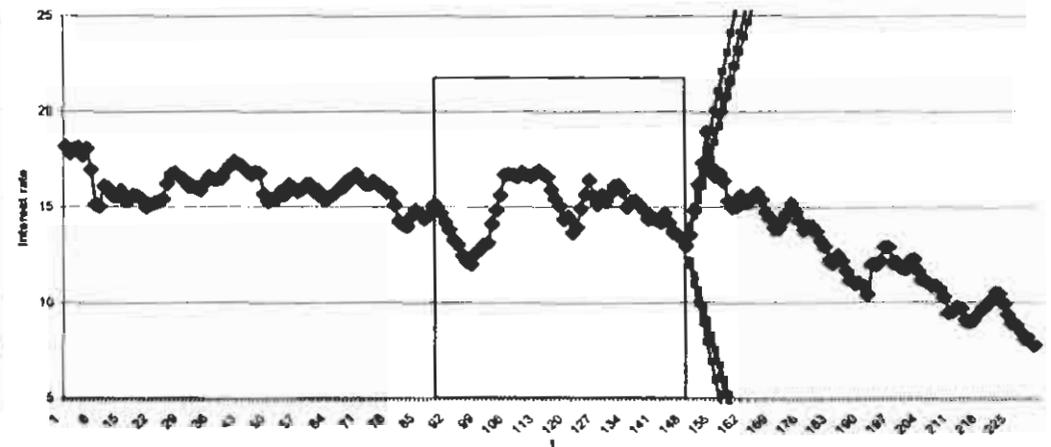
The graphs given here show the predictions made with the normal volatility model (NVM), restricted by limits, at the different points (74, 148 and 196) using only the 60 values before each one.

- For the short-term, the normal volatility model with limits is able to make predictions that include, or are close to, the actual data.
- Except at the Asian Crisis, the limits that restrict the NV model ensure that this model is able to make reasonable medium-term predictions.
- The limits that restrict the predictions of the normal volatility model are too conservative for the long-term and the intervals produced by this model are too narrow. Therefore, long-term predictions using this model are not recommended. However, it has to be noted that when standing at point 74, much more real data is available for the "long-term" than, say, at point 196.

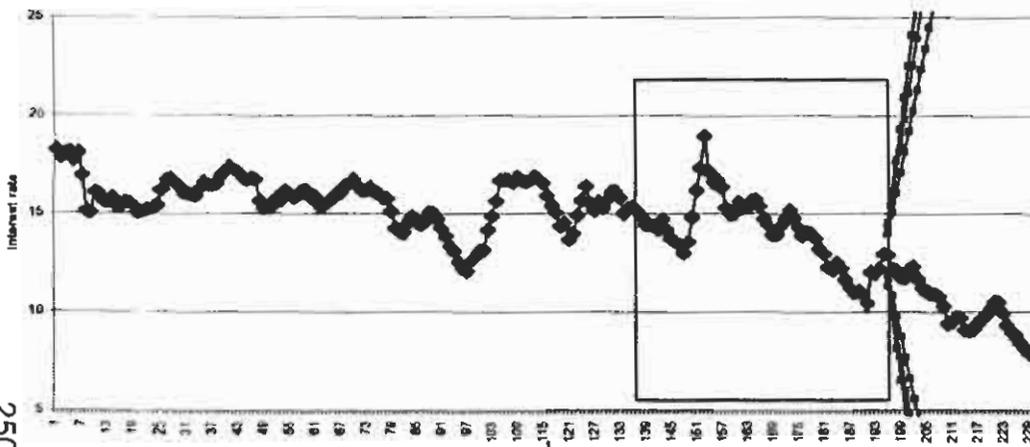
**Graph 6.44. Base Case Model for Extreme Volatility**  
60 values before point 74 Esc MAX99%, 95%, 90% 74



**Graph 6.48. Base Case Model for Extreme Volatility**  
60 values before point 148 Esc MAX99%, 95%, 90% 148



**Graph 6.52. Base Case Model for Extreme Volatility**  
60 values before point 196 Esc MAX99%, 95%, 90% 196

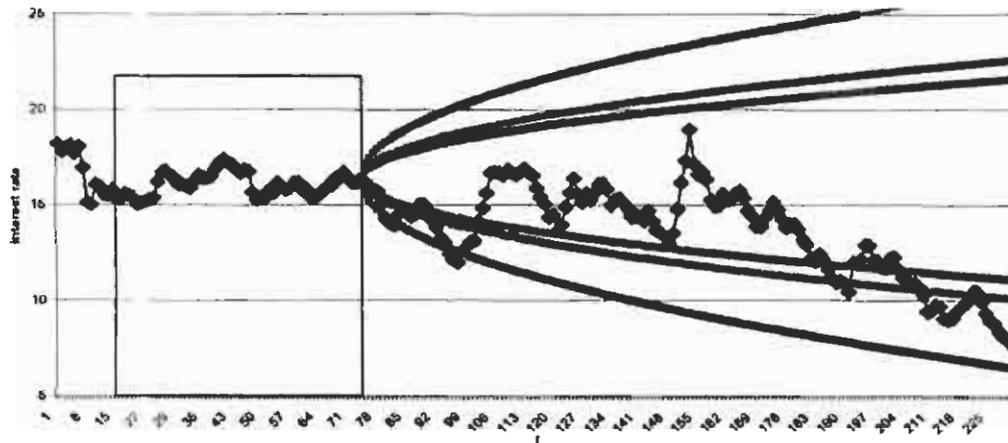


For the Esc time series:

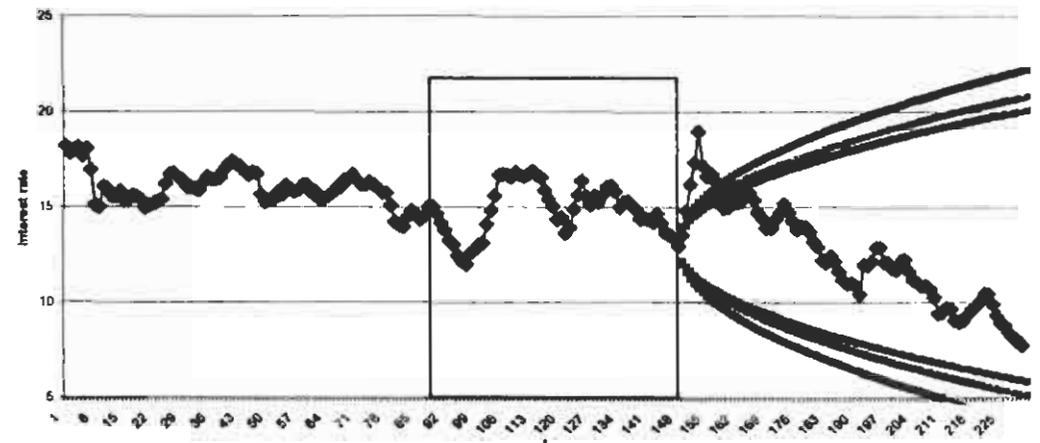
The graphs given here show the predictions of the extreme volatility model (EVM) at the different points (74, 148 and 196) using only the 60 values before each one.

- For the short-term, the extreme volatility model is able to make predictions that include, or are close to, the actual data.
- For the medium-term, this model predicts intervals that start to become rather wide and it is thus, not recommended to use this model at times other than in anticipation of extreme volatility, like at the Asian Crisis (Graph 6.48) where, although the interval does not include all the actual data, it is the one closest to it.
- In the long-term, the intervals predicted using the EV model are too wide. It is recommended not to use this model for making predictions for the long-term.

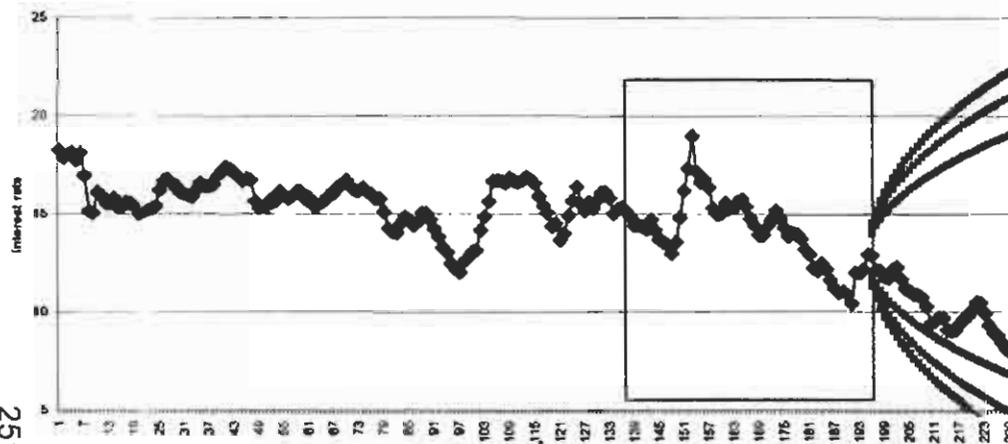
Graph 6.45. Base Case Model for Normal Volatility  
60 values before point 74 Esc MAX99%, 95%, 90% 74



Graph 6.49. Base Case Model for Normal Volatility  
60 values before point 148 Esc MAX99%, 95%, 90% 148



Graph 6.53. Base Case Model for Normal Volatility  
80 values before point 196 Esc MAX99%, 95%, 90% 196

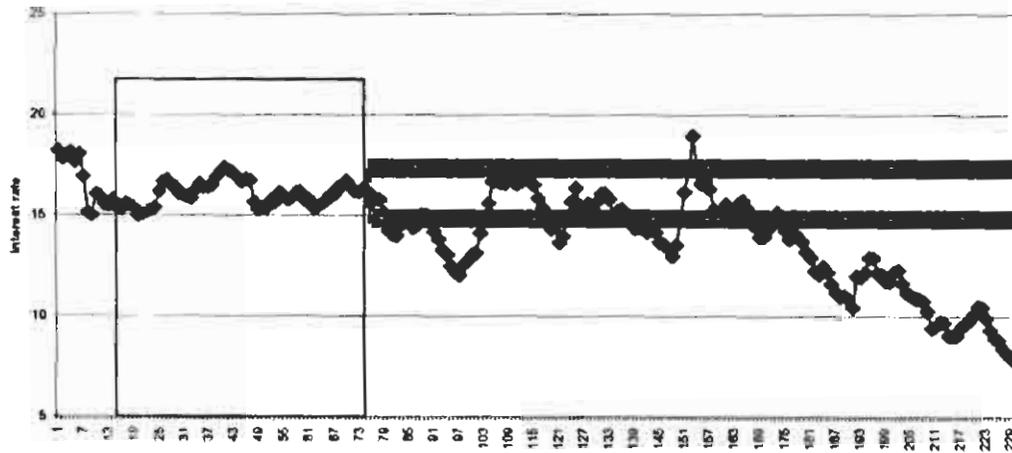


For the Esc time series:

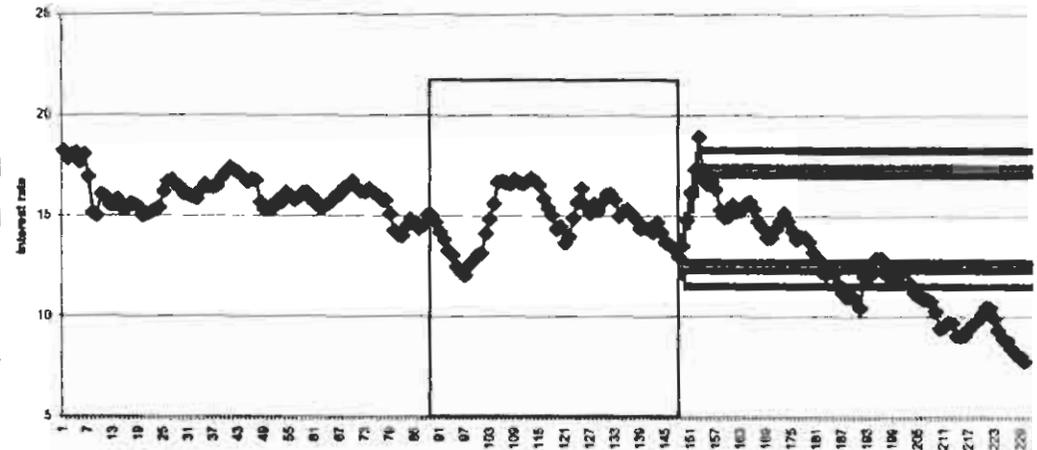
The graphs given here show the predictions of the normal volatility model (NVM) at the different points (74, 148 and 196) using only the 60 values before each one.

- For the short-term, the normal volatility model is able to make predictions that include, or are close to, the actual data.
- Except in extreme volatility conditions such as at the Asian Crisis (Graph 6.49), this model seems to make reasonable medium-term interval predictions. However, sometimes the actual data does lie outside of the predicted interval.
- This unrestricted normal volatility model can be used for making long-term interval predictions because for the most part, these intervals contain much of the actual data.

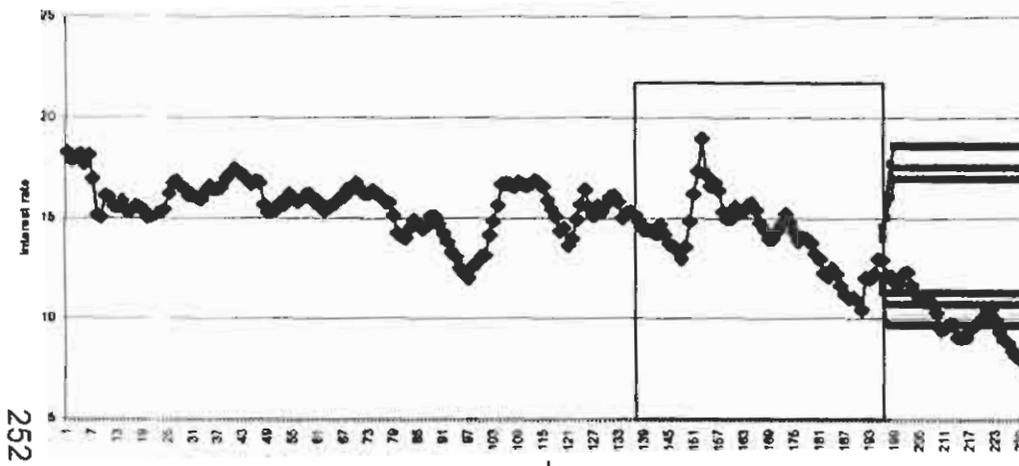
**Graph 6.46. Extreme Volatility Model with Limits**  
60 values before point 74 Esc MAX99%, 95%, 90% 74



**Graph 6.50. Extreme Volatility Model with Limits**  
60 values before point 148 Esc MAX99%, 95%, 90% 148



**Graph 6.54. Extreme Volatility Model with Limits**  
60 values before point 196 Esc MAX99%, 95%, 90% 196

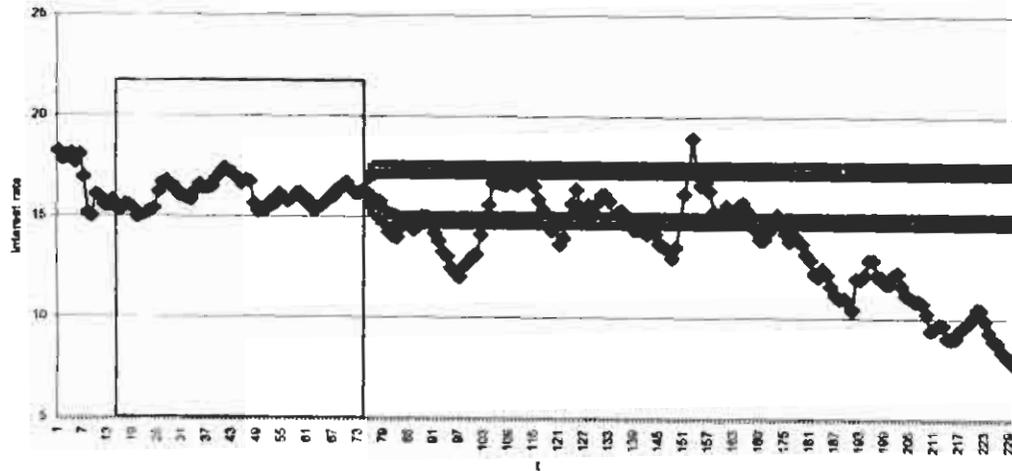


For the Esc time series:

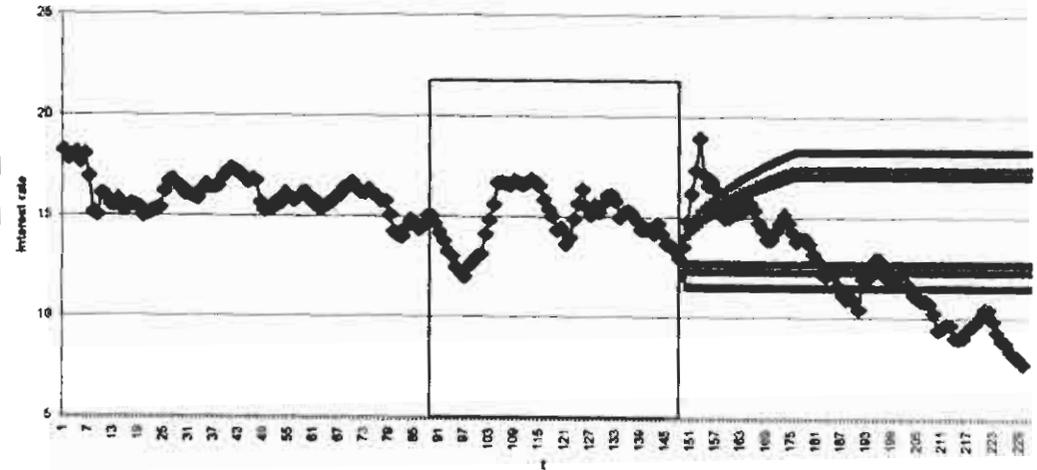
The graphs given here show the predictions made with the extreme volatility model (EVM), restricted by limits, at the different points (74, 148 and 196) using only the 60 values before each one.

- For the short-term, the extreme volatility model with limits is able to make predictions that include, or are close to, the actual data.
- With the exception at the Asian Crisis, the limits that restrict the fast outward movement of the EV model are too conservative and cause really narrow intervals that contain hardly any of the actual data. Thus, medium-term predictions using this model are not recommended except in extreme conditions.
- The limits that restrict the interval predictions of the EVM are too conservative for the long-term and exceptionally narrow intervals that are unable to capture the downward movement of the actual data are produced.

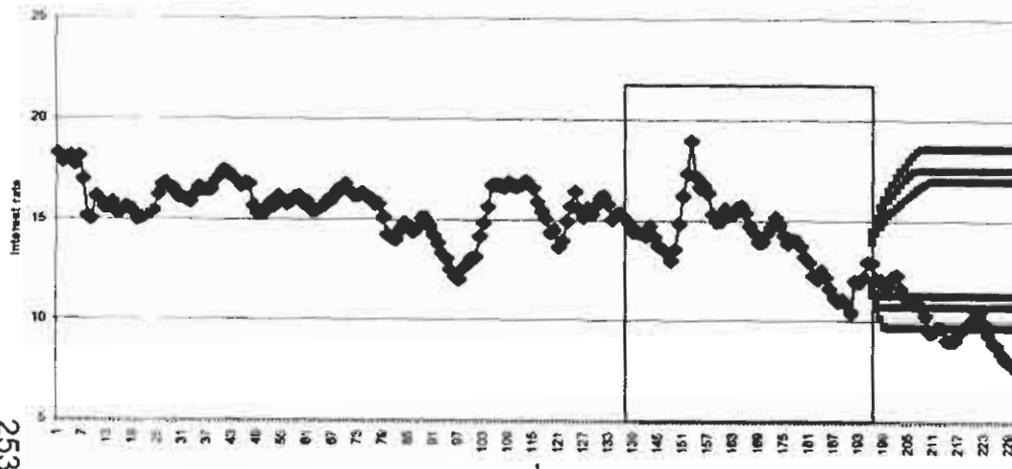
Graph 6.47. Normal Volatility Model with Limits  
60 values before point 74 Esc MAX99%, 95%, 90% 74



Graph 6.51. Normal Volatility Model with Limits  
60 values before point 148 Esc MAX99%, 95%, 90% 148



Graph 6.55. Normal Volatility Model with Limits  
60 values before point 196 Esc MAX99%, 95%, 90% 196



For the Esc time series:

The graphs given here show the predictions made with the normal volatility model (NVM), restricted by limits, at the different points (74, 148 and 196) using only the 60 values before each one.

- For the short-term, the normal volatility model with limits is able to make predictions that include, or are close to, the actual data.
- Except at the Asian Crisis (Graph 6.51), this normal volatility model with limits produces intervals that contain actual data only for a few medium-term predictions, after which, the intervals are too restricted, especially by the lower limits.
- The limits set on the predictions of the NVM are too restrictive for the long-term and the intervals produced by this model are too narrow. They are unable to capture most of the actual data and especially the downward movement at the end.

As always, a more in-depth look can be taken at each model that was developed and the results that were obtained can be analysed more thoroughly. In addition, more models are available that can be examined and tested. However, ultimately, the aim is to be able to predict interest rates as close to the original ones as possible, trying to make, in this case, as small intervals as possible that contain the actual future data.

The models that were developed using volatility estimates (maximum absolute value first differences) and later restricted with limits, are new. They seem to be an improvement and are effective in being able to predict intervals that contain, for the most part, the actual data.

The hybrid model that was developed on the basis of the previous volatility models seems to be the best one. It is able to make accurate interval predictions that contain all of the data for both time series.

Undoubtedly, care has to be taken in making a good model and time spent on this is certainly worth it. Yet, even if the perfect model is found for a time series or part thereof, caution needs to be taken because there are no guarantees that the same model will do equally well in the unknown far future. The idea should be to try to be more attentive to changes in the actual data and adapt models to be able to keep making adequate forecasts.

## CHAPTER 7: CONCLUSIONS AND AVENUES FOR FURTHER RESEARCH

### 7.1. Introduction

In an attempt to manage interest rate risk successfully, the purpose of this study was, essentially, to compare the effectiveness of different forecasting and volatility models in making short- and long-term predictions for two time series that are based on actual interest rate data. A literature study was presented and also (more important, practically) empirical work was done. These two parts link together because in the first part, certain strategies that bank managers use in order to manage interest rate risk are highlighted. For each, the first step is to be able to make accurate forecasts of the rates under consideration.

Chapter 7 is the concluding chapter of this study. Fundamentally, its purpose is to:

1. Present a summary of the study;
2. Provide a discussion of what can be learned from the research and practical work done;
3. Offer recommendations for further research.

### 7.2. Summary

Certainly, banking in South Africa has evolved over the years. Where, previously, banks could provide only a limited amount of services to specific clients, they are now able to supply numerous people with a vast amount of products and services. Banking laws have had to be adapted to this increasingly accessible and fast-paced world and as such, bank managers have had to change and keep up with the latest trends and strategies and introduce innovative ideas to ensure that their banks survive in the competitive economic environment in which they operate.

Indeed, bank managers face many more problems and have been compelled to solve them faster and more accurately than before (Chapter 2), failing which, could result in disastrous consequences for the bank and serious repercussions for all those involved in it. One of the biggest threats that banks face on a daily basis is risk. Specifically, interest rate risk. It has to be managed effectively and to this end,

there are many methods and techniques available that may be implemented and used (Chapter 3).

The strategies that were mentioned have, as a first step, the need to be able to make accurate and meaningful predictions. There is nothing like being able to forecast the next interest rate correctly. Be it one-step ahead (Chapters 4 and 5) or for a longer-term (Chapter 6), it has become necessary to know how the future rates will look. Two specific interest rates that were considered in this study (BA and Esc rates) were put into context in Chapter 2, which also provided background into the South African financial system. In Chapter 3, interest rates and certain ways in which banks manage interest rates and risk were discussed.

Undoubtedly, the literature study part of the work is extremely important (Chapters 2 and 3). Yet, it is the practical part of the work (Chapters 4, 5 and 6) that examines the essence of the study – finding, determining and applying different models to the two data sets, in turn and analysing and comparing the effectiveness of these models in predicting the interest rates for the short- (Chapters 4 and 5) and long-term (Chapter 6). All this is done in an effort to manage interest rate risk by being able to predict the next interest rates accurately, correctly and effectively.

### 7.3. Discussion

#### 7.3.1. Literature Study

Chapters 2 and 3 are based, basically, on theory. Chapter 2 provides an overview of the South African financial system, putting into context the two interest rates (BA and Esc rates) that are used in the later practical chapters. Chapter 3 provides information on interest rates (including, for example, what they are and how they work) and also on interest rate risk (including a discussion on what interest rate risk is, the importance of being able to manage interest rate risk effectively and the various strategies that banks employ in an attempt to try to manage it effectively).

#### 7.3.2. Empirical Chapters

In Chapter 4 experimental and practical simple models were considered for forecasting the two interest rates, one-step ahead. In this chapter, three types of simple techniques were introduced, namely: naïve models, moving average models and exponential smoothing. These techniques yielded seven models (some with variations) and empirical work was done to determine which of the seven models, when applied to each of the data sets individually, was the “best” one.

First, criteria was set and it was according to:

1. How well the model could predict correctly the direction of the next interest rate (PCD)
2. How small the error was in making a prediction (MSE)
3. How good the tracking signal (TS) was, looking at the numbers (low RSFE and within  $\pm 4$  MADs) but also taking the graphs into consideration at the same time that a few “best” models were chosen, with regard to each individual criterion.

From these models, it was suggested that the one that performed the best across each criterion (hoping that the same model would come up each time) would be the “best” and thus, used to forecast the interest rates for the short-term. However, from the results obtained, not one model showed up across all three criteria simultaneously, for either of the data sets. The closest results were for the Esc data set where the second naïve model (Model 1.2) was chosen in terms of the percentage and tracking signals. Therefore, it was decided to settle for a “good” model (according to which criterion was desired the most) instead of the “best” model.

For the BA and Esc rates, many of the second exponential smoothing models made it to the final table of possible “good” models. However, it has to be pointed out that there are substantially more of these models from which to choose. This makes it difficult to decide whether this type of model is better in predicting one-step ahead or whether most of these models may have done only slightly better than the other types of models but because of their volume, have been chosen.

Undoubtedly, time and care should be taken to examine any results obtained more thoroughly. It is from this empirical work that meaningful conclusions may be made. Certain patterns may emerge from the results that could be useful. However, trying to force a pattern where there is none, is also not correct and should definitely be avoided. In addition, something that should be taken into consideration is the amount of results obtained. Understanding and making sense of the many results obtained is important.

Moreover, other criteria could have been used. In this study, the criteria chosen could be used as a starting point from where other significant characteristics could be added to build on what the “best” or a “good” model is.

In Chapter 5, additional work on the BA data set was done. It consisted of dividing the BA data set into sections of one-year data and then applying the same models as in the previous chapter. Again, similar concerns to those observed for Chapter 4 should be addressed. Also, this type of empirical work could be done on the Esc data set. Concerns here would be that the shapes of the graphs are not the same and so, new sections may have to be chosen, making comparisons difficult.

Chapter 6 was another chapter where models were applied practically to the BA and Esc time series, individually. This work was slightly different from before, however, in that it consisted of finding intervals (and later setting limits on these intervals) in order to make long-term predictions.

Essentially, two areas of work were considered: if the time series was stationary, a Box-Jenkins AR(2) model was applied and if the time series was not stationary, then new models were applied. These new models were created (using a new technique that makes use of different volatility estimates<sup>110</sup>) and are a contribution to this field of study.

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<sup>110</sup> The volatility models used in this study referred to models with fixed volatility and not dynamic volatility as in ARCH and GARCH types. Also, in this study, the idea was not to forecast volatility models. In Chapter 6, volatility was used to estimate the interval estimates. Volatility models were developed from the forecasting models. Future work might be to work on forecasting volatility models.

The new models were developed using the maximum absolute value of the first differences (following on from Model 1.2 in Chapter 4) from where volatility estimates (VE) were found. These volatility estimates were used to create intervals of MAX99%, 95% and 90% each in anticipation of extreme volatility conditions (using  $n$ , where  $n$  is the number of periods of the predictions) as well as normal volatility conditions (using square root of  $n$ ). Thereafter, limits were applied to each interval. Results were obtained (numbers and graphs) and analysed.

It was found that these models are an improvement and are certainly effective in making decent long-term predictions. It was also found that in some cases (especially for the Esc time series), the limits were too restrictive and conservative. They did not allow for accurate medium- or long-term predictions.

A hybrid volatility model was then developed. In making a combination of three models (Naïve 1.1, Naïve 1.2 and MA 2.2)<sup>111</sup>, this hybrid volatility model (model for variance) was built. It showed impressive results. Further testing requires more data and can be conducted when this new data becomes available.

Questions that are raised and whose answers need to be taken into account include, for example:

- What is the number of predictions that are desired? That is, in using 196 past values, how long is the desired time of prediction – another 196 future values?
- In using only 60 past values (five years' worth of data), can the models predict correctly only for another 60 observations (five years into the future) and if not, for how long, then, are the past 60 values, for example, able to predict into the future?

The effectiveness of all the models obtained, developed and used in this study can be compared. Below is a summary table of certain models over different time horizons:

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<sup>111</sup> The normal volatility model (NVM) variance was estimated using Model 1.1., the extreme volatility model (EVM) from Model 1.2. and the limits were found using the average model.

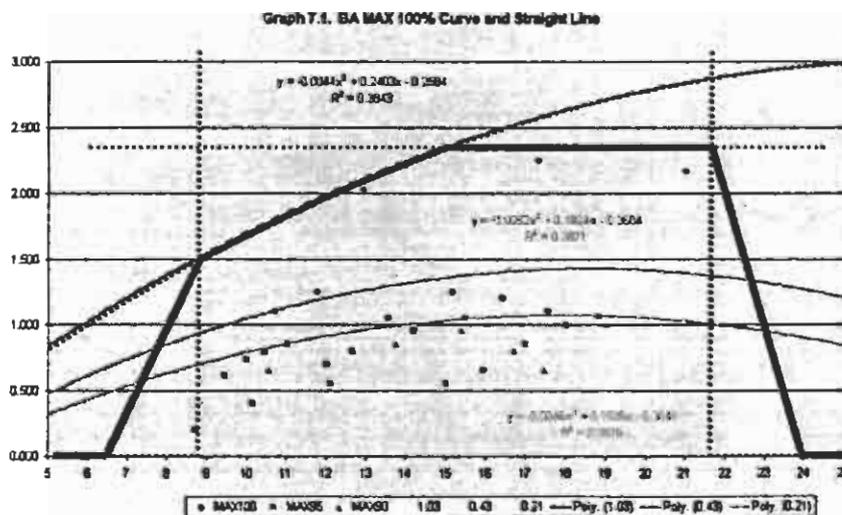
BA MODEL	TIME HORIZON				Esc MODEL	TIME HORIZON			
	SHORT	MEDIUM		LONG		SHORT	MEDIUM		LONG
		Extreme	Normal				Extreme	Normal	
Model 1.2	√	√	√	X	Model 1.2	√	√	√	X
AR(2)	√	√	√	√	AR(2)	√	X	X	X
EVM	√	√	X	X	EVM	√	√	X	X
NVM	√	X	√	√	NVM	√	X	√	√
EVM with Limits	√	√	√	X	EVM with Limits	√	√	X	X
NVM with Limits	√	X	√	X	NVM with Limits	√	X	X	X
Hybrid	√	√	√	√	Hybrid	√	√	√	√

EVM = Extreme Volatility Model  
NVM = Normal Volatility Model

EVM = Extreme Volatility Model  
NVM = Normal Volatility Model

**Table 7.1. Summary table comparing how effective the different models used in this study are, in predicting over different time horizons.**

The work that is shown in the chapter is not all that was attempted. Many other models were tried and several ideas were also explored. For example, instead of using only the maximums of the absolute value first differences for the second type of models, it was decided to take the minimum of a straight line and a curve. Other intervals were considered as well. A graph of this is shown below:



As it turned out, no better results were obtained from this (some intervals are just too small). However, taking the time to explore such an avenue was important and as

always, these results may be analysed further to determine whether something of merit can be uncovered that could aid in predicting interest rates better.

In addition, other amounts of past data, not just the 60 values (or five years' worth of data) were tested. Considerations were made, for example, for 120 values and also for specific real time frames such as from 8 August 1999, when the current Governor of the Reserve Bank, Mr. TT Mboweni, commenced his duties. Also, predictions at points other than the three mentioned (74, 148 and 196) were experimented with briefly.

Other ways in which to estimate sigma that is used in volatility, for example, could be determined. A more standard time unit could be used. Evidently, there is a vast amount of data that may be used and certainly, many other methods and models can be tested. This study focused on applying a few existing models and techniques to two specific time series.

In the endeavour to find the best results, one of the main conclusions that was reached was that the numbers obtained should always be considered in conjunction with the corresponding graphs. It does not help to find a model that is able to predict well on paper (a high percentage, for example) if the graphs show different results that are not reflected in the numbers and vice versa.

Clearly, many things (such as tips, do's and don'ts) were picked up along the way. However, the main aims of each chapter still need to be addressed. This is done next.

#### 7.4. Chapter Aims

Provided below are comments regarding each of the aims set out for every chapter of this study. This is done in order to determine whether each of these aims were achieved adequately. Chapter 1 provided the introduction to and the aims of the study.

## Chapter 2: Background

- Background on the South African financial system and its four essential components was provided
- The two data sets that were used in this study were put into context. It can be seen, clearly, where each of them fits into the financial system

## Chapter 3: Management of Interest Rate Risk

- Interest rates and risks were described and particular attention was given to interest rate risk
- The importance of predicting and managing interest rates correctly, with particular focus on banks, was shown
- The structure and functions of an ALCO were described
- Some of the strategies used by banks to measure, manage and minimise interest rate risk were identified and discussed

## Chapter 4: Short-term Predictions with Simple Forecasting Models

- Simple forecasting models used to make short-term predictions were identified
- Criteria to select the “best” model(s) were set
- The chosen forecasting models were applied to each of the two data sets, separately
- Results as to the “best” and “good” model(s) were obtained

## Chapter 5: Further Work On BA Data Set – Sections

- The work done in Chapter 4 was applied to sections of the BA data set

## Chapter 6: Long-term Predictions with Forecasting and Volatility Models

- An appropriate Box-Jenkins model was identified and applied to the two time series separately
- A volatility formula was applied to the two time series and limits to the intervals were obtained. Long-term predictions were made

Having addressed adequately each aim set out for this study, something needs to be said about the aim of the entire study. This forms part of the final conclusion and recommendations and is done next.

## 7.5. Conclusions and Recommendations

One of the main aims for undertaking this study was to determine whether two specific interest rates could be predicted using only past data of the particular rate being considered. The question was whether meaningful short- and long-term forecasts could be made if different forecasting techniques and models were found and applied to the data for different time horizons. Since forecasting the next interest rate is so important to individuals and banks, for example, it was felt that the study, which certainly has practical applications, would be interesting.

Therefore, since data of two interest rates (BA and Esc) were available, they were obtained and used. The models that were found were also readily accessible and applied to the data, thus, testing some existing available models.

Certain conclusions were reached, which are given at the end of each chapter. Yet, it has to be said that there are many other different methods, models and techniques available that could have been considered. Those that were used in this study (especially the ones used in Chapter 4) were chosen because they are very basic and were selected for their simplicity. It was deemed best to start with the basics and determine what kind of results could be achieved with these, before attempting more complicated (and perhaps unnecessary) procedures.

Also, there are definitely many other interest rates that could have been chosen. Clearly, one of the biggest avenues for further research is to find a model or models that could be used as the standard for other (maybe all) interest rates, taking into account the atmosphere in which interest rates occur.

In addition, another avenue for research is in considering factors that affect interest rates. Outside events that occur in reality, for example. Something like inflation

could be used. The possibilities are endless and this study (which makes contributions to the field of study) could be used as a starting point.

The same models could be tested on different interest rates. Different models could be tested on the same interest rates. Studies could be conducted to gauge a more general and wider range of techniques to follow and interest rates to use. Also, dynamic volatility models could be explored.

Nevertheless, no matter what methods are utilised, results will always be found. It is important that these be considered as a whole (numbers and graphs) and that they be examined carefully. Sense has to be made from them (especially if a large number of results are obtained) in order for them to have any meaning or contribution. This was done. Patterns may be found but too many unnecessary results could distort the truth and lead to incorrect conclusions.

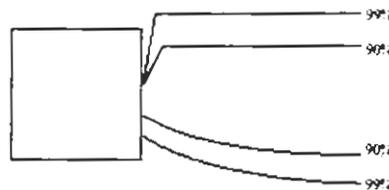
Surely, something to remember is that predicting is not an exact science and there is evidence that many experienced forecasters get it wrong once in a while. It is vital to remember to check what is being attempted and what is being done. Care has to be taken to ensure that any technique that is used is applied correctly and that the outcomes reflect what was intended to be determined. Research and theoretical work has to be done.

Finding results is an essential part of empirical work but these need to be examined as a whole and analysed thoroughly and with insight. Only then will they be able to add any meaning to the study under consideration and provide value in the field of interest.

Although the focus of this study has been on the models that are most effective in making accurate predictions, this study has, indeed, demonstrated that in managing interest rate risk, there are certain forecasting and volatility models that are not effective in making predictions. Such models include models with limits that are too conservative.

However, the study has also demonstrated that there are models that are effective in making short- (one-step ahead) and long-term (interval) predictions for the two specific time series, BA and Esc. These include the straight-line model (Model 1.2 of Chapter 4) for the short-term and the newly developed volatility models of Chapter 6 (which are a contribution to the field) for the long-term.

Certainly, the hybrid volatility model is able to make predictions that include the available data. This model is a combination of the strengths of three models:



1. Model 1.1 – which, although is not able to predict correctly the direction of the next interest rate (see Chapter 4), has the smallest variance (volatility) and is therefore used to make long-term predictions;
2. Model 1.2 – which is good at predicting the direction of the rates in the short-term and is thus, used in the hybrid volatility model to make predictions for extreme conditions in the short-term;
3. Model 2.2 – whose lower limit was not good in the long-term but whose upper limit seemed to work well in the long-term (since only the Asian Crisis data was above the limit).

In order to ascertain whether future predictions at the last known data point are correct, more data is necessary and can be tested only when it becomes available.

Thus, the study has compared the effectiveness of forecasting and volatility models, in managing interest rate risk.

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Article 1

Title:

Forecasting interest rates one-step ahead with simple models.

Abstract

Managing interest rate risk is and has been a major concern of banks for many years. Interest rates determine a bank's profitability and have an effect on a bank's liquidity and investment portfolio and it is, thus, extremely important to manage interest rate risk effectively. In attempting to do this, it is necessary to predict interest rates as accurately as possible. Several models are available for this purpose. The focus of this article is on presenting and applying several simple forecasting models to two real interest rate data sets and selecting those models that seem to perform better, based on set criteria.

## 1.1. Introduction

In the quest to manage interest rate risk effectively, it is important to predict interest rates as close to the actual ones as possible, making as little error as possible. Various techniques and models are available for this. However, in this article, the focus is on several simple forecasting models that were selected and applied and whose results were compared, in order to determine which of them is best able to make short-term predictions for two data sets of actual interest rates.

The way in which the "best" models were chosen, was based on how well each model performed against a certain set of criteria. These criteria were set out beforehand and were also used to conclude whether the results obtained were sufficient, or if even better results could be obtained by considering other models or methods.

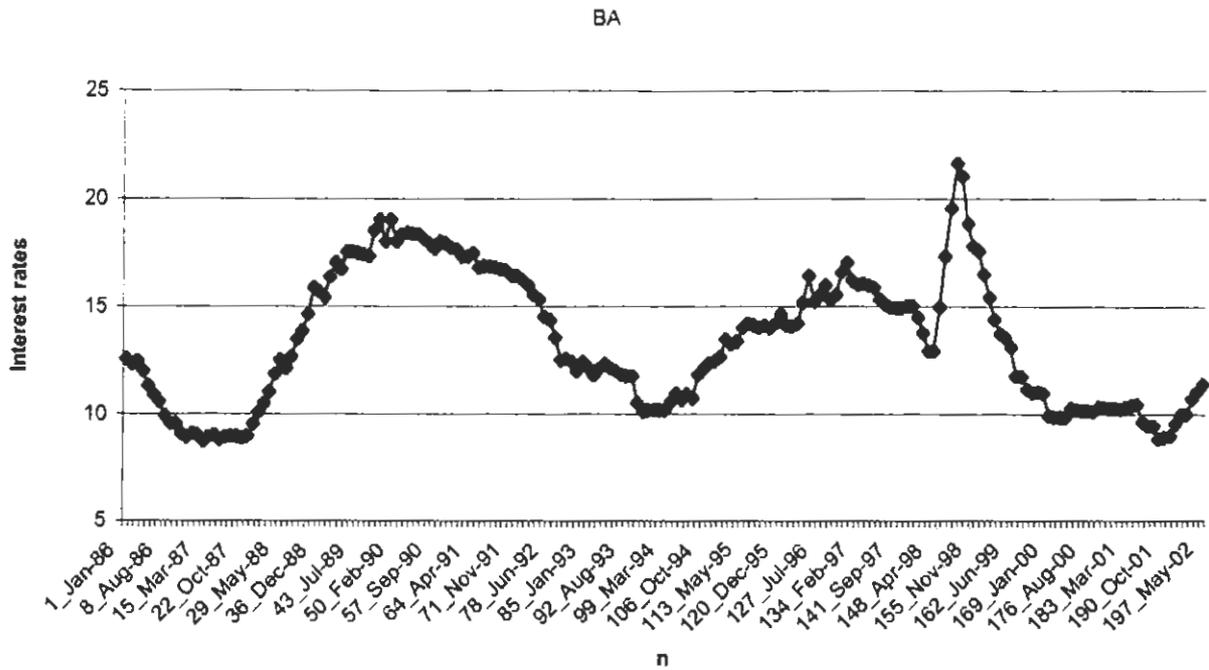
## 1.2. About the Data

Two data sets were used in the study on which this article is based, namely:

- Bankers' Acceptances (**BA rates**) which is money market short-term month-end data and
- Eskom (**Esc rates**) which is capital market long-term month-average data.

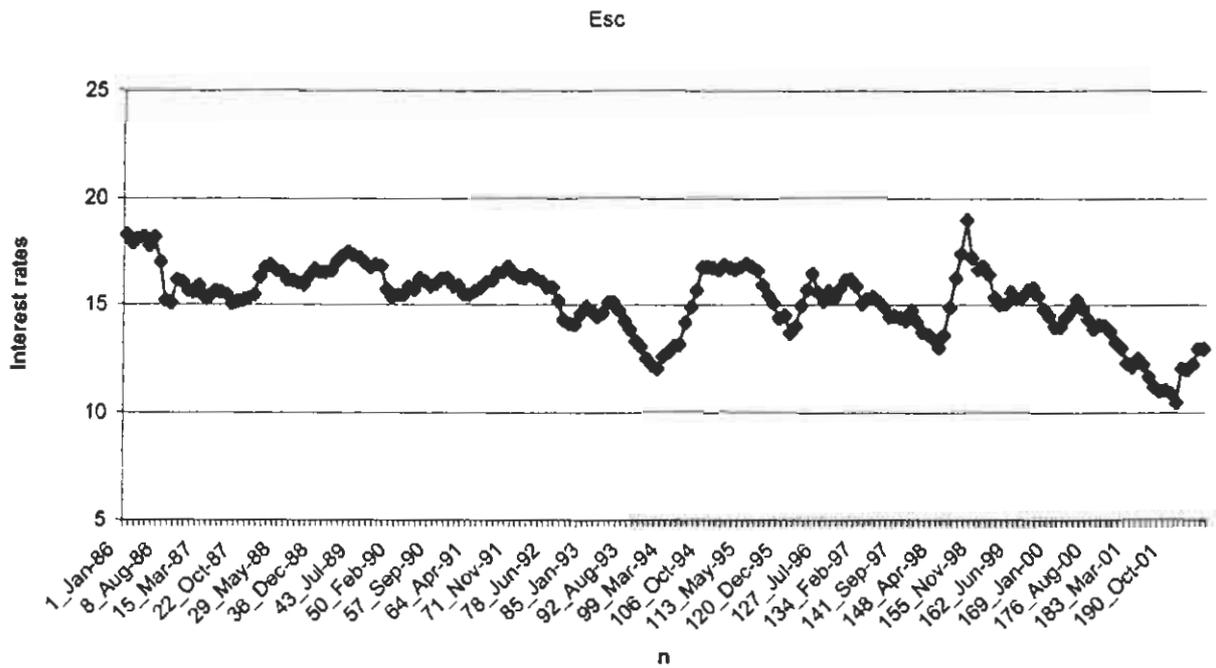
Both data sets (illustrated in the graphs below) contain data starting on January 1986 and thereafter, monthly data until

- May 2002 for the BA data set (197 observations) and
- April 2002 for the Esc data set (196 observations).



Graph 1 [Above] BA data set

Graph 2 [Below] Esc data set



After looking at the data and its general shape, basic information was found for each data set. Below is a short summary table:

	BA	Esc
<b>SUM</b>	2 640.98	2 980.74
<b>AVERAGE</b>	13.406	15.208
<b>STD DEV</b>	3.115	1.567
<b>MIN</b>	8.70	10.47
<b>MAX</b>	21.60	18.97

Then it was decided to select and apply several appropriate forecast models to each data set.

### 1.3. Table of Chosen Forecast Models

The following simple forecast models were selected to be applied to each of the data sets separately and their results compared:

<u>REFERENCE IN TEXT</u>	<u>MODEL</u>	<u>COMMENT</u>
	<b><u>Naïve Models</u></b>	
1.5.1.1.	$Y'_{t+1} = Y_t$	Model 1.1. Also referred to as the simple, first naïve or same-value model
1.5.1.2.	$Y'_{t+1} = Y_t + (Y_t - Y_{t-1})$	Model 1.2. Also referred to as the second naïve or straight line model
1.5.1.3.	$Y'_{t+1} = Y_t * (Y_t / Y_{t-1})$	Model 1.3. Also referred to as the third naïve or percentage model
	<b><u>Moving Average Models</u></b>	
1.5.2.1.	$(Y_t + Y_{t-1}) / 2$	Model 2.1. Also referred to as the first MA model
1.5.2.2.	$(Y_t + Y_{t-1} + \dots + Y_{t-m+1}) / m$	Model 2.2. Also referred to as the second MA model, where $m = 3$
	<b><u>Exponential Smoothing Models</u></b>	
	$Y'_{t+1} = \alpha Y_t + (1 - \alpha) Y'_t$	With smoothing constant $\alpha$ (also referred to as alpha or A in the text, graphs or tables)
1.5.3.1.	Single Smoothed	Model 3.1. Also referred to as the first exponential smoothing models, where $\alpha$ is alternately equal to 0.1, 0.4, 0.6 and 0.9
1.5.3.2.	Double Smoothed	Model 3.2. Also referred to as the second exponential smoothing models, where combinations of $\alpha_1$ and $\alpha_2$ are used

## 1.4. Criteria

Once the models had been chosen, it was necessary to decide on certain criteria which would give an indication of what the models were expected to show and how each model would be compared with the others. Depending on the results that each model yielded according to this criteria, it was determined that two types of outcomes were possible for each model:

- That the model was a “good” model and/ or
- That the model was the “best” model

Subsequently, criteria for each of these outcomes was set.

### 1.4.1. Criteria for a “Good” Model

For a model to be chosen as a “good” forecast model, able to predict interest rates accurately, that model would have to adhere to certain conditions:

#### 1.4.1.1. 1<sup>st</sup> Criterion – Percentage of Correct Direction Predictions (PCD)

Instead of predicting the exact number of the next interest rate (which would be quite difficult for any model), the intention with this criterion was to determine the accuracy of the model in predicting correctly the **direction** of the next interest rate. Here, three directions were possible, namely: UP (where the interest rate had increased), CONSTANT (where the interest rate had remained at the same level) or DOWN (where the interest rate had decreased).

Thus, if the actual interest rate from the current to the next period had gone UP, for example, a “good” model should be able to predict this direction from one observation to the next, correctly. In so doing, the model would score a point for each correct direction prediction and no points if the direction prediction had been incorrect.

At the end of all possible comparisons, the points were to be added and divided by the number of comparisons that had been made. In this way, a percentage score for each model would be obtained.

The best possible result for this criterion is a correct direction prediction of 100%. If no model is able to get such a score, then the model that obtains the highest percentage of correct direction predictions is classified as a “good” model and considered for the “best” model, subject to other criteria.

#### 1.4.1.2. 2<sup>nd</sup> Criterion – Mean Squared Error (MSE)

Since not all the models (if any) were going to predict the direction of the next interest rate correctly all the time, it was decided to determine (at the times where the model did not predict correctly) how much of an error was made in terms of the actual interest rates. Therefore, the mean squared error or **MSE** (which would also be needed later for the models and is, accordingly, described later in the text) was chosen as the second criterion to determine whether the model could be considered a “good” one.

The best possible result for this criterion is a mean squared error of zero. Again, if no model is able to get such a score, then the model that obtains the smallest MSE is classified as a “good” model.

#### 1.4.1.3. 3<sup>rd</sup> Criterion – Tracking Signals (TS)

The third criterion that was selected to determine which of the seven models (and their versions) could be classified as “good” forecast models, was **tracking signals**. A tracking signal or TS is, according to Render, *et al.* (2003:171), “a measurement of how well the forecast is predicting actual values”. It serves as a way to monitor forecasts to make sure that they are performing well.

A TS was calculated for each model according to the following formula:

$$\text{Tracking Signal} = \frac{\text{Running Sum of the Forecast Errors (RSFE)}}{\text{Mean Absolute Deviation (MAD)}}$$

Where  $\text{RSFE} = \sum (\text{actual interest rate in period } i - \text{forecast interest rate in period } i)$   
and  $\text{MAD} = \sum |\text{forecast errors}| / n$

Positive tracking signals indicate that the actual interest rate is greater than the forecast. Negative signals mean that the interest rate is less than the forecast. A good tracking

signal (one that centres closely around zero) is one with a low RSFE – it has about as much positive error as it has negative error.

Tracking signals are compared with predetermined upper and lower control limits and when a TS exceeds either of these limits, a signal is tripped. In the study, 4 was used as the Upper Limit (UL) and  $-4$  as the Lower Limit (LL). Also, in each case maximums of  $\pm 4$  MADs were used which suggests that for a forecast to be “in control”, 99.9% of the errors are expected to fall within  $\pm 4$  MADs<sup>1</sup>.

#### ◆ SUMMARY OF CRITERIA

- 1 – PCD – the higher, the better
- 2 – MSE – the smaller, the better
- 3 – TS – low RSFE and within  $\pm 4$  MADs

#### 1.4.2. Criteria for the “Best” Model

The “best” model is the one that predicts interest rates equal to the actual ones. If this is not possible, then the next “best” model is the one that predicts rates as close to the actual ones as possible.

Setting criteria for what is the “best” model or the “best” version of a model comes from the criteria for a “good” model. Indeed, if only one criterion is to be considered at a time in order to select a “good” model, then the “best” model is the one that performs best for that criterion.

If, instead, a combination of the criteria determines the “best” model (or version of the model), then a compromise between the criteria is needed. In this case, the better option is to find a *large* percentage and a *small* MSE instead of the *largest* percentage and the *smallest* MSE, as well as a *low* RSFE instead of the *lowest* RSFE.

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<sup>1</sup> According to Render, *et al.* (2003:174), Mean Absolute Deviation (MAD) is a “technique for determining the accuracy of a forecasting model by taking the average of the absolute deviations”. It is a measure of the overall forecast error. A value of 12.5 for example means that on average, each forecast missed the actual value by 12.5 units.

## 1.5. Forecast Models

Three forecasting methods that fall into the quantitative approach category are: naive models, moving averages and exponential smoothing. For every model in each of these categories, a representative table was created in Excel, from where the results were obtained.

### 1.5.1. Naïve Models

These models are based solely on past observations of interest rates. They do not rely on any other information or variables to predict the next value and they “do not attempt to explain the underlying causal relationships that produce the variable being forecast” (Shim, Siegel & Liew, 1994:35). Although having the advantage of being economical, they have the distinct disadvantage of not supplying any other information about the interest rates being forecasted.

In the study, three naïve models are considered, namely:

$$1.5.1.1. \quad Y'_{t+1} = Y_t$$

$$1.5.1.2. \quad Y'_{t+1} = Y_t + (Y_t - Y_{t-1})$$

$$1.5.1.3. \quad Y'_{t+1} = Y_t * (Y_t / Y_{t-1})$$

The symbol  $Y'_{t+1}$  is used to represent the forecast value and  $Y_t$  is used to represent the actual value.

$$1.5.1.1. \quad Y'_{t+1} = Y_t$$

This is the simplest example of a naïve model, where the actual interest rates of the current period are used as the forecast for the next period. In other words, the next interest rate is just the current actual interest rate.

#### ◆ Procedure and Findings – Naïve Models: 1.1.

Table 1 below is an example of a portion of the table that was created and used in Excel to represent the very first naïve model for the BA data set. It contains the row and

column headings from Excel (rows five to 15 and columns B to J), as well as the first ten rows of data that were obtained using this model.

...	B	C	D	E	F	G	H	I	J
5	t	$Y_t$	$Y'_{t+1}=Y_t$	$e_t=Y_t-Y_{t+1}$	Prediction	Actual	Direction		
6	1	12.55							
7	2	12.3	12.55	-0.250	Constant	Down	0		0 = Wrong
8	3	12.45	12.30	0.150	Constant	Up	0		1 = Correct
9	4	12	12.45	-0.450	Constant	Down	0		
10	5	11.3	12.00	-0.700	Constant	Down	0		
11	6	10.85	11.30	-0.450	Constant	Down	0		
12	7	10.55	10.85	-0.300	Constant	Down	0		
13	8	9.9	10.55	-0.650	Constant	Down	0		
14	9	9.55	9.90	-0.350	Constant	Down	0		
15	10	9.55	9.55	0.000	Constant	Constant	1		

**Table 1. Representative portion of the table used in Excel, depicting the first naïve model using the BA data set. The symbol  $Y'_{t+1}$  used above and in the rest of the article is equivalent to  $Y_{t+1}$ , which represents the forecast value or predicted interest rate value.**

In the table above (as in the tables for the other models), the column heading “**Prediction**” indicates which direction (UP, CONSTANT or DOWN) the model predicts the next interest rate will follow and the column heading “**Actual**” indicates the actual direction that the observed interest rates followed. In column H (“**Direction**”), a match between “**Prediction**” and “**Actual**” is indicated by a 1 and a no match by a 0. From here, the PCD is found. MSE is found using column E.

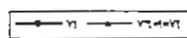
Owing to comparative purposes, it was decided to modify all the models to accommodate the same number of comparisons for each model, every time for each of the data sets. The summary table and graphs for the first naïve model are shown below. The tracking signal graphs (obtained once again by using Excel) indicate that this is not such a good model, since most of the values do not lie between the  $-4, 4$  lines and the signal is regularly tripped.

1.1.	MSE	Matches	Comparisons	PCD
BA	0.3508	12	194	6.19%
Esc	0.2402	4	193	2.07%

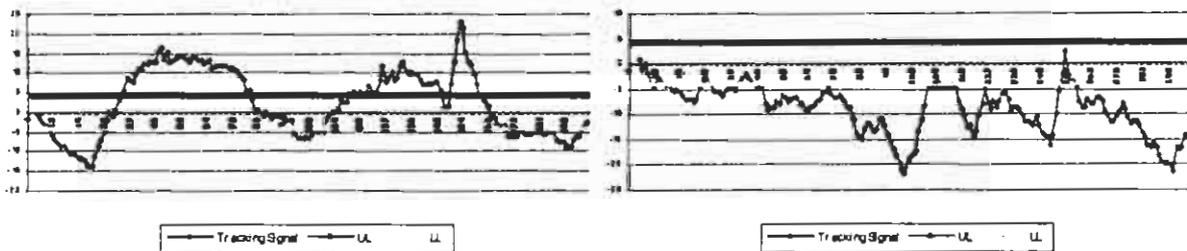
Graph 1. Actual vs. Predicted BA 1.1.



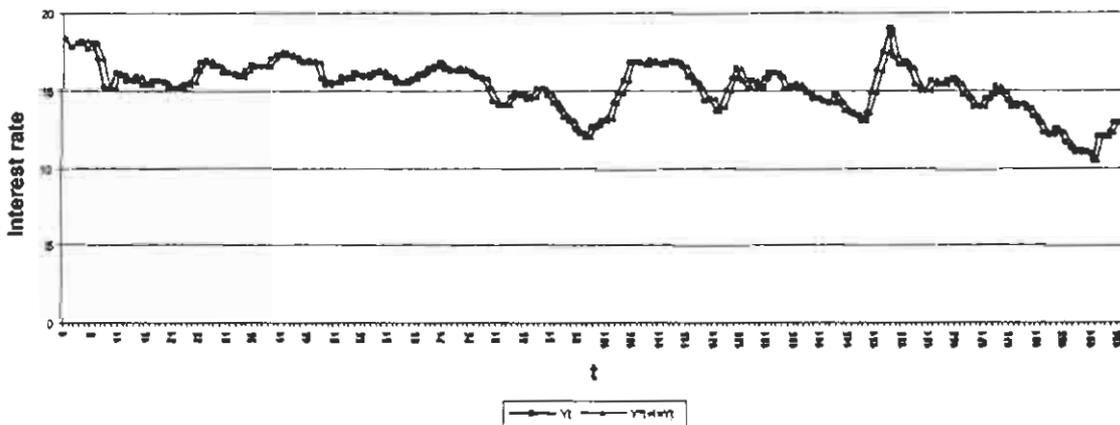
Graph 2. BA 1.1. TS 4



Graph 4. Esc 1.1. TS 4



Graph 3. Actual vs. Predicted Esc 1.1.



$$1.5.1.2. \quad Y'_{t+1} = Y_t + (Y_t - Y_{t-1})$$

The second type of naive model builds on the first and considers trends. It “adds the latest observed absolute period-to-period change to the most recent observed level of the variable” (Shim, *et al.*, 1994:36).

◆ **Procedure and Findings – Naïve Models: 1.2.**

Table 2 below is an example of a portion of the table that was created and used also in Excel to represent the second naive model for the BA data set. It contains the same

column headings as before and the first five rows of data. The structure of this model is similar to the first naïve model but there are a few differences between the two models.

...	B	C	D	E	F	G	H
5	t	$Y_t$	$Y_{t+1}$	$e_t = Y_t - Y_{t+1}$	Prediction	Actual	Direction
6	1	12.55					
7	2	12.3					
8	3	12.45	12.05	0.400	Down	Up	0
9	4	12	12.60	-0.600	Up	Down	0
10	5	11.3	11.55	-0.250	Down	Down	1

***Table 2. Representative portion of the table used in Excel, depicting the first few rows of the second naïve model using the BA data set.***

The first difference is in column D – where the model is represented. Evidently, this column changes for each model. Another noticeable difference in the second naïve model is that the **Predictions** (column F) are not all CONSTANT as in the first naïve model. Once again, MSE, PCD and tracking signals were obtained for both data sets for this model and can be compared.

$$1.5.1.3. \quad Y'_{t+1} = Y_t \times \left( \frac{Y_t}{Y_{t-1}} \right)$$

The third type of naïve model incorporates “the rate of change rather than the absolute amount” (Shim, *et al.*, 1994:36). In this case, a ratio of the actual and the previous value is included. A similar procedure to that of the first two models was carried out for this model and criteria results were found. The next type of models were then looked at.

### 1.5.2. Moving Average Models

According to Shim, *et al.* (1994:37), **smoothing techniques** are a “higher form” of naïve models. There are two characteristic forms of these techniques: moving average and exponential smoothing. The simpler one is moving averages or MA.

Moving averages “are averages that are updated as new information is received” (Shim, *et al.*, 1994:37). In order to predict the interest rate for the  $m^{\text{th}}$  term, the number of previous observations that are to be used, has to be decided on.

Since weights are given to observations, determining the number of observations to use for the average can be difficult. If, for example, a six-observation moving average is chosen, then old data receives a weight of 5/6 and the current observation receives a weight of 1/6. Evidently, the choice of the number of periods to use in a moving average is “a measure of the relative importance attached to old versus current data” (Shim, *et al.*, 1994:38).

Below are the two variations of the moving average model that were used:

$$1.5.2.1. \quad (Y_t + Y_{t-1}) / 2$$

$$1.5.2.2. \quad (Y_t + Y_{t-1} + \dots + Y_{t-m+1}) / m$$

The advantage in using the moving average is that it is simple to use and easy to understand. There are, however, two shortcomings that Shim, *et al.* (1994:39) identify:

- It requires you to retain a great deal of data and carry it along with you from forecast period to forecast period
- All data in the sample are weighted equally. If more recent data are more valid than older data, perhaps they should be given greater weight

$$1.5.2.1. \quad Y'_{t+1} = \frac{Y_t + Y_{t-1}}{2}$$

In this first variation of the MA model, the average is found using only two observations of actual interest rate values at a time. A similar procedure to that done for the naïve models was carried out for the first MA model.

$$1.5.2.2. \quad Y'_{t+1} = \frac{Y_t + Y_{t-1} + \dots + Y_{t-m+1}}{m}$$

In the second variation of the MA models, the average is found using  $m$  observations of actual interest rate values. For certain reasons (which are discussed in the study), it was decided to consider only  $m=3$  (for both data sets) for the second moving average model. On deciding this, a similar procedure to that done before, was carried out.

### 1.5.3. Exponential Smoothing

$$Y'_{t+1} = \alpha Y_t + (1 - \alpha) Y'_t$$

The second and more complicated of the two **smoothing techniques** is the forecasting method known as exponential smoothing. This method gets around the disadvantages of the moving average model in that it uses a weighted average of past data as the basis for a forecast. The procedure “gives heaviest weight to more recent information and smaller weights to observations in the more distant past” (Shim, *et al.*, 1994:39). However, the disadvantage of this method is that it “does not include industrial or economic factors such as market conditions, prices, or the effects of competitors’ actions” (Shim, *et al.*, 1994:39).

To initialise the exponential smoothing process, the initial forecast is needed. This can either be first actual observations or an average of the actual data for a few periods. The latter was chosen. Also, finding the correct  $\alpha$  (alpha) is important since “the higher the  $\alpha$ , the higher the weight given to the more recent information” (Shim, *et al.*, 1994:40). A way of obtaining the most desirable  $\alpha$  is to work out the Mean Squared Error<sup>2</sup> (MSE) for several  $\alpha$ s and then use the  $\alpha$  that produces the smallest MSE.

The two types of exponential smoothing models used in the study are:

1.5.3.1. Single Smoothed

1.5.3.2. Double Smoothed

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<sup>2</sup> According to Shim, *et al.* (1994:42),

$$MSE = \frac{\sum_{t=1}^n (Y_t - Y'_t)^2}{(n - i)}$$

where  $i$  = the number of observations used to determine the initial forecast

MSE is the average sum of the variations between the historical interest rates and the forecast rates for the corresponding periods.

### 1.5.3.1. Single Smoothed

The single smoothed form of the exponential smoothing model consists of finding the  $\alpha$  that minimises the MSE and then applying this value to the exponential smoothing formula. The values that were experimented with for  $\alpha$  are: 0.9, 0.6, 0.4 and 0.1.

◆ **Procedure and Findings – Exponential Smoothing Models: 3.1.**

A similar procedure to that done for the naïve and moving average models was followed. A summary of the results are shown in Table 3. For both data sets,  $\alpha = 0.9$  gives the smallest MSE. However, in both cases this corresponds to the lowest percentage of correct direction predictions.

BA			3.1.		
Alpha	MSE		M	C	PCD
0.1	3.8427	Biggest	72	194	37.11%
0.4	0.8966	Bigger	71	194	36.60%
0.6	0.5763	Big	73	194	37.63%
0.9	0.3831	Smallest	69	194	35.57%

(a)

<b>M</b> = Matches
<b>C</b> = Comparisons
<b>PCD</b> = Predict Correct Direction

Esc			3.1.		
Alpha	MSE		M	C	PCD
0.1	1.2319	Biggest	95	193	49.22%
0.4	0.5023	Bigger	79	193	40.93%
0.6	0.3567	Big	77	193	39.90%
0.9	0.2577	Smallest	74	193	38.34%

(b)

**Table 3. Results from applying different  $\alpha$  values to the first exponential smoothing model using (a) the BA data set and (b) the Esc data set.**

### 1.5.3.2. Double Smoothed

The second form of exponential smoothing is the double smoothed form (it involves two smoothings). In this case, the single smoothed form of the model is applied twice to the data, thus, the original data is smoothed as above; the results are then taken and smoothed again, using the same method as before.

In symbol form, the model used may be represented as in Shim, *et al.* (1994:46):

$$Y'_{t+1} = \text{Single-smoothed} + (\text{Single-smoothed} - \text{Double-smoothed}) + \text{Trend Adjustment}$$

$$= Y'_t + (Y'_t - S''_t) + b_t$$

where  $Y'_t = \alpha Y_{t-1} + (1-\alpha) Y'_{t-1}$ , and the trend adjustment,  $b_t$ , can be approximated by the amount of change each period in  $S''$ . That is:  $b_t = S''_t - S''_{t-1}$ .

According to Shim, *et al.* (1994:46), the double-smoothed values have two useful properties:

1. They are smoother than the single-smoothed values, which means they will provide a clearer indication of the trend;
2. The double-smoothed values lag the single-smoothed values by about as much as the single-smoothed values lag the original data.

◆ **Procedure and Findings – Exponential Smoothing Models: 3.2.**

The second exponential smoothing model makes use of two alpha values, namely:  $\alpha_1$  and  $\alpha_2$ . As can be seen in Table 4, the method that was used to represent this model in Excel is slightly different from the way the naïve, moving average and single exponential smoothing models were represented. Here, two smoothings take place.

...	E	F	G
3	Alpha 1	1	0
4	Alpha 2	0.2	0.8

...	B	C	D	E	F	I	K	L	M	N
8	t	Yt(data)	Y't(single)	S''t(double)	S''t-S''t-1(bt)	Forecast	Real e <sup>2</sup>	Prediction	Actual	Direction
9	1	12.55	12.550	12.550						
10	2	12.3	12.300	12.500	-0.050	12.550	0.063	Constant	Down	0
11	3	12.45	12.450	12.490	-0.010	12.050	0.160	Down	Up	0
12	4	12	12.000	12.392	-0.098	12.400	0.160	Down	Down	1
...	...	...	...	...	...	...	...	...	...	...
206							354.0287			
207							SSE			
208							1.8063			
209							MSE			

***Table 4. Representative portion of the table created in Excel, depicting the first few rows of the second exponential smoothing model using the BA data set for  $\alpha_1=1$  and  $\alpha_2=0.2$ . Column I contains the forecasts for the model.***

Experiments were conducted with various combinations of alpha values for  $\alpha_1$  and  $\alpha_2$  and the same procedure was followed for the Esc data set. Naturally, the results obtained (which include PCD, MSE and TS for all combinations) were many.

### 1.6. Summary of Results

In the study, for each model, results were obtained and graphs drawn. The results for all the models are summarised in the tables below:

BA										
Model	Symbol	Value	MSE	M	C	PCD	s	RSFE	MAD	TS
1.1.	-	-	0.3508	12	194	6.19	0.5923	-1.0500	0.3939	-2.6659
1.2.	-	-	0.4247	110	194	56.70	0.6517	0.1800	0.4495	0.4005
1.3.	-	-	0.4295	110	194	56.70	0.6553	-4.4669	0.4500	-9.9264
2.1.	-	-	0.5766	66	194	34.02	0.7594	-1.6650	0.5007	-3.3250
2.2.	$m =$	3	0.8263	74	194	38.14	0.9090	-2.4833	0.5995	-4.1421
3.1.	$\alpha =$	0.1	3.8427	72	194	37.11	1.9603	-20.9984	1.6264	-12.9111
	$\alpha =$	0.4	0.8966	71	194	36.60	0.9469	-3.7927	0.6580	-5.7641
	$\alpha =$	0.6	0.5763	73	194	37.63	0.7591	-2.0309	0.5106	-3.9775
	$\alpha =$	0.9	0.3831	69	194	35.57	0.6190	-1.1248	0.4097	-2.7457
3.2.	Refer to Table 6 below									

(a)

Esc										
Model			MSE	M	C	PCD	s	RSFE	MAD	TS
1.1.	-	-	0.2402	4	193	2.07	0.4901	-5.1300	0.3563	-14.3971
1.2.	-	-	0.3330	116	193	60.10	0.5771	-0.2100	0.4092	-0.5132
1.3.	-	-	0.3377	58	193	30.05	0.5811	-3.2889	0.4089	-8.0438
2.1.	-	-	0.3740	69	193	35.75	0.6116	-7.5900	0.4544	-16.7032
2.2.	$m =$	3	0.5072	76	193	39.38	0.7122	-10.4267	0.5231	-19.9308
3.1.	$\alpha =$	0.1	1.2319	95	193	49.22	1.1099	-55.4607	0.8659	-64.0471
	$\alpha =$	0.4	0.5023	79	193	40.93	0.7088	-13.5542	0.5143	-26.3528
	$\alpha =$	0.6	0.3567	77	193	39.90	0.5973	-8.6182	0.4419	-19.5029
	$\alpha =$	0.9	0.2577	74	193	38.34	0.5076	-5.5962	0.3716	-15.0578
3.2.	Refer to Table 6 below									

(b)

**Table 5. Summary table of the results for all models for (a) the BA data set and (b) the Esc data set.**

<b>M</b> =Matches	<b>1</b> =Naïve models
<b>C</b> =Comparisons	<b>2</b> =Moving Average models
<b>s</b> =Standard deviation	<b>3</b> =Exponential Smoothing models

Owing to the substantial amount of results produced for the second exponential smoothing models, the summary table below highlights only the “extremes” for PCD and MSE for both data sets:

BA		$\alpha_1$	$\alpha_2$	
MIN MSE	0.3018	0.7	1	PCD 56.19%
MAX MSE	11.4235	1	0	PCD 40.21%
MIN PCD	6.19%	0.5	1	MSE 0.3508
MAX PCD	61.86%	1	0.2	MSE 1.8225

Esc		$\alpha_1$	$\alpha_2$	
MIN MSE	0.2246	0.6	1	PCD 57.51%
MAX MSE	11.0059	1	0	PCD 52.33%
MIN PCD	2.07%	0.5	1	MSE 0.2402
MAX PCD	59.59%	1	1	MSE 0.3330

(a)

(b)

**Table 6. Summary table for the results of the “extremes” for PCD and MSE of the second exponential smoothing models for (a) BA data set and (b) Esc data set.**

From the tables above, were chosen “good” and “bad” models with regard to PCD and MSE<sup>3</sup>. They are, for the two data sets:

BA 194	Model	$\alpha_1$	$\alpha_2$	MSE	PCD	RSFE	MAD	TS
MAX PCD	3.2.	1	0.2	1.8225	61.86	9.8081	0.9569	10.2503
MIN MSE	3.2.	0.7	1	0.3018	56.19	21.4364	1.4838	14.4472
MIN PCD	1.1.	-	-	0.3508	6.19	-1.0500	0.3939	-2.6659
	3.2.	0.5	1	0.3508	6.19	0.9200	0.3837	2.3976
MAX MSE	3.2.	1	0	11.4235	40.21	-187.2500	2.8086	-66.6700

Esc 193	Model	$\alpha_1$	$\alpha_2$	MSE	PCD	RSFE	MAD	TS
MAX PCD	1.2.	-	-	0.3330	60.10	-0.2100	0.4092	-0.5132
MIN MSE	3.2.	0.6	1	0.2246	57.51	-3.3026	0.3461	-9.5427
MIN PCD	1.1.	-	-	0.2402	2.07	-5.1300	0.3563	-14.3971
	3.2.	0.5	1	0.2402	2.07	-5.1300	0.3563	-14.3971
MAX MSE	3.2.	1	0	11.0059	52.33	550.7100	2.9064	189.4836

**Table 7. Table showing: selected “good” models (with regard to PCD and MSE) for each data set, from which the “best” model may be chosen; as well as selected “bad” models, which should be avoided.**

However, the models with the best tracking signals are the following:

<sup>3</sup> The tracking signals are also shown for comparison purposes.

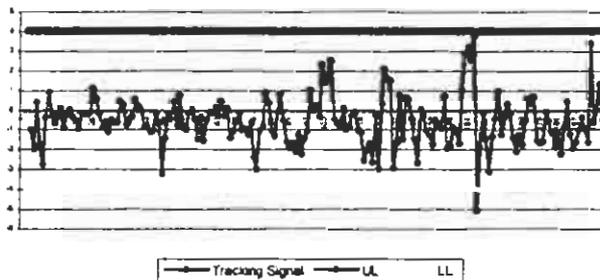
BA							
Model	$\alpha_1$	$\alpha_2$	PCD	MSE	RSFE	MAD	TS
1.2	-	-	56.70	0.4247	0.1800	0.4495	0.4005
3.2	0.1	0.1	32.47	2.1800	0.4273	1.1545	0.3701
3.2	0.3	0.6	37.11	0.5770	0.3493	0.4983	0.7010
3.2	0.3	0.7	35.57	0.6080	-0.1495	0.5243	-0.2852
3.2	0.3	0.8	34.54	0.6417	-0.4983	0.5473	-0.9104
3.2	0.4	1	36.08	0.4617	0.3527	0.4513	0.7817

Esc							
Model	$\alpha_1$	$\alpha_2$	PCD	MSE	RSFE	MAD	TS
1.2	-	-	60.10	0.3330	-0.2100	0.4092	-0.5132
3.2	0.8	0.8	56.99	0.2855	0.3218	0.3793	0.8484
3.2	0.9	0.9	58.55	0.3022	0.1449	0.3890	0.3726
3.2	1	1	59.59	0.3330	-0.0100	0.4091	-0.0244

**Table 8. Table showing: selected "good" models (with regard to tracking signals) for both data sets, from which the "best" model may also be chosen.**

Only the Esc data set has one model that is present in both tables – the second naïve model (highlighted in the TS table and whose TS graph is shown below). Perhaps this one could be considered the "best" overall model for the Esc data set.

Graph 5. Esc 1.2. TS 4



As for the BA data set, the "best" overall model would have to be chosen amongst those listed above. In this case, choosing the "best" model would depend on what criteria is most valued or sought after.

### 1.7. Conclusion

The focus of this article is on the different simple forecasting models that can be used to predict interest rates and how accurate they really are in predicting those rates. Three

types of quantitative forecasting methods were used – naïve models, moving average models and exponential smoothing.

Naïve techniques are based solely on previous experience. Moving averages and exponential smoothing “employ a weighted average of past data as the means of deriving the forecast” (Shim, *et al.*, 1994:50). All three methods, as well as their different variations, were applied to two data sets (BA and Esc).

In order to decide on the “best” model, three criteria were used, namely: PCD (percentage of correct direction predictions), MSE (mean squared error) and TS (tracking signals). Using this criteria, the best model (the one that can produce the interest rates closest to the actual observed interest rates) can be chosen for each data set.

For the BA data set, the “best” model should be chosen from a few “good” models – each the best with regard to PCD, MSE and TS, separately – depending on what criterion is most desired. For the Esc data set, the “best” model might be the second naïve model, as it appears as a good model for PCD and TS and the MSE (0.3330) is not that much higher than the minimum MSE (0.2246). Nevertheless, other models (of the ones listed above) may also be considered for the “best” model, for the same reason as that for the BA data set – they are good with respect to individual criteria.

In addition, while the maximum and minimum results are pointed out, it may be useful to consider other models that are not the extremes but that do well all around. For that, perhaps a more in-depth look at the results is required.

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2005

Vanderbijlpark

## Article 2

Title:

Forecasting BA and Esc interest rates long-term with volatility models

### Abstract

Managing interest rate risk is and has been a major concern of banks for many years. Interest rates determine a bank's profitability and have an effect on a bank's liquidity and investment portfolio and it is, thus, extremely important to manage interest rate risk effectively. In attempting to do this, it is necessary to predict interest rates as accurately as possible. Several models are available for this purpose. The focus of this article is on presenting and applying several more advanced volatility forecasting models to two real time series and analysing some of the results obtained.

## 1.1. Introduction

Forecasting is an essential part of our lives. It plays a vital role in predicting many things in areas such as business, industry, government and our daily lives. This is because “many important decisions depend on the anticipated future values of certain variables” Pankratz (1983:3). Indeed, when forecasting, there has to be a certain awareness with regard to risks. Banks, in particular, need to be able to forecast interest rates and so, they face a serious challenge – managing interest rate risk effectively.

Certainly, there are many tools available to do this. However, in trying to manage interest rate risk effectively, there is nothing like being able to forecast interest rates correctly. This article looks at two time series<sup>1</sup> and explores long-term forecasts for them. One of the aims is to try to find an interval wherein the future interest rates (not only in the short-term but in the longer term as well<sup>2</sup>) are most likely to lie, using models based on the data, as well as first and possibly, second differences.

Two broad areas of work are investigated (stationary time series is compared to non-stationary time series), making use of two types of volatility models<sup>3</sup>. If the time series is stationary, then Box-Jenkins, AR(2) models<sup>4</sup> are considered. If the time series is non-stationary, then newly developed models with volatility limits are used.

Before looking at the models, however, the data for both the time series are defined first.

## 1.2. The Data

Two data sets were used in the study on which this article is based, namely:

- Bankers' Acceptances (**BA rates**) which is money market short-term month-end data and
- Eskom (**Esc rates**) which is capital market long-term month-average data.

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<sup>1</sup> Based on two actual interest rate data sets, namely: Banker's Acceptances and Eskom.

<sup>2</sup> Levenbach and Cleary (1984:22) define a *time horizon* as “the period of time into the future for which forecasts are required. The periods are generally short-term (one to three months), medium-term (three months to two years), and long-term (more than two years)”.

<sup>3</sup> The word “volatility” used throughout the article refers to models with fixed volatility and not dynamic volatility as in models such as the ARCH and GARCH types.

<sup>4</sup> Autoregressive models of order 2. The Autoregressive Integrated Moving Average (ARIMA) models introduced by George E. P. Box and Gwilym M. Jenkins contain autoregressive as well as moving average parameters and include differencing in the formulation of the model. The parameters are described by (p,d,q), where p refers to the autoregressive parameter, d is the number of differencing passes or “degree of differencing” (Gottman, 1981:262) and q refers to the moving average parameter.

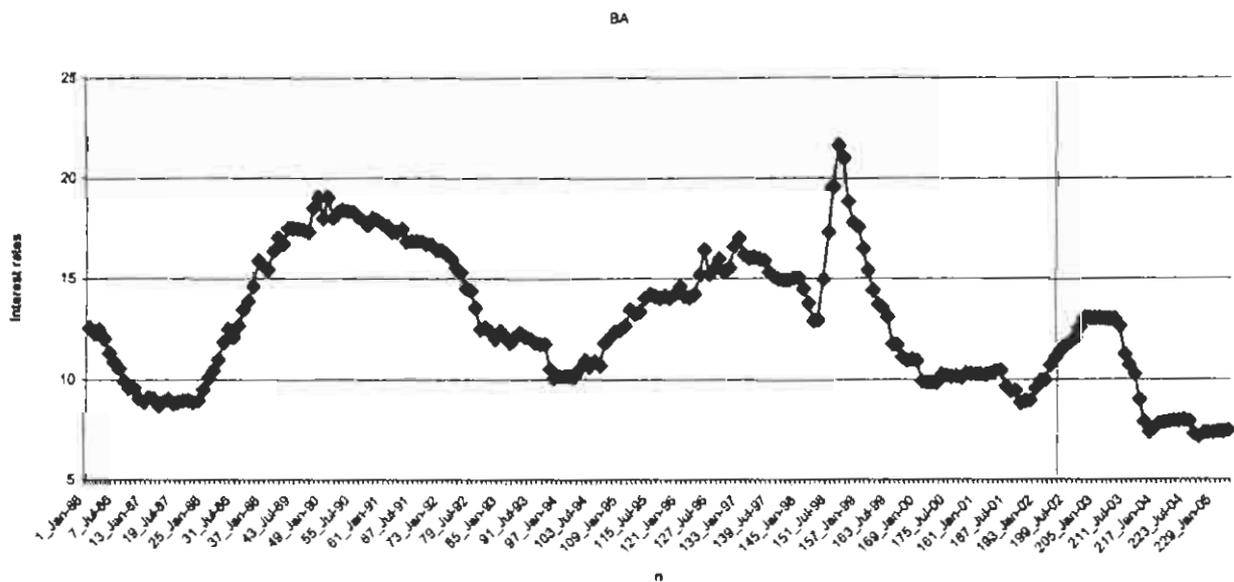
Both data sets (illustrated in the graphs below) contain data starting on January 1986 and thereafter, monthly data until:

- March 2005 for the BA data set (reaching a total of 231 observations) and
- February 2005 for the Esc data set (a total of 230 observations).

In the study, the following data:

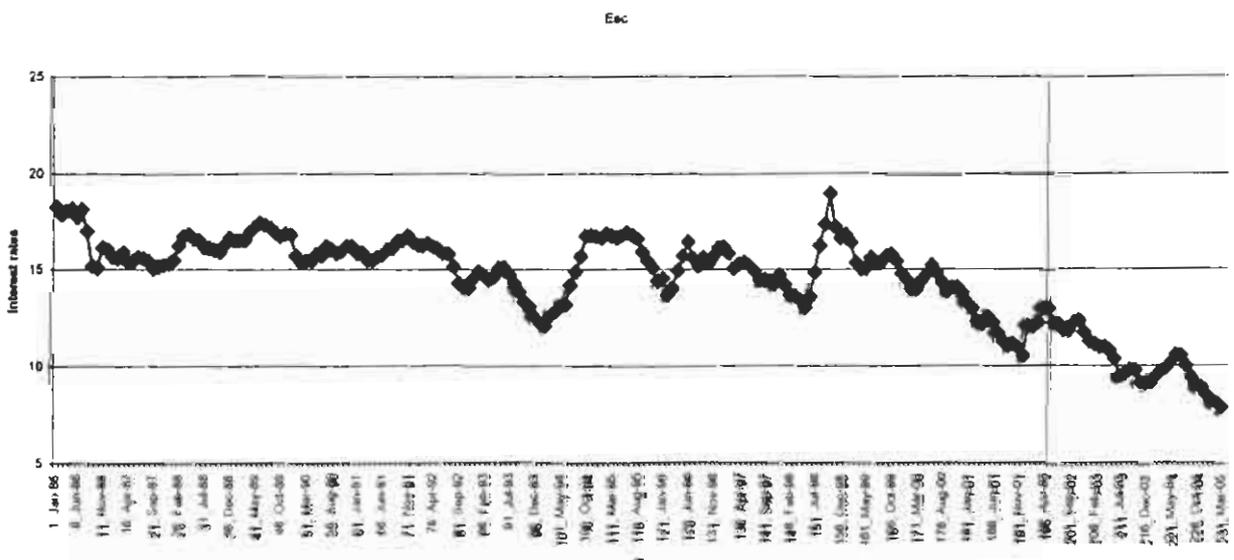
- Up to May 2002 for the BA data set (197 observations) and
- Up to April 2002 for the Esc data set (196 observations)

had been used for testing simpler models. Therefore, it was decided to use this data for forecasting longer-term and the latter part of the data to test the results (determine whether the actual data falls within the intervals set).



**Graph 1. [Above] BA data set.**

**Graph 2. [Below] Esc data set.**



With this data in mind, the two types of models were examined.

### 1.3. Box-Jenkins, AR(2) models

Broadly, the following is looked at:

- A brief overview of what nonseasonal Box-Jenkins methods entail
- Requirements for a time series in order for it to be described by classical Box-Jenkins models
- What making a tentative identification of an appropriate Box-Jenkins model involves
- AR(2) models for the BA and Esc time series using Excel and STATISTICA

#### 1.3.1. Box-Jenkins Methodology

According to Bowerman and O'Connell (1993:436), the Box-Jenkins methodology consists of a four-step iterative procedure:

- **Step 1:** Tentative identification: historical data are used to tentatively identify an appropriate Box-Jenkins model.
- **Step 2:** Estimation: historical data are used to estimate the parameters of the tentatively identified model.
- **Step 3:** Diagnostic checking: various diagnostics are used to check the adequacy of the tentatively identified model and, if need be, to suggest an improved model, which is then regarded as a new tentatively identified model.
- **Step 4:** Forecasting: once a final model is obtained, it is used to forecast future time series values.

Since classical Box-Jenkins forecasting models describe *stationary* time series<sup>5</sup>, it has to be determined whether each time series that is being analysed is stationary. If the time series is, indeed, stationary, then it is possible to proceed with the tentative identification of an appropriate Box-Jenkins model. However, if the time series is nonstationary then **differencing** (taking first and sometimes even second differences<sup>6</sup>) may be used to transform the time series.

<sup>5</sup> Bowerman and O'Connell (1993:4) define a time series as a "chronological sequence of observations on a particular variable".

<sup>6</sup> As explained in Bowerman and O'Connell (1993:437), the *first differences* of the time series values  $y_1, y_2, \dots, y_n$  are:  
$$z_t = y_t - y_{t-1} \text{ where } t = 2, \dots, n$$
  
The *second differences* of the time series values  $y_1, y_2, \dots, y_n$  are, according to Bowerman and O'Connell (1993:441):  
$$z_t = (y_t - y_{t-1}) - (y_{t-1} - y_{t-2})$$
  
$$= y_t - 2y_{t-1} + y_{t-2} \text{ for } t = 3, 4, \dots, n$$

### 1.3.1.1. A Stationary Time Series

Bowerman and O'Connell (1993:437) suggest that a time series is stationary "if the statistical properties (for example, the mean and the variance) of the time series are essentially constant through time". Pankratz (1983:11) states that a stationary time series "has a mean, variance, and autocorrelation function that are essentially constant through time".

There are certain ways to determine whether a time series is stationary or not. These include analysing the behaviour of the Sample Autocorrelation Function (SAC) and Sample Partial Autocorrelation Function (SPAC) for the values<sup>7</sup> of a stationary time series  $z_b, z_{b+1}, \dots, z_n$ .

#### 1. Stationary Time Series: Three Conditions for Stationarity

Parameter estimates are used to determine whether the model that is chosen satisfies the stationarity conditions. These are discussed in the section on nonseasonal autoregressive models (1.3.1.2.).

#### 2. Stationary Time Series: Sample Autocorrelation Function (SAC)

In considering a working series of time series values  $z_b, z_{b+1}, \dots, z_n$ , the sample autocorrelation function is, according to Bowerman and O'Connell (1993:445), a "listing, or graph, of the sample autocorrelations at lags  $k = 1, 2, \dots$ ". The *sample autocorrelation at lag k*, denoted by  $r_k$ , is, as Bowerman and O'Connell (1993:442) state:

$$r_k = \frac{\sum_{t=b}^{n-k} (z_t - \bar{z})(z_{t+k} - \bar{z})}{\sum_{t=b}^n (z_t - \bar{z})^2}$$

where  $\bar{z} = \frac{\sum_{t=b}^n z_t}{(n-b+1)}$

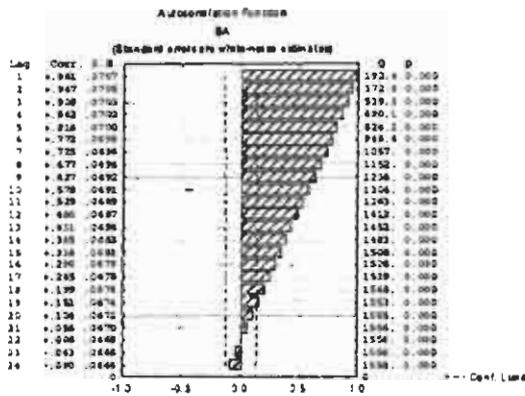
The SAC can be used to find a stationary time series because according to Bowerman and O'Connell (1993:450), in general, it can be shown that for *nonseasonal* data:

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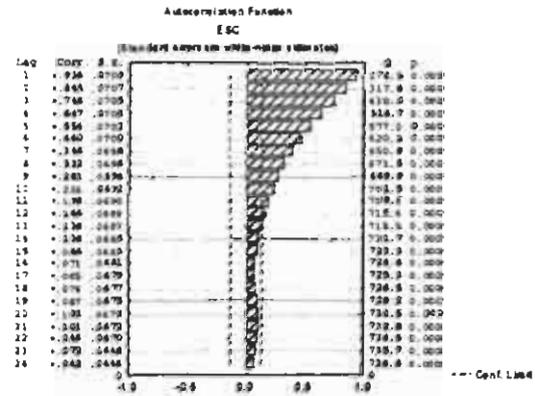
<sup>7</sup> Whether they be the original or transformed time series values.

1. If the SAC of the time series values  $z_b, z_{b+1}, \dots, z_n$  either *cuts off fairly quickly* or *dies down fairly quickly*, then the time series values should be considered *stationary*.
2. If the SAC of the time series values  $z_b, z_{b+1}, \dots, z_n$  *dies down extremely slowly*, then the time series values should be considered *nonstationary*.

The SAC was computed using STATISTICA for both the BA time series as well as the Esc time series and the resulting graphs are shown below:



**Graph 3. STATISTICA output of the SAC for the original BA values**



**Graph 4. STATISTICA output of the SAC for the original Esc values**

In looking at the graphs of the SAC for both of the time series (above), the terms “fairly quickly” and “extremely slowly” are, to some extent, subjective. Thus, it may be necessary to obtain the SAC for the first differences<sup>8</sup> but it is possible that these time series are stationary.

### 3. Stationary Time Series: Sample Partial Autocorrelation Function (SPAC)

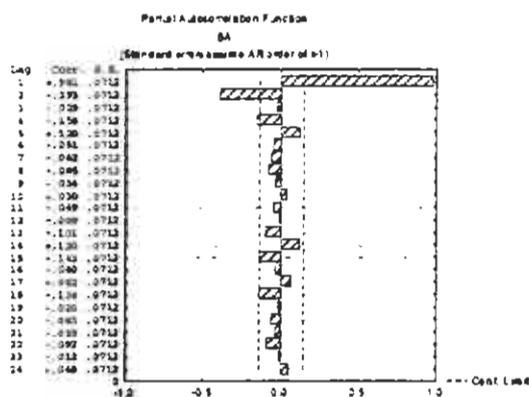
The sample partial autocorrelation function is a “listing, or graph, of the sample partial autocorrelations at lags  $k = 1, 2, \dots$ ” (Bowerman & O’Connell, 1993:454). The *sample partial autocorrelation at lag k*, denoted by  $r_{kk}$ , is defined in Bowerman and O’Connell (1993:453) as:

$$r_{kk} = \begin{cases} r_1 & \text{if } k = 1 \\ \frac{r_k - \sum_{j=1}^{k-1} r_{k-1,j} r_{k-j}}{1 - \sum_{j=1}^{k-1} r_{k-1,j} r_j} & \text{if } k = 2, 3, \dots \end{cases}$$

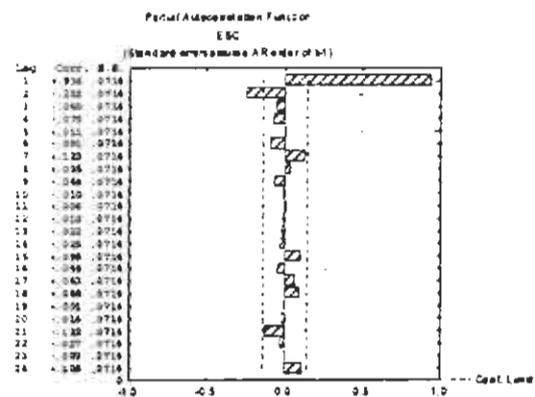
where  $r_{kj} = r_{k-1,j} - r_{kk} r_{k-1,k-j}$  for  $j = 1, 2, \dots, k-1$

<sup>8</sup> Gottman (1981:262) warns about the dangers of overdifferencing – it will “introduce spurious and meaningless patterns into the transformed, overdifferenced series”.

The behaviour of the SPAC helps in identifying Box-Jenkins models. The lag at which the SPAC cuts off for the series gives an indication of what type of model it should be tentatively identified as. The SPAC for both the BA time series as well as the Esc time series were computed using STATISTICA and the resulting graphs are shown below:



**Graph 5. STATISTICA output of the SPAC for the original BA values**



**Graph 6. STATISTICA output of the SPAC for the original Esc values**

It is possible to conclude from the graphs above that, for both time series, the SPAC seems to cut off after lag 2. The significance in each case of this taking place suggests that these models may be tentatively identified as autoregressive models of order 2 or AR(2) models.

### 1.3.1.2. Nonseasonal Autoregressive Models

According to Bowerman and O'Connell (1993:469), the model

$$z_t = \delta + \phi_1 z_{t-1} + \phi_2 z_{t-2} + \dots + \phi_p z_{t-p} + a_t$$

is called "the *nonseasonal autoregressive model of order p*" and the term "autoregressive" refers to the fact that "this model expresses the current time series value  $z_t$  as a function of past time series values  $z_{t-1}, z_{t-2}, \dots, z_{t-p}$ ".

$\phi_1, \phi_2, \dots, \phi_p$  are unknown parameters relating  $z_t$  to  $z_{t-1}, z_{t-2}, \dots, z_{t-p}$ .

$a_t$  is a random shock<sup>9</sup>

$$\delta = \mu(1 - \phi_1 - \phi_2 - \dots - \phi_p)$$

<sup>9</sup> The random shock  $a_t$  is, as Bowerman and O'Connell (1993:457) explain, a value that is "assumed to have been randomly selected from a *normal distribution* that has *mean zero* and a *variance* that is the *same* for each and every time period  $t$ ". In addition, the random shocks  $a_1, a_2, a_3, \dots$  in different time periods "are assumed to be *statistically independent* of each other" (Bowerman & O'Connell, 1993:458).

Bowerman and O'Connell (1993:489) identify the three conditions for stationarity<sup>10</sup> for a second-order Autoregressive Model

$$z_t = \delta + \phi_1 z_{t-1} + \phi_2 z_{t-2} + a_t$$

They are:

$$\phi_1 + \phi_2 < 1$$

$$\phi_2 - \phi_1 < 1$$

$$|\phi_2| < 1$$

The parameter estimates calculated in STATISTICA are both **significant** (indicated in red when computed in the program) for both the BA as well as the Esc time series. Below they are indicated in bold:

Variable: BA			
Transformations:			
Model: (2,0,0)			
No. of obs.:197 Initial SS=37307. Final SS=57.495 (.1541%) MS=.29636			
Parameters (p/Ps-Autoregressive, q/Qs-Moving aver.); highlight: p<.05			
	Const.	p(1)	p(2)
Estimate:	13.192	<b>1.3758</b>	<b>-.4032</b>
Std.Err.:	1.2823	.06540	.06553

(a)

Variable: ESC			
Transformations:			
Model: (2,0,0)			
No. of obs.:196 Initial SS=45809. Final SS=41.390 (.0904%) MS=.21445			
Parameters (p/Ps-Autoregressive, q/Qs-Moving aver.); highlight: p<.05			
	Const.	p(1)	p(2)
Estimate:	15.255	<b>1.2782</b>	<b>-.3377</b>
Std.Err.:	.52676	.06778	.06861

(b)

**Output 1. Output given in STATISTICA showing how both parameter estimates are significant in both the (a) BA and (b) Esc time series.**

In each case, the following can be shown:

BA		Esc	
p(1)	1.3758	p(1)	<b>1.2782</b>
p(2)	-0.4032	p(2)	<b>-0.3377</b>
1	1.3758 + (-0.4032) = 0.9726 which is <1	1	1.2782 + (-0.3377) = 0.9405 which is <1
2	(-0.4032) - 1.3758 = -1.779 which is <1	2	(-0.3377) - 1.2782 = -1.6159 which is <1
3	-0.4032  = 0.4032 which is <1	3	-0.3377  = 0.3377 which is <1

(a)

(b)

**Table 1. Table showing how the three conditions for stationarity are met for (a) BA time series and (b) Esc time series using output from STATISTICA.**

<sup>10</sup> According to Bowerman and O'Connell (1993:488), the Box-Jenkins methodology "requires that the model to be used in describing and forecasting a time series be both *stationary* and *invertible*". There are no conditions for invertibility for this model.

The tables above indicate that in each case, the models adhere to the conditions for stationarity for this type of model (an AR(2) model), that is, the three conditions are satisfied. Thus, it may be said that both the time series are stationary.

### 1.3.1.3. Forecasting with Nonseasonal Autoregressive Models

Univariate Box-Jenkins models or UBJ models are, as Pankratz (1983:5) mentions, often referred to as ARIMA models. "Univariate", "one variable" or single-series means that forecasts "are based *only on past values of the variable being forecast*" (Pankratz, 1983:5) and not on any other data series. In addition, an ARIMA model "is an algebraic statement telling how observations on a variable are statistically related to past observation on the same variable" (Pankratz, 1983:5).

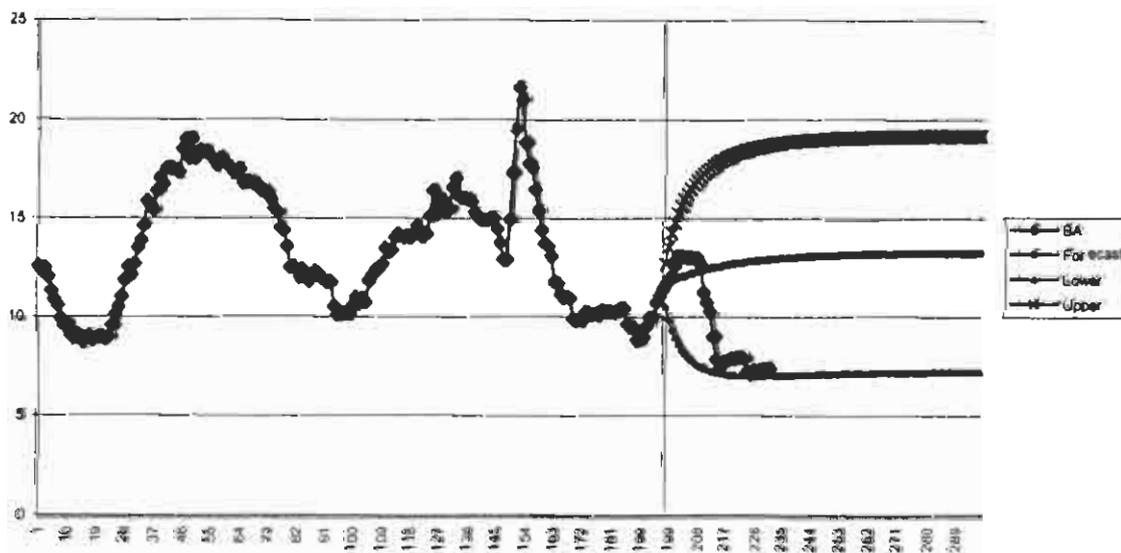
#### 1. Forecasting with AR Models: AR(2) Models

Having tentatively identified the models for the BA and Esc time series as second-order autoregressive models, forecasts<sup>11</sup> may now be made using the data, STATISTICA and

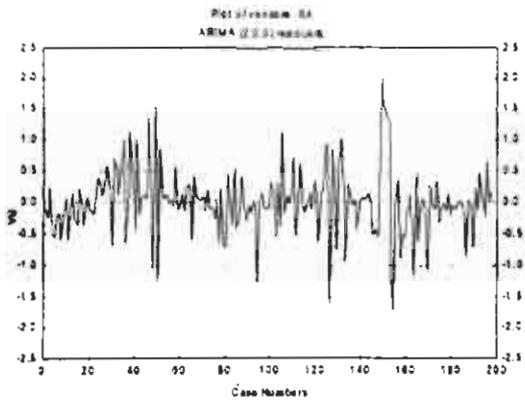
$$z_t = \delta + \phi_1 z_{t-1} + \phi_2 z_{t-2} + a_t \quad (\text{Eq. 1})$$

Forecasts were made, firstly, for the original BA and Esc time series. The next 100 values from the previously last known data point were predicted in each case. The prediction graphs are shown below, along with graphs of the residuals for each time series:

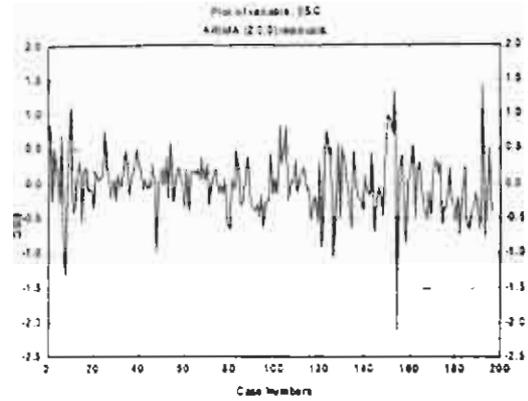
Graph 7. Showing predictions for AR(2) model for BA



<sup>11</sup> Bowerman and O'Connell (1993:3) state that "predictions of future events and conditions are called forecasts, and the act of making such predictions is called forecasting".



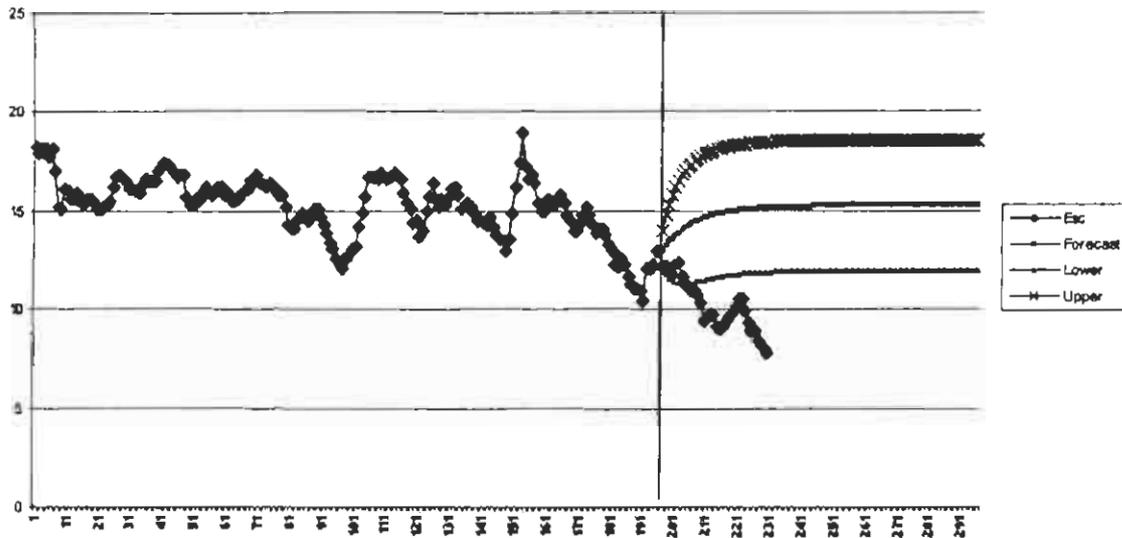
**Graph 8. STATISTICA output – graph of the residuals for the original BA time series**



**Graph 9. STATISTICA output – graph of the residuals for the original Esc time series**

In each case, analyses may be performed on these residuals.

**Graph 10. Showing predictions for AR(2) model for Esc**



In addition, a short table showing some of the predictions is presented below:

Forecasts; Model:(2,0,0)				
Input: BA				
Start of origin: 1 End of origin: 197				
CaseNo.	Forecast	Lower 95.00%	Upper 95.00%	Std.Err.
198	11.58211	10.50842	12.6558	0.544393
199	11.69961	9.87342	13.5258	0.925934
200	11.78784	9.36023	14.21546	1.230875
...	...	...	...	...
295	13.17855	7.20935	19.14776	3.02657
296	13.1792	7.20997	19.14843	3.026581
297	13.17982	7.21057	19.14907	3.026592

(a)

Forecasts; Model:(2,0,0)				
Input: Esc				
Start of origin: 1 End of origin: 196				
CaseNo.	Forecast	Lower 95.00%	Upper 95.00%	Std.Err.
197	13.07448	12.16111	13.98785	0.463091
198	13.24975	11.76747	14.73203	0.751536
199	13.42835	11.53143	15.32527	0.961766
...	...	...	...	...
294	15.25438	11.96575	18.54301	1.667381
295	15.2544	11.96577	18.54302	1.667381
296	15.25441	11.96578	18.54304	1.667381

(b)

**Table 2. Table showing some of the values (to where the intervals level off) predicted in STATISTICA for an AR(2) model using (a) BA time series and (b) Esc time series.**

From the forecasting graphs, it can be seen that the model is able to predict an interval for the BA time series wherein (for the most part) the future values are most likely to lie. However, should the rates go any lower, it may be that the interval (the lower 95% limit) is too narrow. As for the Esc time series, the interval that is predicted is initially correct. However, after about only six predictions, the interval no longer contains the future interest rate values and is in a region far above that of the actual data, especially (as it looks from the newly acquired data) if the rates go any lower.

#### 1.4. Developing Models With Volatility Limits

Having an outline for this section of the work makes it easier to understand, thus:

##### 1.4.1. Outline for Section

Using the absolute value of the maximum errors obtained from each data set

1. Knowing the future – that is, using all the data up to point 196 (and then back casting at points 74 and 148<sup>12</sup>);
2. Not knowing the future – that is, using only past data (which brings up the question of how much past data is needed to predict how accurate in the future). In this study, only the last 60 interest rate values or five years' worth of data prior to each point are used.

Create intervals of:

3. 99% = MAX99<sup>13</sup>: estimate 99% volatility by the 99<sup>th</sup> percentile of absolute value first differences;
4. 95% = MAX95: estimate 95% volatility by the 95<sup>th</sup> percentile of absolute value first differences;
5. 90% = MAX90: estimate 90% volatility by the 90<sup>th</sup> percentile of absolute value first differences.

and in each instance make predictions using:

---

<sup>12</sup> These points were selected because in this study, an analysis is not done on every point. Instead, only three points are considered, namely:

1. Point 74 (February 1992) – just before there appears to be a downward trend;
2. Point 148 (April 1998) – before the Asian crisis (an extreme high);
3. Point 196 (April 2002) – the previously last known interest rate (for the sake of simplicity and for comparison purposes, the last known point for the BA data set is chosen also as point 196).

<sup>13</sup> MAX99 is an overall estimate of volatility by the 99% percentile of the absolute first differences that are used.

6. Extreme volatility – using n – adding n volatility estimates for n future periods:

$$\text{Upper Limit: } Y_{t+n} = Y_t + n * \text{MAX P} \quad \text{where P can be 99, 95 or 90}$$

$$\text{Lower Limit: } Y_{t+n} = Y_t - n * \text{MAX P} \quad \text{where P can be 99, 95 or 90;}$$

7. Normal volatility – using square root of n ( $\sqrt{n}$ ):

$$\text{Upper Limit: } Y_{t+n} = Y_t + \sqrt{n} * \text{MAX P} \quad \text{where P can be 99, 95 or 90}$$

$$\text{Lower Limit: } Y_{t+n} = Y_t - \sqrt{n} * \text{MAX P} \quad \text{where P can be 99, 95 or 90.}$$

To find:

8. A base case, where the upper and lower interval limits that are found continue outwards without any restrictions or limits;

9. A restricted case, where limits are put on the base case. The limits based on  $\bar{x} \pm z \times s$ , where the standard deviation (s) is found with the calculation formula

$$s = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}} \quad \text{are used.}$$

In each case test the results.

#### 1.4.2. Empirical Work

It was decided to start with the previously last known interest rate (point 196 or April 2002 for both data sets) and determine what would be the prediction if one were to stand at that data point 'not knowing the future' (the newly acquired data). Thereafter, using all past data, make predictions and set intervals (as well as limits later on) and then use the latest data to test the results.

Obtaining a base case at data point 196 (April 2002) in this way, would allow for a type of back casting at other points. Two other points in particular were chosen for back casting:

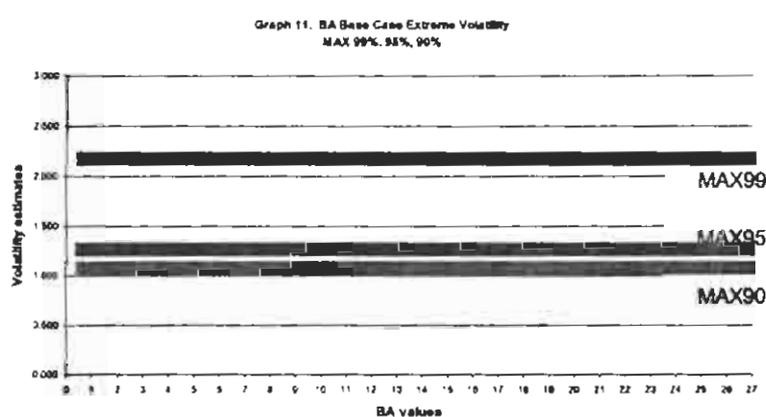
1. Point 74 (February 1992) – just before there appears to be a downward trend;
2. Point 148 (April 1998) – before the Asian crisis (an extreme high).

Thus, for both data sets in turn, all the previously used data were selected and first differences were taken. Subsequently, the absolute values of these differences were found. Thereafter, the original data and corresponding absolute value first differences were sorted and from them were found the 99, 95 and 90 percentiles by removing:

- The largest 1% (2 values) of the differences, for a 99% interval
- The largest 5% (10 values) of the differences, for a 95% interval and
- The largest 10% (20 values) of the differences, for a 90% interval

Then, for each of the three intervals, the following procedure was followed:

The remaining data and corresponding absolute value first differences were divided into groups of ten (forming, in this case, 20 groups). In each group, a maximum absolute value first difference was identified. For each interval, a maximum absolute value point is found. These are the Volatility Estimates (VE) which can be seen in the graph below for the BA time series:



From the graph it can be seen that: for the 99% interval, the maximum absolute value first difference is 2.170; for the 95% interval it is 1.200; and for the 90% interval it is 1.000.

These values are used further.

### 1.4.3. Possible Models

From the empirical work conducted above, it is possible to obtain the following models for each of the time series:

1. Base case model when a period of extreme volatility is expected – where the upper and lower limits for each of the intervals consist of going up and down by the respective volatility estimate each time. They produce steep intervals but become unusable fairly quickly because they fan out fast;
2. Back casting models for extreme volatility conditions – at the two chosen points;
3. Base case model in anticipation of a period of normal volatility – where the upper and lower limits for each of the intervals consist of going up and down by the respective volatility estimate divided by the square root of  $n$  (where  $n$  is the number

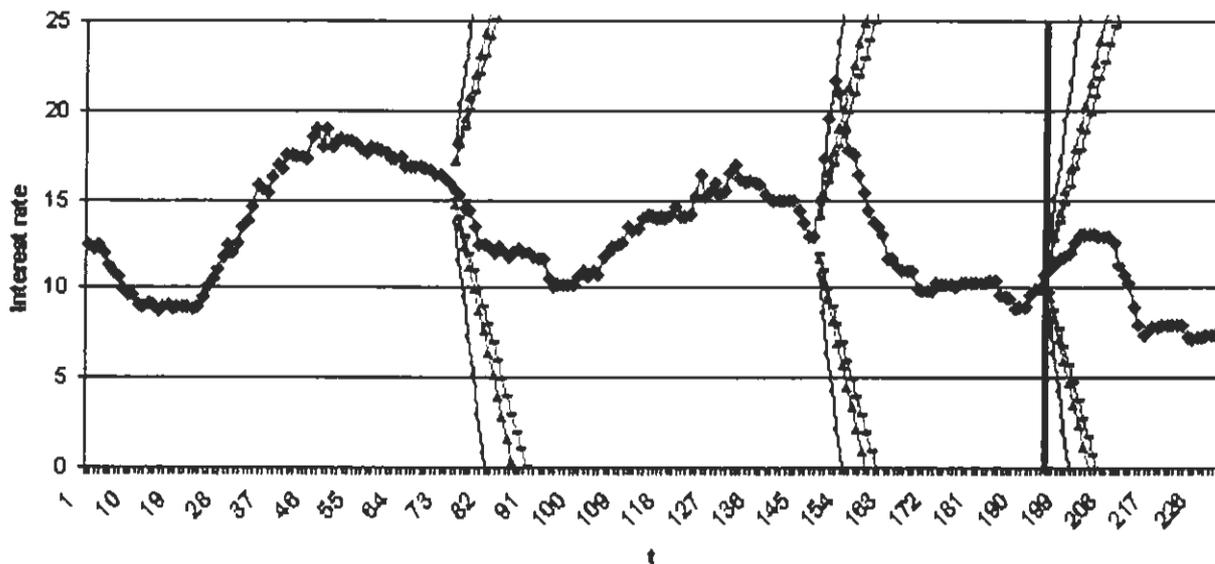
of predictions, starting at 1 for the first prediction), for each subsequent prediction.

These models fan out slower than the extreme models;

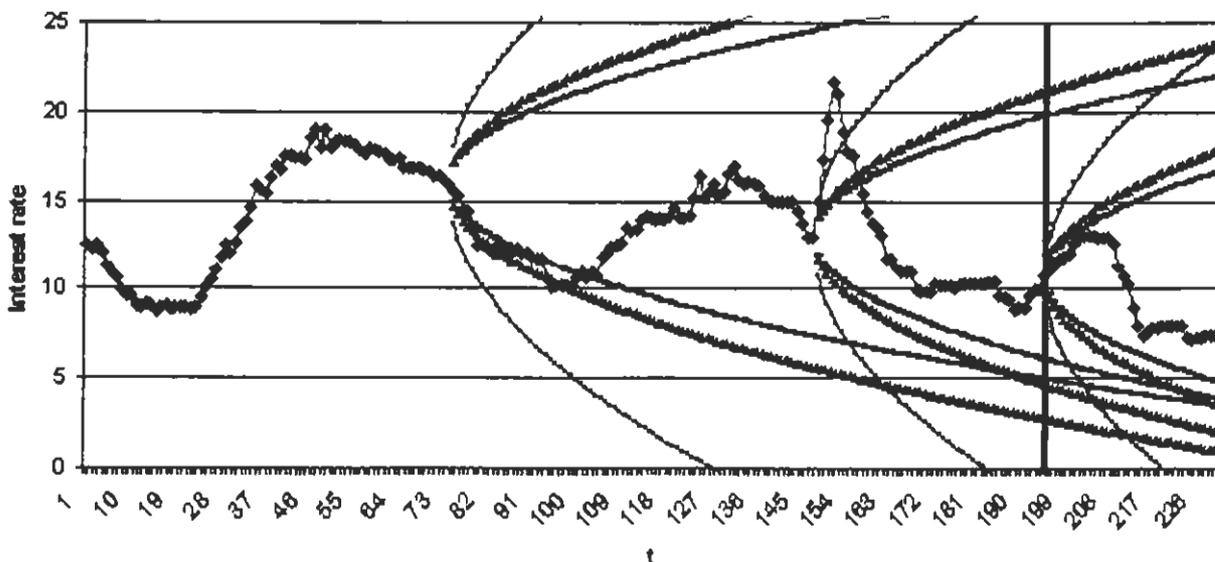
4. Back casting models for normal volatility conditions – at the chosen points.

Examples of some of these models may be seen below:

**Graph 12. Base Case and Back Casting Models for Extreme Volatility  
BA MAX99%, 95%, 90%**



**Graph 13. Base Case and Back Casting Models for Normal Volatility  
BA MAX99%, 95%, 90%**



From the graphs above, it may be seen that these predictions (for most models) become unusable in the far future. The limits are just too wide. Therefore, models that fan out initially but then reach a limit at which they remain in the long-term, were produced. These are discussed next.

#### 1.4.3.1. Models with Limits Based on $\bar{x} \pm z \times s$

Since the intervals of the predictions for the base case and back casting models are too wide, new models must be developed that have intervals that reach an acceptable limit wherein the future interest rates are likely to lie. One solution is to make volatility a function of the level of the time series.

Consequently, each of the models described above were modified to level off at limits based on

$$\bar{x} \pm z \times s \quad (\text{Eq. 2})$$

where  $\bar{x}$  is the average or mean of the data being used<sup>14</sup>

$z$  is a critical value read from Table B.3 in Steyn, Smit, du Toit, and Strasheim (1994:683) each time, using:

For a 99% interval, the value of 2.576

For a 95% interval, the value of 1.960

For a 90% interval, the value of 1.645

and  $s$  is the standard deviation<sup>15</sup> (which can be estimated in various ways, creating different models) obtained using the calculation formula given in Steyn, *et al.* (1994:131):

$$s = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}}$$

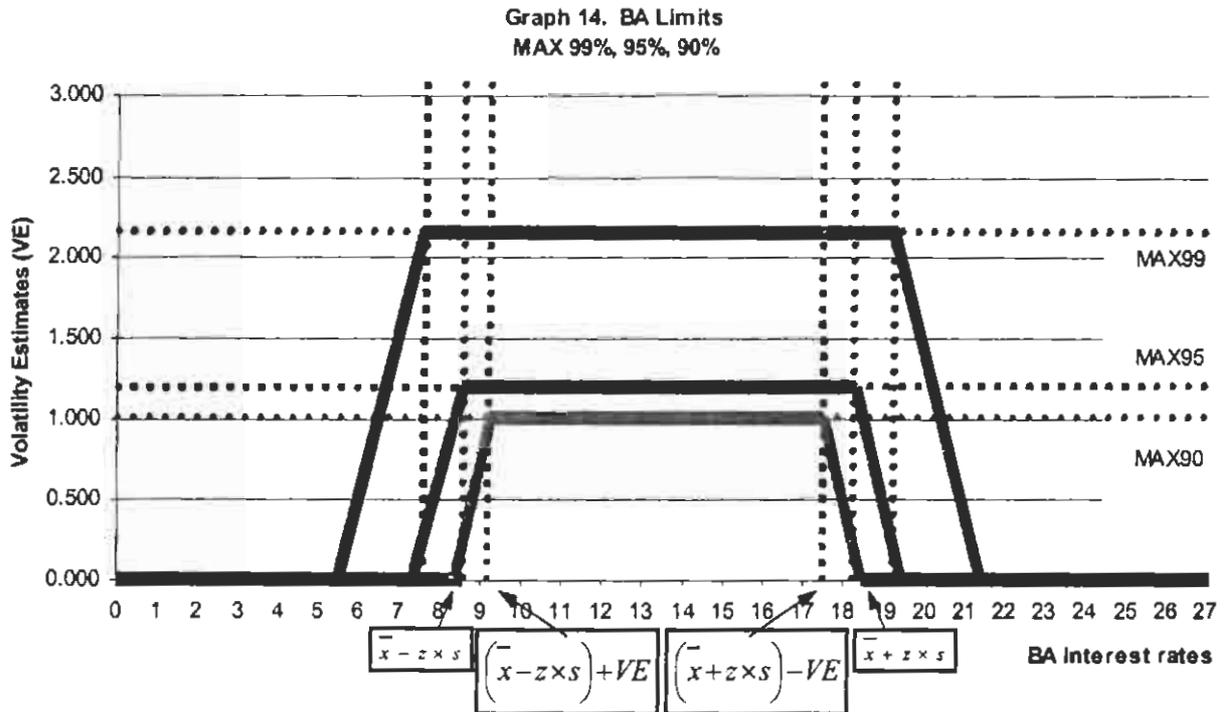
<sup>14</sup> The arithmetic mean (or average) of a set of observations  $x_1, x_2, \dots, x_n$  is defined in Steyn, *et al.* (1994:99) by:

$$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n} \\ = \frac{\sum x}{n}$$

<sup>15</sup> The standard deviation of  $x_1, x_2, \dots, x_n$  is defined in Steyn, *et al.* (1994:130) by:

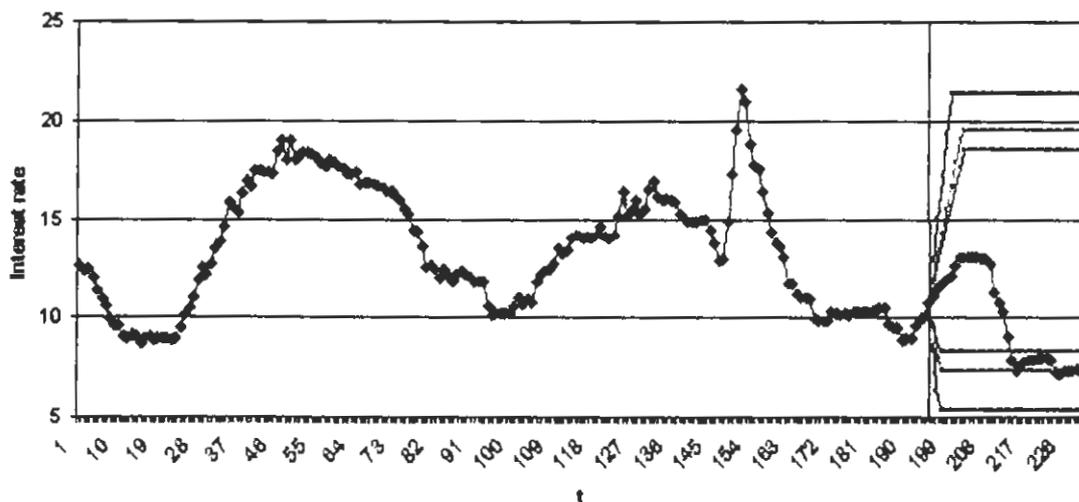
$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

Each time, the same procedures were followed for both time series. The new graphs showing the limits for the BA time series as well as the extreme and normal volatility models are illustrated below:

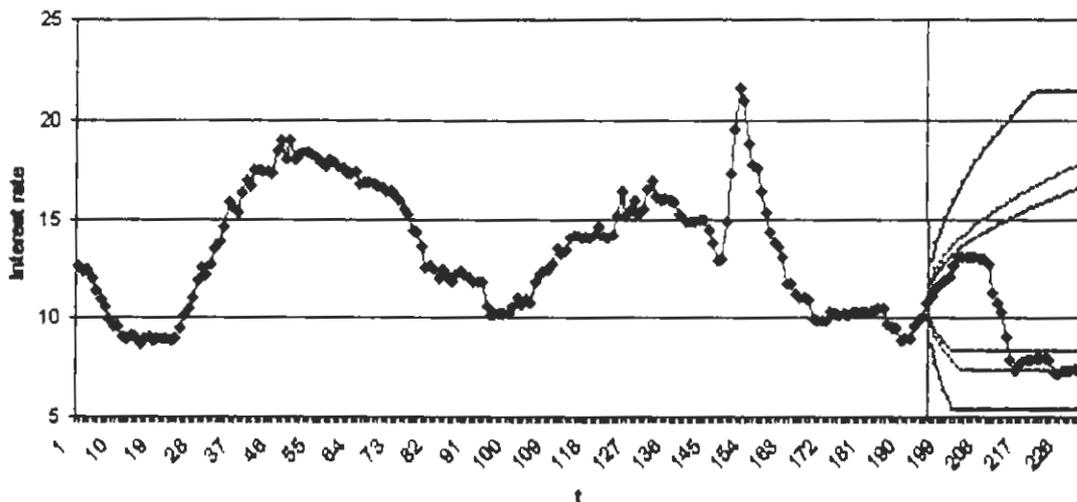


In the graph above (and for all graphs of this kind), the limits are set at  $\bar{x} \pm z \times s$  for each of the three intervals. In order for the predictions not to exceed these limits, a Volatility Estimate (VE) is added to each of the corresponding lower limits so that as from those points, the predictions can start to be such that they do not exceed the limits. At the other end, a VE is subtracted from each of the corresponding upper limits in order to achieve the same result (not to allow the predictions past the limits).

**Graph 15. Extreme Volatility Model with Limits**  
BA MAX99%, 95%, 90%



Graph 16. Normal Volatility Model with Limits  
BA MAX99%, 95%, 90%



For each of the intervals, it is possible to determine whether the actual data remains within the interval set out at each prediction point. In addition, it is possible to verify whether the actual data remains within the limits or if these are too restrictive (or narrow) and cause future predictions to be incorrect.

#### 1.4.4. Meaningful Models

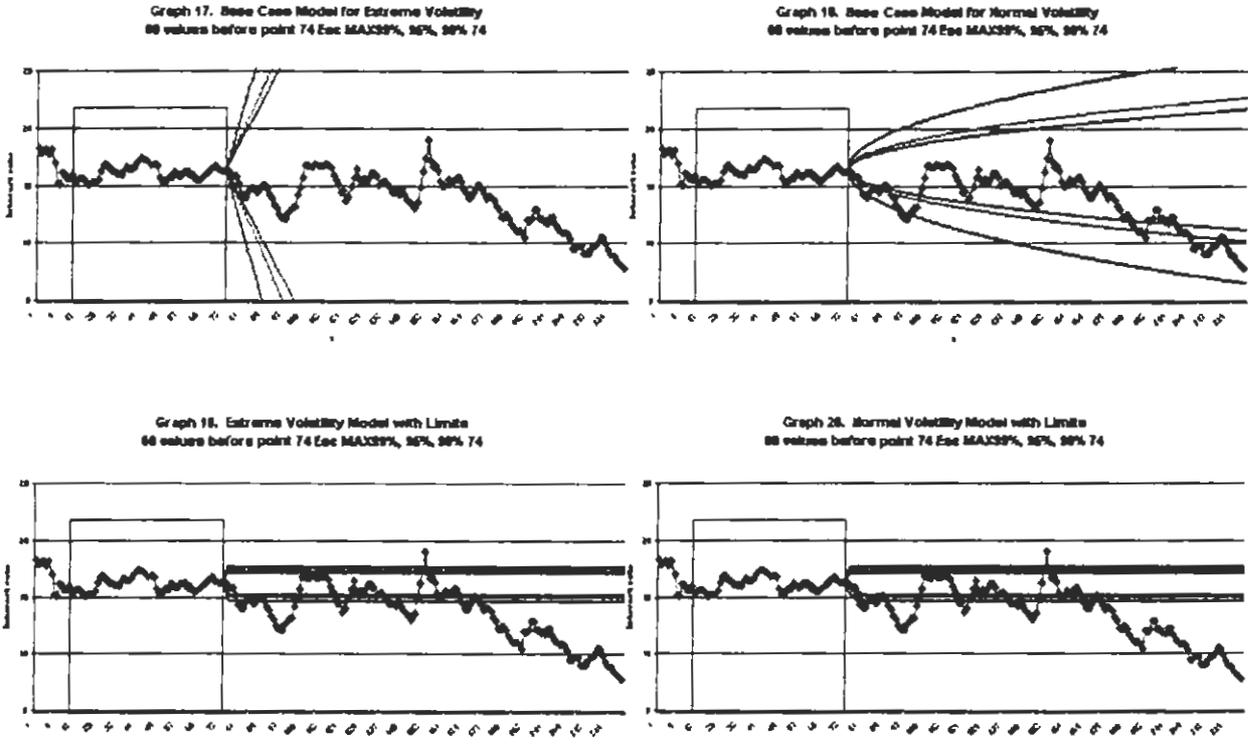
Having developed the models above, the question of how much data is needed in order to make a good prediction still remains. Using 196 interest rate data points requires having access to over 16 years' worth of data, which in some instances may be difficult to acquire. It may be worth the trouble to get that information, especially to see the "bigger picture" in the long run. However, going too far back into the past and working with too much data may cause a distorted view of the future, not only because the future is more dependent on the immediate past, but also, because necessitating so much data is impractical.

The actual data (the type of data) being forecasted needs to be taken into consideration as well as the techniques that are going to be used on that data to make predictions for the future<sup>16</sup>. However, banks tend to favour working with data of five to ten years. Therefore, it was decided to go back to each point (74, 148 and 196) for both data sets individually and determine what the forecasts would look like, if only the 60 data values immediately prior to each of those points were used to make the predictions.

<sup>16</sup> See, for example, H. Levenbach and J.P. Cleary, *The modern forecaster: The forecasting process through data analysis* (1984:27).

Thus, the same procedure as before was followed each time but using only the 60 values (five years' worth of data) before each point<sup>17</sup>. The results obtained consisted of base case models for extreme as well as normal volatility (that become unusable fairly quickly) and more importantly, models that tend to limits set by using the conventional equation explained above (Eq. 2).

Some of these graphs<sup>18</sup> are given below. Specifically, the graphs of the Esc time series at point 74 when only 60 values are used to make the predictions.



It can be seen that using only these values, the limits in this case would produce an interval that is much too narrow. The summary table below identifies the limits for each model at the different points and also shows the size of the interval in each case:

<sup>17</sup> First differences were obtained and the top 1%, 5% and 10% removed. The data and corresponding absolute value first differences were then divided into groups of ten (forming, in this case, 6 groups). In each group, a minimum, average and maximum absolute value first difference was identified. The maximum values were plotted on a graph and the maximum absolute value point in each interval was found.

<sup>18</sup> Please note that in the graphs, MAX99%, 95%, 90% refers to MAX99%, MAX95% and MAX90%.

BA	Point		Lower Limit	Upper Limit	Size of Interval
197	196	99%	5.38	21.43	16.05
		95%	7.30	19.51	12.21
		90%	8.28	18.53	10.25
60	74	99%	5.83	24.09	18.26
		95%	8.01	21.91	13.89
		90%	9.13	20.79	11.66
	148	99%	8.43	18.65	10.23
		95%	9.65	17.43	7.78
		90%	10.27	16.80	6.53
	196	99%	4.32	21.06	16.74
		95%	6.32	19.06	12.74
		90%	7.35	18.04	10.69

(a)

Esc	Point		Lower Limit	Upper Limit	Size of Interval
196	196	99%	11.17	19.24	8.07
		95%	12.14	18.28	6.14
		90%	12.63	17.78	5.15
60	74	99%	14.58	17.65	3.07
		95%	14.95	17.28	2.33
		90%	15.14	17.09	1.96
	148	99%	11.51	18.32	6.81
		95%	12.32	17.50	5.18
		90%	12.74	17.09	4.35
	196	99%	9.68	18.62	8.94
		95%	10.75	17.55	6.80
		90%	11.29	17.00	5.71

(b)

**Table 3. Summary table showing the limits that were used for each model at the various points for (a) the BA time series and (b) the Esc time series.**

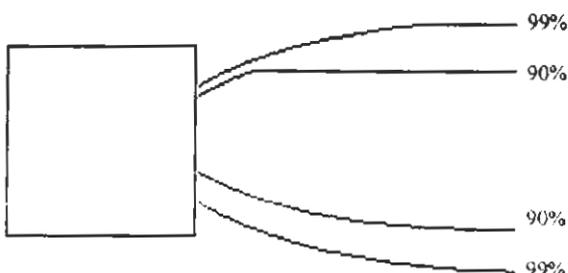
Analysing the results obtained is extremely important. In addition to the graphs, the percentage of actual data that lies inside of the interval should be considered at the same time.

Questions that are raised and whose answers need to be taken into account include, for example:

- What is the number of predictions that are desired? That is, in using 196 past values, how long is the desired time of prediction – another 196 future values?
- In using only 60 past values (five years' worth of data), can the models predict correctly only for another 60 observations (five years into the future) and if not, for how long, then, are the past 60 values, for example, able to predict into the future?

#### 1.4.5. Hybrid

Considering the recent graphs, a hybrid model was developed. It looks like this:



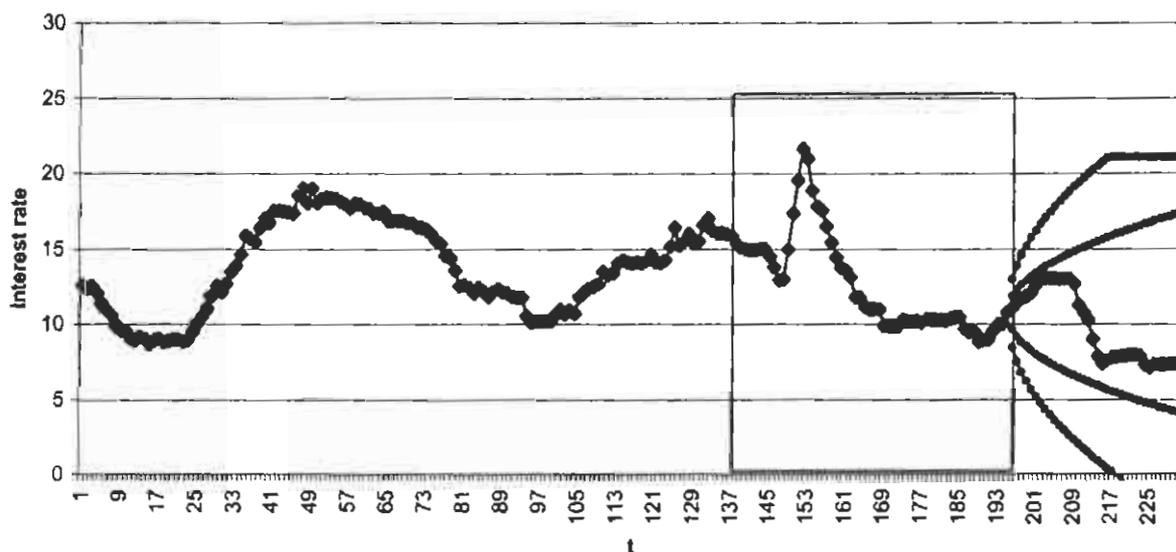
The hybrid model suggests that predictions should be made as follows:

1. Select the amount of data to use (for example, 60 values). Follow the procedures as above to find volatility estimates for MAX90% and MAX99%
2. Start making long-term forecasts with the normal volatility model and make upper and lower predictions for an interval of 90%;
3. Then, for the upper interval only, find and set a limit according to Eq.2;
4. Repeat Steps 2 and 3 for a 99% interval.

This new model can be used to predict intervals that should contain all the future data in the short-, medium- and long-terms. If any data lies outside of the 90% interval, then it should be covered by the 99% interval (especially for the latest Esc data – there is a downward movement). If the data lies in any area above the 99% upper interval limit or below the 99% interval, then it is considered extreme.

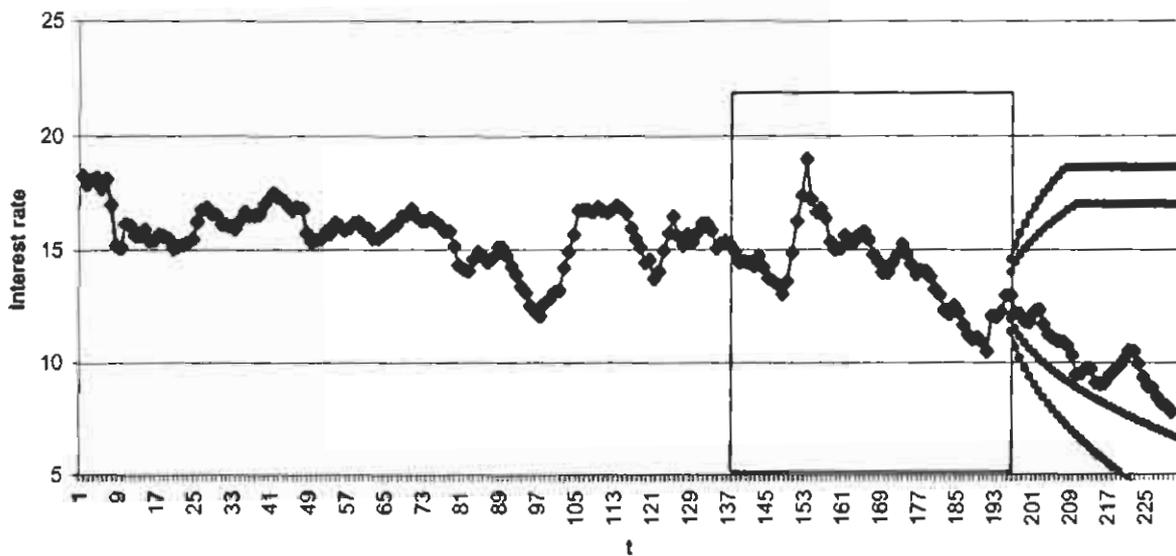
This hybrid model was tested out on the last 60 values before point 196 for the BA and Esc time series, in order to make a prediction for the future. The resulting graphs are shown below:

Graph 21. Hybrid Model  
60 values before point 196 BA MAX99%, 90% 196



In the graph above, the 90% upper limit eventually levels off at 18.04. All the available BA data lies within the intervals and limits set. This graph will be an improvement on the earlier graph for the same section in the longer-term, when the latter creates a wider upper interval and the former levels off at the limit.

Graph 22. Hybrid Model  
60 values before point 196 Esc MAX99%, 90% 196



From the graph above it can be seen that all the available Esc data lies within the intervals and limits that were set with the hybrid model. Although there is still a lot of space between the upper limit and the actual data, it is slightly less than the earlier graph and thus, an improvement.

In order to ascertain whether correct predictions were made for the longer-term, more actual data is needed. This will be possible only once the data is available in reality. Yet, since all the data lies within the 90% intervals (and limits) for both time series, the hybrid model seems to be one that is able to make reasonably good predictions.

### 1.5. Conclusion

In attempting to manage interest rate risk effectively by predicting interest rates for two data sets (BA and Esc), the aim of this article is to focus on more advanced models (of fixed volatility) that can be used in order to make longer-term forecasts for the two time series. The idea is to find an interval that will contain the future actual data, or at least most of it. Being able to find a good interval with the least amount of past data is also important.

In endeavouring to obtain better predictions for the two real time series, two broad areas of work were explored. These areas are distinguished by answering the questions: is a stationary time series or a non-stationary time series involved? If it's the latter, are they extreme or normal conditions?

For stationary time series, Box-Jenkins autoregressive models of order two were discussed. For non-stationary time series, new models were developed.

For the Box-Jenkins models<sup>19</sup>, a package called STATISTICA was used in addition to Excel. The conditions for stationarity were observed (which is a requirement for each of the time series for these models) and both time series were tentatively identified as AR(2) models. Predictions were then made. These models were able to estimate an interval that contained most of the actual BA data. However, an interval much higher up than where the actual data really is, was predicted for the Esc time series.

For the non-stationary times series, new models were developed. These new models create 99%, 95% and 90% intervals based on their respective volatility estimates (which are found with new work done using the maximum absolute value first differences). Every time, intervals were created in anticipation of extreme volatility conditions and normal volatility conditions.

Described in greater detail: a base case was found for each time series, where all the previously known data values were used. From here, back casting was done at two other chosen points (74 and 148) that reflected a different direction in which the actual data was moving. Each time, two cases were examined – one in times when extreme volatility was expected and another, when a period of less, or normal, volatility was anticipated. Results were obtained.

Each interval was then restricted by adding volatility limits. Thus, limits based on  $\bar{x} \pm z \times s$  were considered for each interval in extreme and normal circumstances. These limits were obtained and the results analysed.

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<sup>19</sup> As Pankratz (1983:47) explains, an ARIMA process "refers to the set of possible observations on a time-sequenced variable, along with an algebraic statement (a generating mechanism) describing how these observations are related".

However, using so many past interest rates (196 values) to make predictions for such a short amount of time seemed excessive. Since indications were to use five to ten years' worth of data, models using only the 60 values before each point were developed. Again, cases of extreme volatility (that makes use of  $n$ , where  $n$  is the number of periods of the predictions) and normal volatility (that make use of the squared root of  $n$ ) were explored.

Amongst other things, it was found that adding limits is not always the best thing to do. This is because they may be too narrow, causing the actual data to lie outside of the intervals (which means or confirms that the data is non-stationary).

A hybrid model was also suggested. This model makes interval predictions for 90% and 99% and then applies only upper limits on these. Areas that are not covered by the model are considered extreme. The hybrid model was tested on both time series, using the 60 values before point 196. In each case positive results were achieved. Further long-term results can be tested only once actual data is available.

Many results can be summarised and analyses considering both graphs and tables, simultaneously, should be performed. Amongst other things, it could be seen that if the data before the prediction point is more or less the same, the limits obtained could turn out to be too narrow, causing the actual data to lie outside of the intervals. Some important questions to consider were also raised.

As always, a more in-depth look can be taken at each model that was developed and the results that were obtained can be analysed more thoroughly. In addition, more models are available that can be examined and tested. However, ultimately, the aim is to be able to predict interest rates as close to the original ones as possible, trying to make as small intervals as possible that contain the actual future data.

The models that were developed using volatility estimates (maximum absolute value first differences) and later restricted with limits, are new. They seem to be an improvement and are effective in being able to predict intervals that contain, for the most part, the actual data.

Undoubtedly, care has to be taken in making a good model and time spent on this (as well as analysing the results obtained) is certainly worth it. Yet, even if the perfect model is

found for a time series or part thereof, caution needs to be taken because there are no guarantees that the same model will do equally well in the unknown far future. The idea should be to try to be more attentive to changes in the actual data and adapt models to be able to keep making adequate forecasts.

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**BUILDING TOWARDS GROWTH AND SUSTAINABILITY**  
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**EMERALD CASINO RESORT, VANDERBIJLPARK**

**28 - 31 AUGUST 2005**

**A PRESENTATION BY:**

**HELENA FERNANDES**

**N7053**

29/08/2005

# **A comparison of the effectiveness of different models in forecasting interest rates**

## ABSTRACT

Interest rate risk is one of the most important types of risk to which banks are continually exposed. Interest rates determine a bank's profitability and have an effect on a bank's liquidity and investment portfolio and it is, thus, extremely important to manage interest rate risk effectively.

In managing interest rate risk, it is important to predict interest rates as accurately as possible. Several models are available for this purpose. The effectiveness of these models for forecasting over different time horizons is compared.

# INTRODUCTION

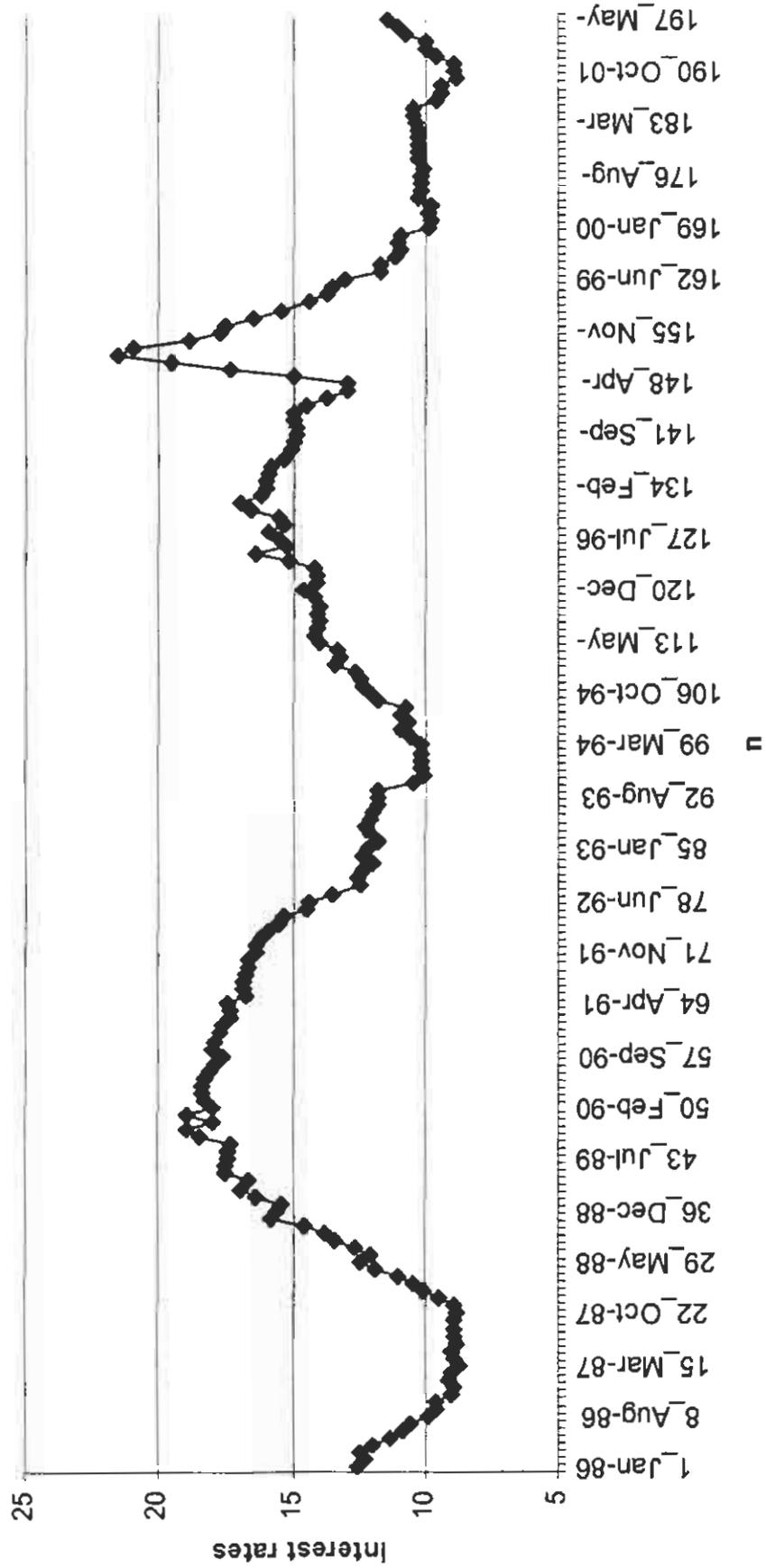
- FORECASTING IS AN ESSENTIAL PART OF OUR LIVES
- IT AFFECTS BANKS
- INTEREST RATES
- INTEREST RATE RISK
- MANAGING INTEREST RATE RISK

# IN MANAGING INTEREST RATE RISK

- FORECASTING INTEREST RATES IS ESSENTIAL
- MANY TECHNIQUES FOR MANY RATES  
↓
- TWO INTEREST RATES

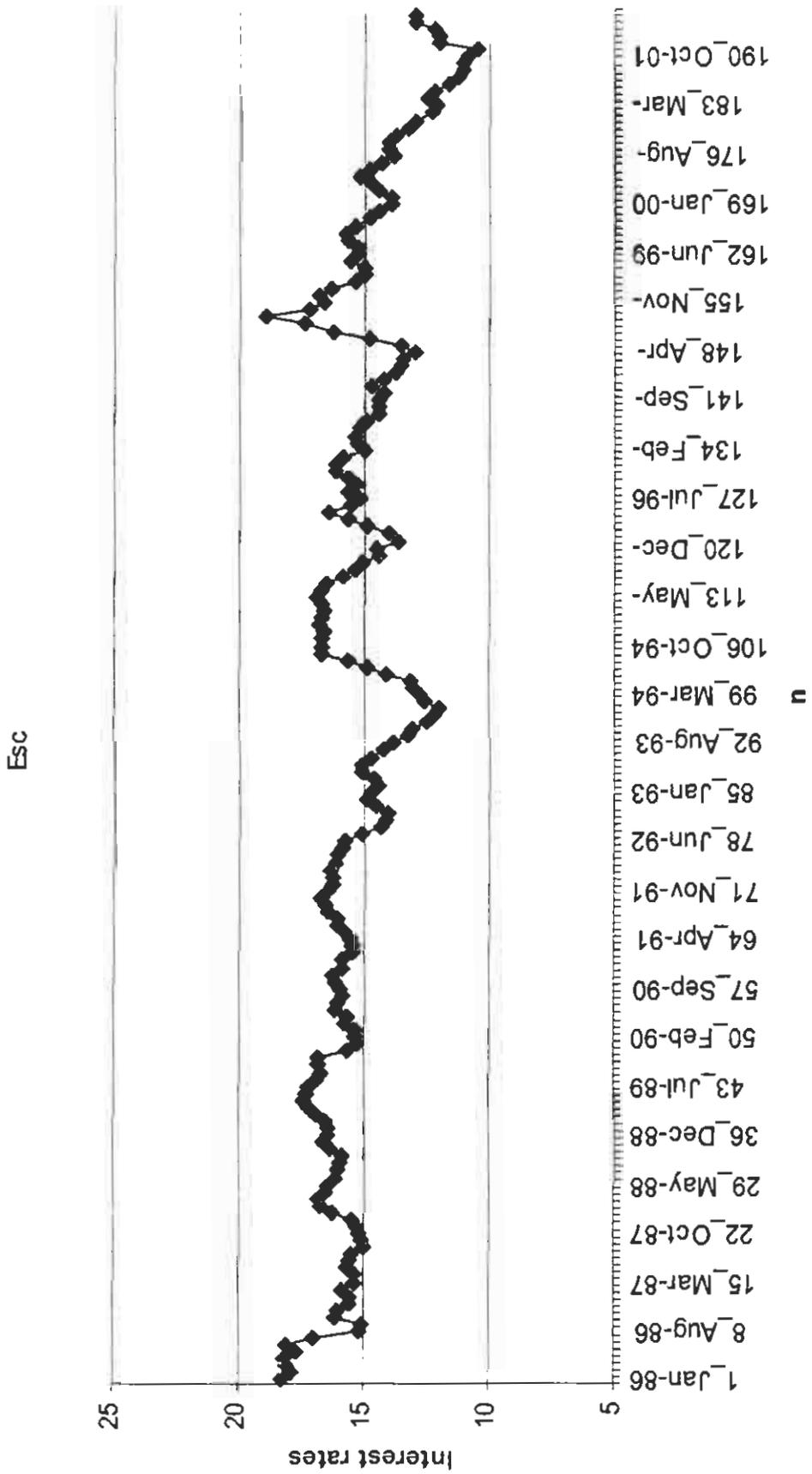
# TWO DATA SETS: 1 = BA

BA



198-70

# TWO DATA SETS: 2 = Esc



# TWO TYPES OF FORECASTS

## 1-STEP AHEAD

## LONG-TERM

1

**SIMPLE METHODS  
AND TECHNIQUES**



**7 MODELS**

2

**MORE ADVANCED  
VOLATILITY MODELS**



**2 TYPES OF MODELS**

# SIMPLE METHODS AND TECHNIQUES

1.1.

1.2.

1.3.

**NAÏVE MODELS      MOVING AVERAGE MODELS      EXPONENTIAL SMOOTHING**

**MODELS**

**MODELS**

**SMOOTHING**

$$1. Y'_{t+1} = Y_t$$

$$2. Y'_{t+1} = Y_t + (Y_t - Y_{t-1})$$

$$3. Y'_{t+1} = Y_t * (Y_t / Y_{t-1})$$



$$Y'_{t+1} = \alpha Y_t + (1 - \alpha) Y'_t$$

1. Single Smoothed

2. Double Smoothed

$$1. (Y_t + Y_{t-1}) / 2$$

$$2. (Y_t + Y_{t-1} + \dots + Y_{t-m+1}) / m$$

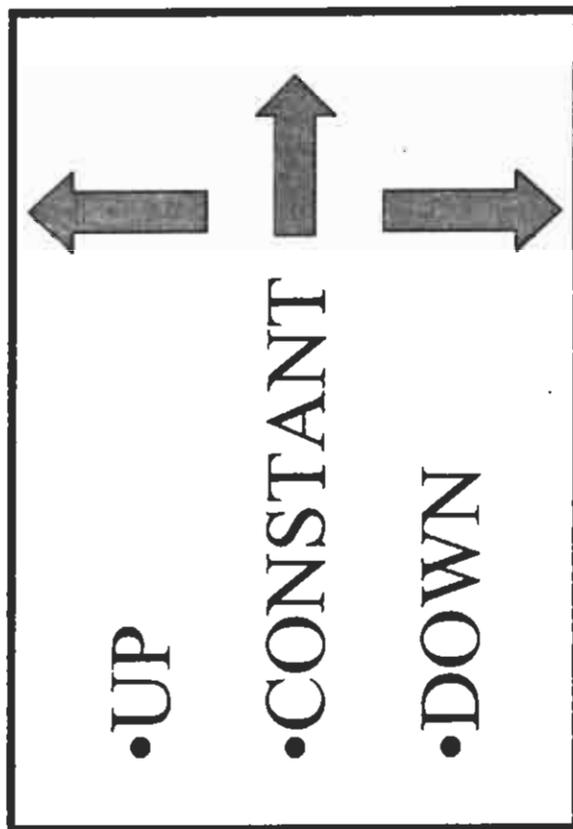
# CRITERIA FOR THE “BEST” MODEL

- 1. PREDICT CORRECT DIRECTION (PCD)**
- 2. MEAN SQUARED ERROR (MSE)**
- 3. TRACKING SIGNALS (TS)**

# 1. PREDICT CORRECT DIRECTION (PCD)

DOES THE NEXT  
INTEREST RATE  
GO

DO WE PREDICT  
THE DIRECTION  
IS



IN REALITY      →      ←      FROM OUR MODELS

## 2. MEAN SQUARED ERROR (MSE)

DEFINED AS:

THE AVERAGE SUM OF THE VARIATIONS  
BETWEEN THE HISTORICAL DATA AND THE  
FORECAST VALUES FOR THE CORRESPONDING  
PERIODS

$$MSE = \frac{\sum_{t=1}^n \left( Y_t - Y'_t \right)^2}{(n - i)}$$

*where  $i$  = the number of observations used to find the  
initial forecast*

### 3. TRACKING SIGNALS (TS)

$$\text{Tracking Signal} = \frac{\text{Running Sum of the Forecast Errors (RSFE)}}{\text{Mean Absolute Deviation (MAD)}}$$

$$\text{where RSFE} = \sum \left( \begin{array}{c} \text{actual rate} \\ \text{in period } i \end{array} - \begin{array}{c} \text{forecastrate} \\ \text{in period } i \end{array} \right)$$

$$\text{and } \text{MAD} = \sum |\text{forecast errors}| / n$$

- LOW RSFE
- WITHIN  $\pm 4$  MADs

# CRITERIA FOR THE “BEST” MODEL

1. PCD – THE HIGHER, THE BETTER
2. MSE – THE SMALLER, THE BETTER
3. TS – LOW RSFE AND  
WITHIN  $\pm 4$  MADs

# SIMPLE METHODS AND TECHNIQUES

## 1.1.

- EASY TO CALCULATE

### NAÏVE

- SHOULD BE COMPARED

TO MORE SOPHISTICATED  
MODELS

### MODELS

- BASED ONLY ON PAST (HISTORICAL) OBSERVATIONS
- DO NOT ATTEMPT TO EXPLAIN ANY UNDERLYING CAUSAL RELATIONSHIPS – DISADVANTAGE

$$1. Y_{t+1} = Y_t$$

= 1<sup>ST</sup> NAÏVE, SAME-VALUE

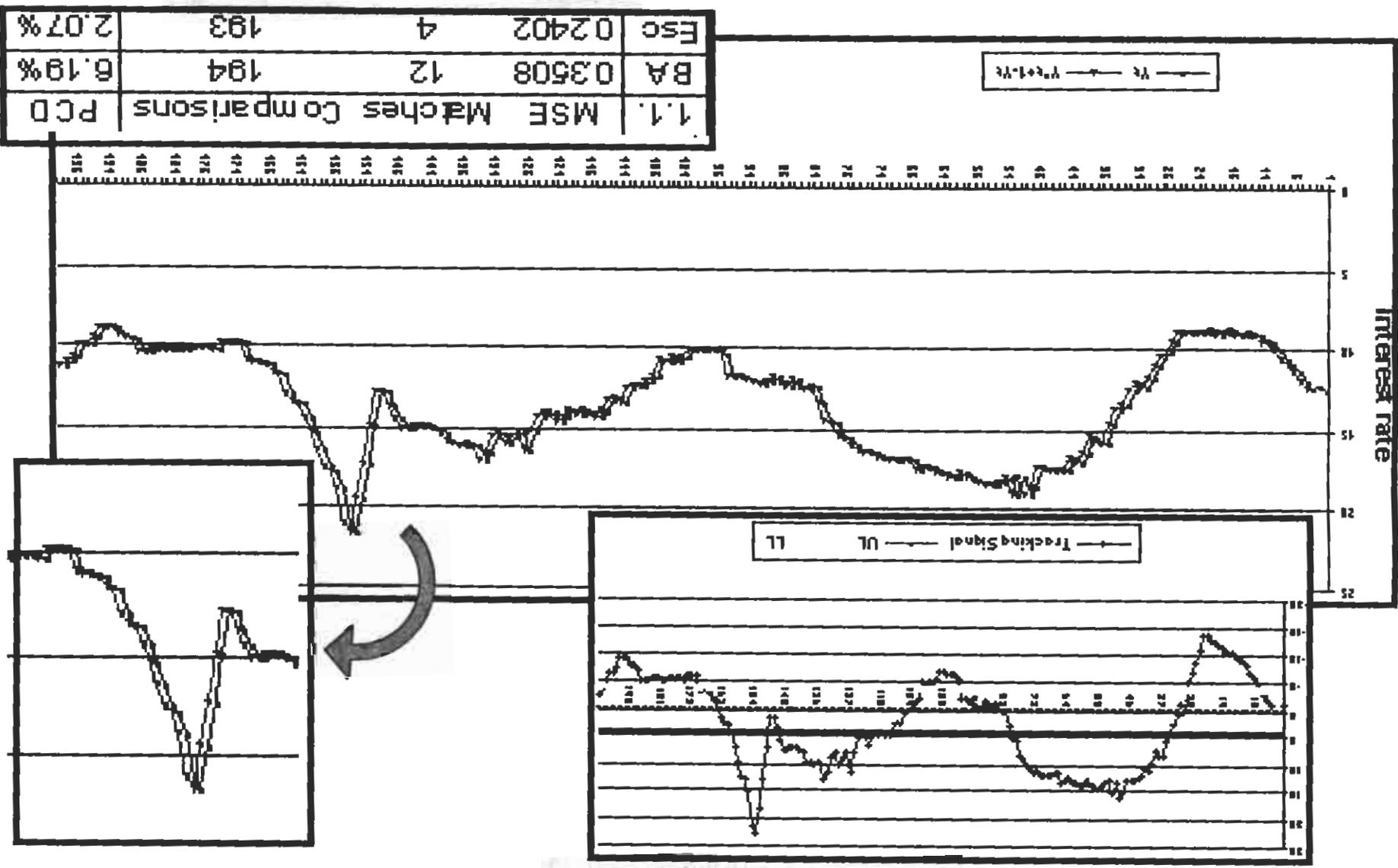
$$2. Y_{t+1} = Y_t + (Y_t - Y_{t-1})$$

= 2<sup>ND</sup> NAÏVE, STRAIGHT-LINE

$$3. Y_{t+1} = Y_t * (Y_t / Y_{t-1})$$

= 3<sup>RD</sup> NAÏVE, PERCENTAGE

# EXAMPLE: BA 1<sup>ST</sup> NAIVE MODEL



# SIMPLE METHODS AND TECHNIQUES

1.2.

## MOVING AVERAGE

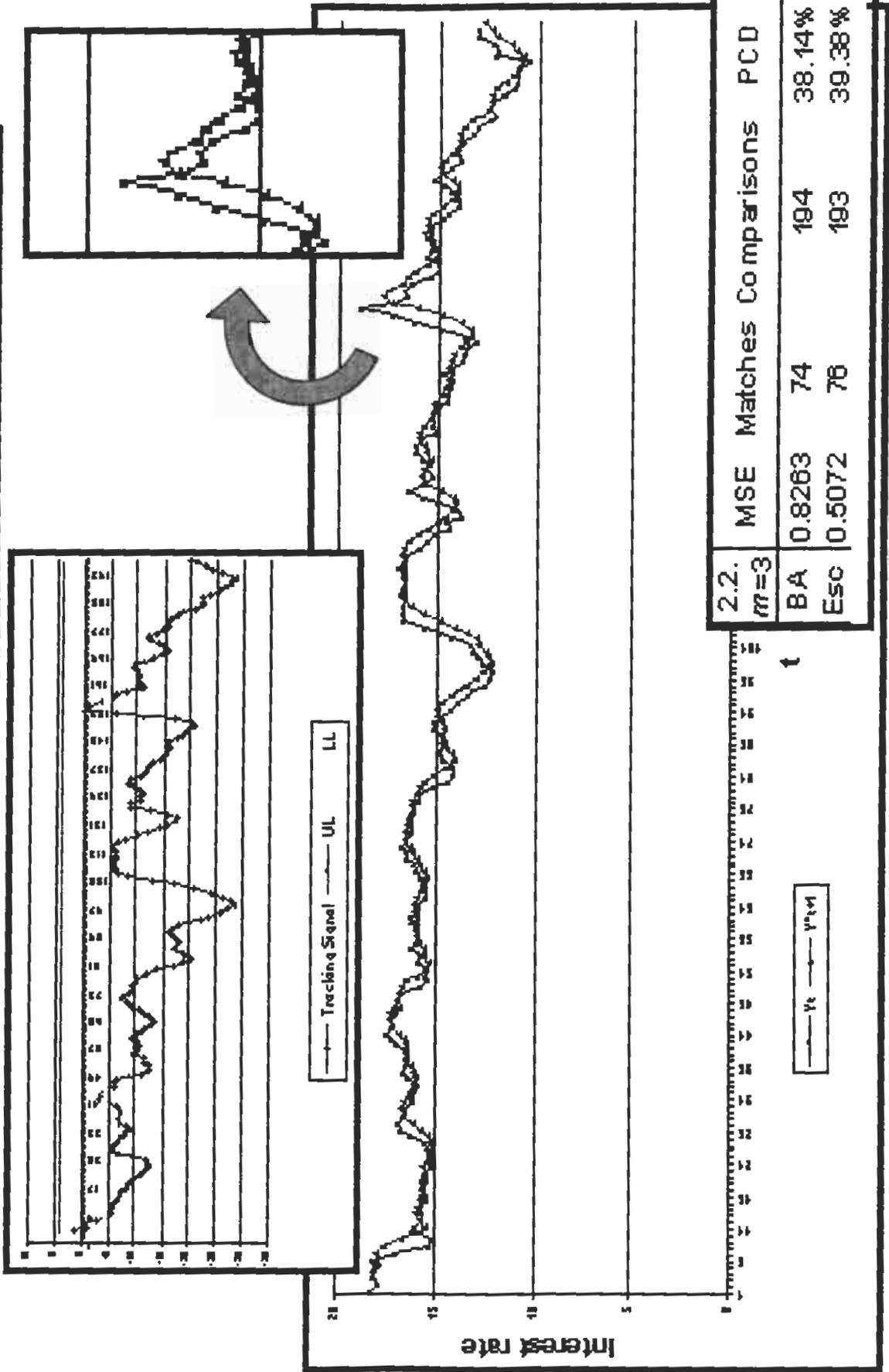
### MODELS

- MUST RETAIN AND CARRY A LOT OF DATA
- ALL DATA IN THE SAMPLE ARE WEIGHTED EQUALLY
- MOVING AVERAGES ARE AVERAGES THAT ARE UPDATED AS NEW INFORMATION IS RECEIVED.
- AVERAGE IS USED AS FORECAST FOR NEXT PERIOD

$$1. (Y_t + Y_{t-1}) / 2 = 1^{\text{ST}} \text{ MA MODEL}$$

$$2. (Y_t + Y_{t-1} + \dots + Y_{t-m+1}) / m = 2^{\text{ND}} \text{ MA MODEL, where } m=3$$

# EXAMPLE: ESC 2<sup>ND</sup> MA MODEL



# SIMPLE METHODS AND TECHNIQUES

1

1.3.

## EXPONENTIAL

### SMOOTHING

$$Y'_{t+1} = \alpha Y_t + (1 - \alpha) Y'_t$$

$\alpha$  = smoothing constant

Weight

MSE

1. Single Smoothed

2. Double Smoothed

1<sup>ST</sup> EXPONENTIAL  
SMOOTHING MODEL

$\alpha$  is alternately equal to:

0.1, 0.4, 0.6 and 0.9

2<sup>nd</sup> EXPONENTIAL  
SMOOTHING MODEL

combinations of  $\alpha_1$  and  $\alpha_2$  are  
used

# 1ST EXPONENTIAL SMOOTHING MODELS

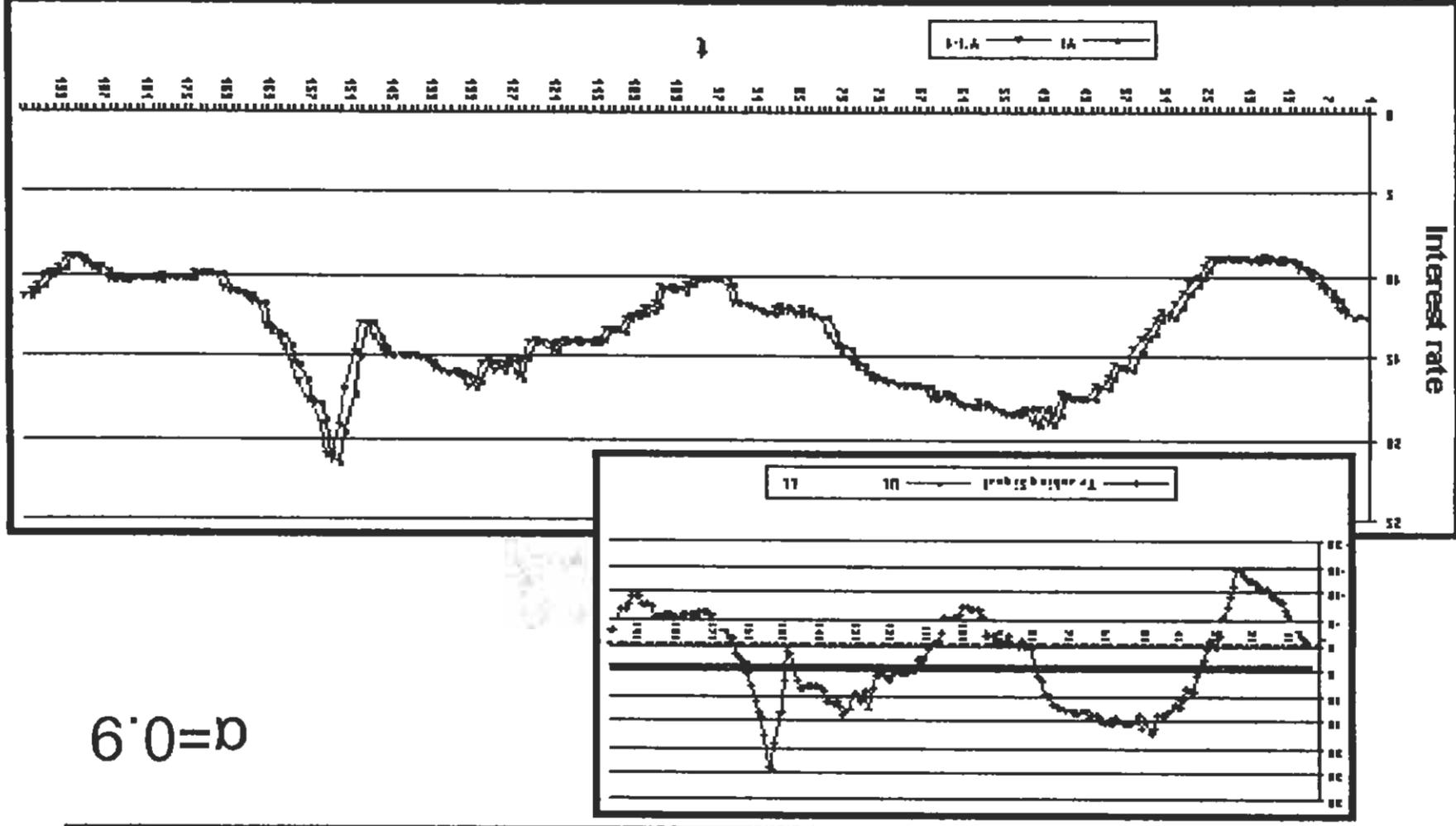
BA		3.1.			
Alpha	MSE	M	C	PCD	
0.1	3.8427	72	194	37.11	
0.4	0.8986	71	194	36.60	
0.6	0.5763	73	194	37.63	
0.9	0.3831	69	194	35.57	



Esc		3.1.			
Alpha	MSE	M	C	PCD	
0.1	1.2319	85	193	49.22	
0.4	0.5023	79	193	40.93	
0.6	0.3567	77	193	39.90	
0.9	0.2577	74	193	38.34	

# EXAMPLE: BA 1<sup>ST</sup> EXPONENTIAL SMOOTHING MODEL

$$\alpha = 0.9$$



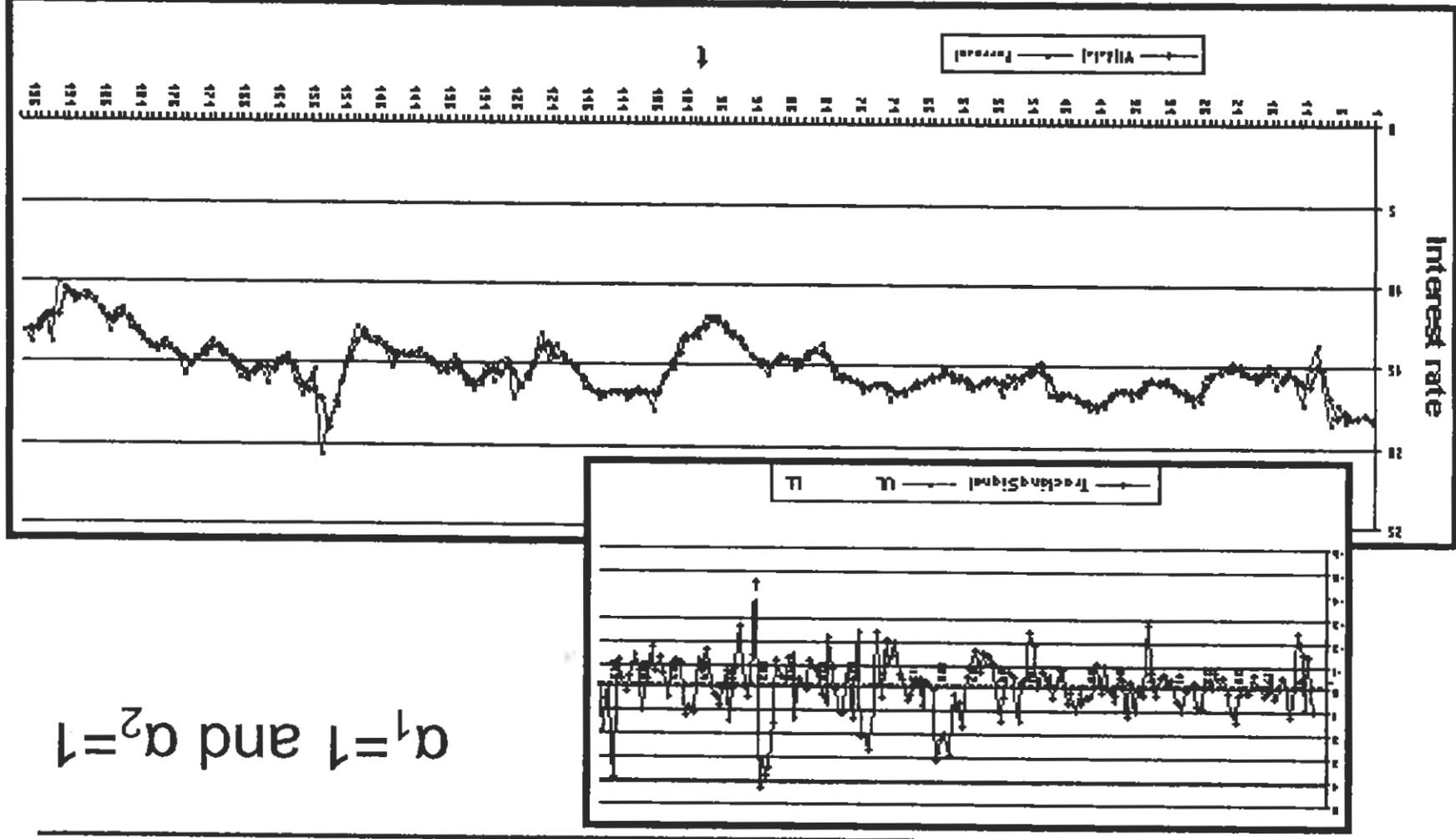
## 2ND EXPONENTIAL SMOOTHING MODELS

BA	$\alpha_1$	$\alpha_2$		
MIN MSE	0.3018	0.7	1	PCD 56.19%
MAX MSE	11.4235	1	0	PCD 40.21%
MIN PCD	6.19%	0.5	1	MSE 0.3508
MAX PCD	61.86%	1	0.2	MSE 1.8225

Esc	$\alpha_1$	$\alpha_2$		
MIN MSE	0.2246	0.6	1	PCD 57.51%
MAX MSE	11.0059	1	0	PCD 52.33%
MIN PCD	2.07%	0.5	1	MSE 0.2402
MAX PCD	59.59%	1	1	MSE 0.3330

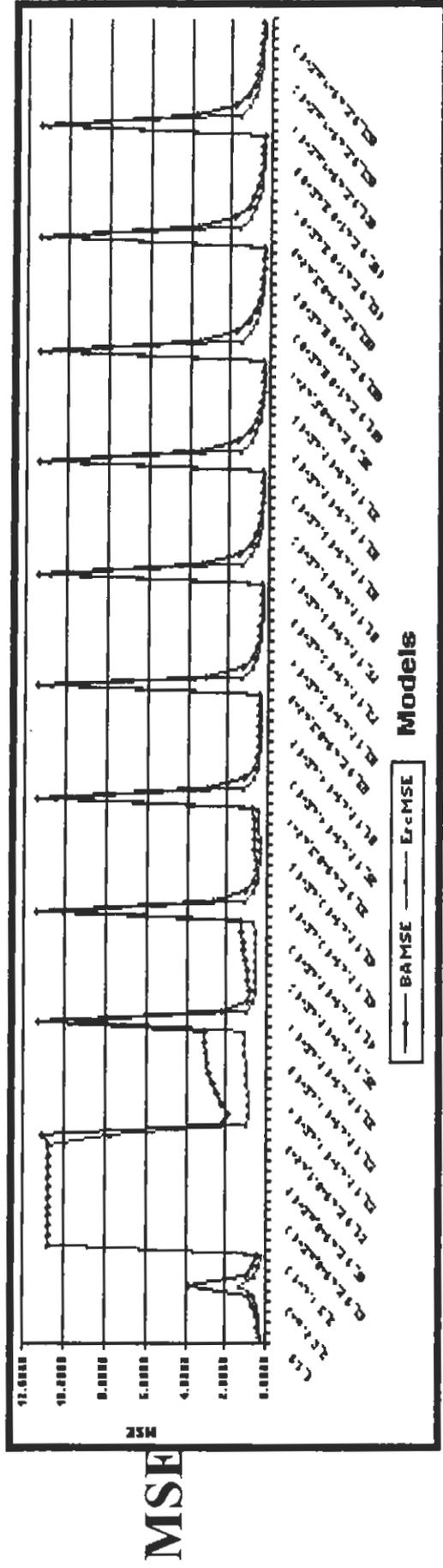
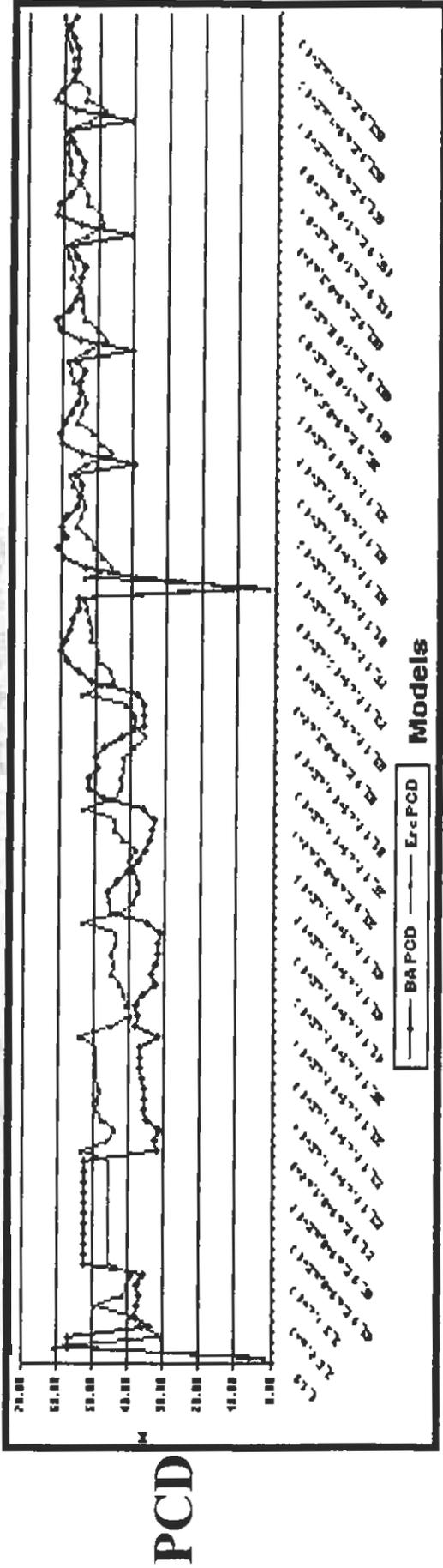
# EXAMPLE: ESC 2<sup>ND</sup> EXPONENTIAL SMOOTHING MODEL

$$\alpha_1=1 \text{ and } \alpha_2=1$$



# SIMPLE METHODS AND TECHNIQUES

## ALL MODELS - GRAPHS



# SIMPLE METHODS AND TECHNIQUES

## ALL MODELS – TABLES OF THE BEST

BA 194	Model	$\alpha_1$	$\alpha_2$	MSE	PCD	RSFE	MAD	TS
<b>MAX PCD</b>	3.2.	1	0.2	1.8225	<b>61.86</b>	9.8081	0.9569	10.2503
<b>MIN MSE</b>	3.2.	0.7	1	<b>0.3018</b>	56.19	21.4364	1.4838	14.4472
<b>TS</b>	1.2	-	-	0.4247	56.70	0.1800	0.4495	0.4005
	3.2	0.1	0.1	2.1800	32.47	0.4273	1.1545	0.3701
	3.2	0.3	0.6	0.5770	37.11	0.3493	0.4983	0.7010
	3.2	0.3	0.7	0.6080	35.57	-0.1495	0.5243	-0.2852
	3.2	0.3	0.8	0.6417	34.54	-0.4983	0.5473	-0.9104
	3.2	0.4	1	0.4617	36.08	0.3527	0.4513	0.7817

Esc 193	Model	$\alpha_1$	$\alpha_2$	MSE	PCD	RSFE	MAD	TS
<b>MAX PCD</b>	1.2.	-	-	0.3330	<b>60.10</b>	-0.2100	0.4092	-0.5132
<b>MIN MSE</b>	3.2.	0.6	1	<b>0.2246</b>	57.51	-3.3026	0.3461	-9.5427
<b>TS</b>	<b>1.2</b>	-	-	<b>0.3330</b>	<b>60.10</b>	<b>-0.2100</b>	<b>0.4092</b>	<b>-0.5132</b>
	3.2	0.8	0.8	0.2855	56.99	0.3218	0.3793	0.8484
	3.2	0.9	0.9	0.3022	58.55	0.1449	0.3890	0.3726
	3.2	1	1	0.3330	59.59	-0.0100	0.4091	-0.0244

# SIMPLE METHODS AND TECHNIQUES

## CONCLUSIONS

- THREE TYPES OF MODELS:
  1. NAÏVE: 3 MODELS
  2. MOVING AVERAGE: 2 MODELS
  3. EXPONENTIAL SMOOTHING: 2 MODELS
- EACH TYPE OF MODEL HAS ADVANTAGES / DISADVANTAGES

# SIMPLE METHODS AND TECHNIQUES

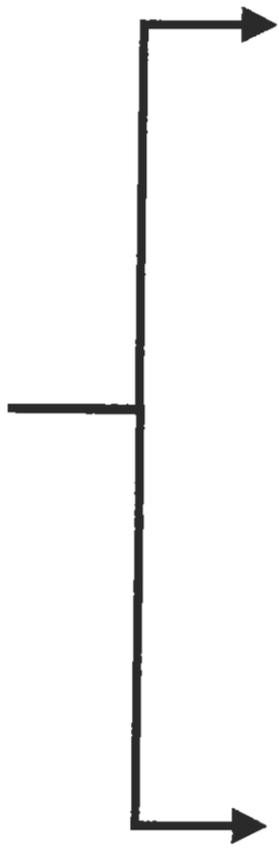
## CONCLUSIONS

- “BEST” MODEL
  - ✓ DEPENDS ON OUTCOMES / AIMS
  - ✓ SETTLE FOR A “GOOD” MODEL
- LOOK AT RESULTS AS A WHOLE
  - ✓ CONSIDER THE NUMBERS AND GRAPHS

**VOLATILITY MODELS**

**LONG-TERM**

**INTERVALS**



2.1.

2.2.

**BOX-JENKINS**

**MODELS WITH**

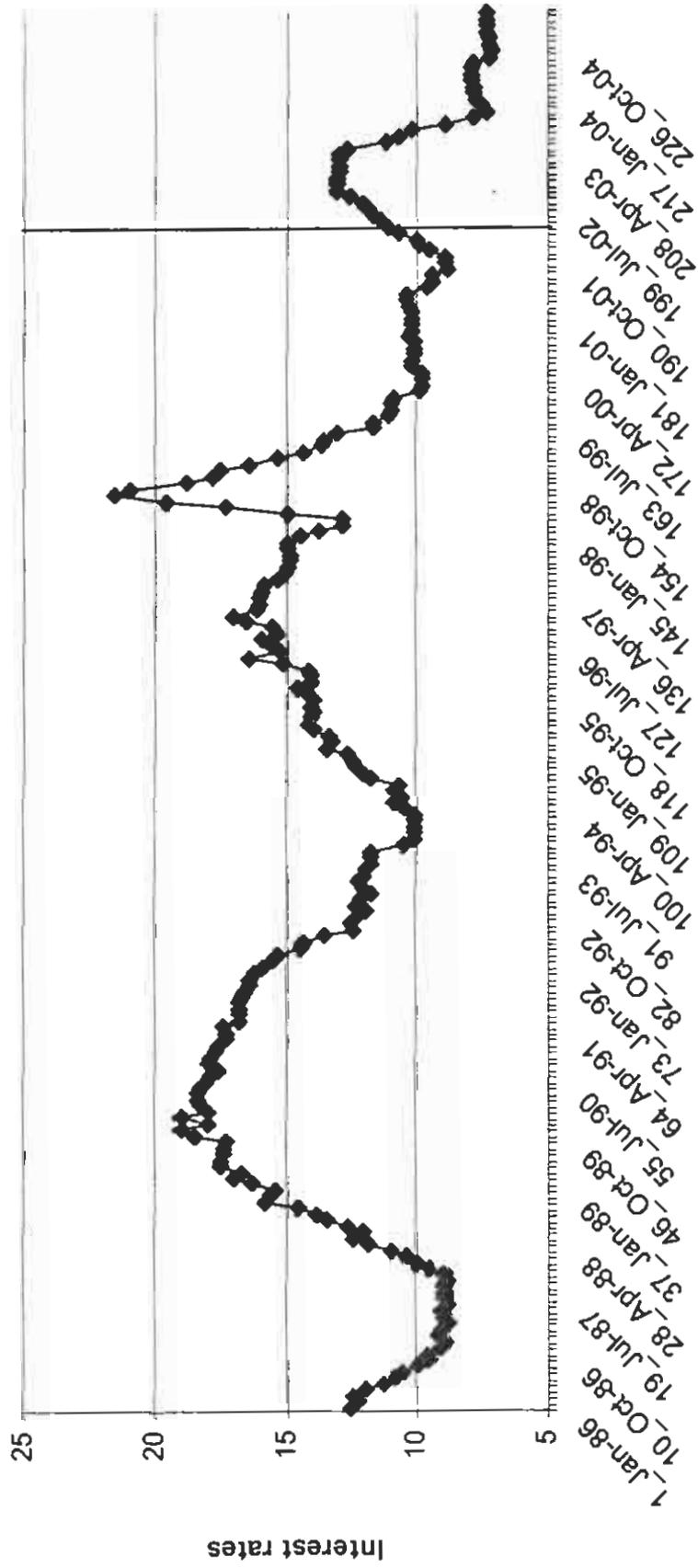
**AR(2) MODELS**

**LIMITS**

**REVISE THE TIME SERIES DATA**

# BA TIME SERIES

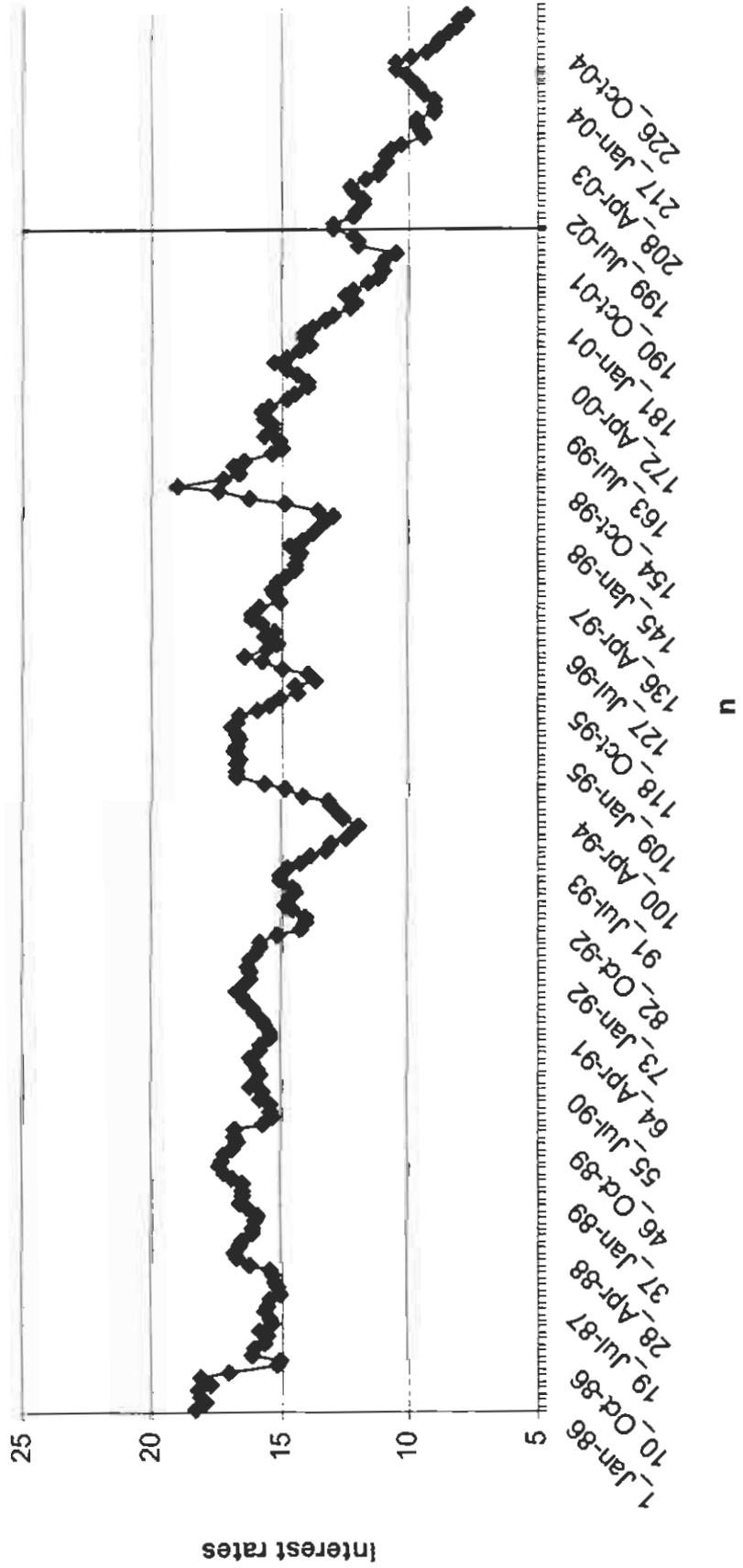
BA



11

# Esc TIME SERIES

Esc



# VOLATILITY MODELS

## 2.1.

### BOX-JENKINS

### AR(2) MODELS

- **4-STEP ITERATIVE PROCEDURE**
- **TENTATIVE IDENTIFICATION OF A MODEL**
- **STATIONARY TIME SERIES**
  - SAC
  - SPAC
  - 3 CONDITIONS FOR STATIONARITY

# 1. SAMPLE AUTOCORRELATION FUNCTION (SAC)

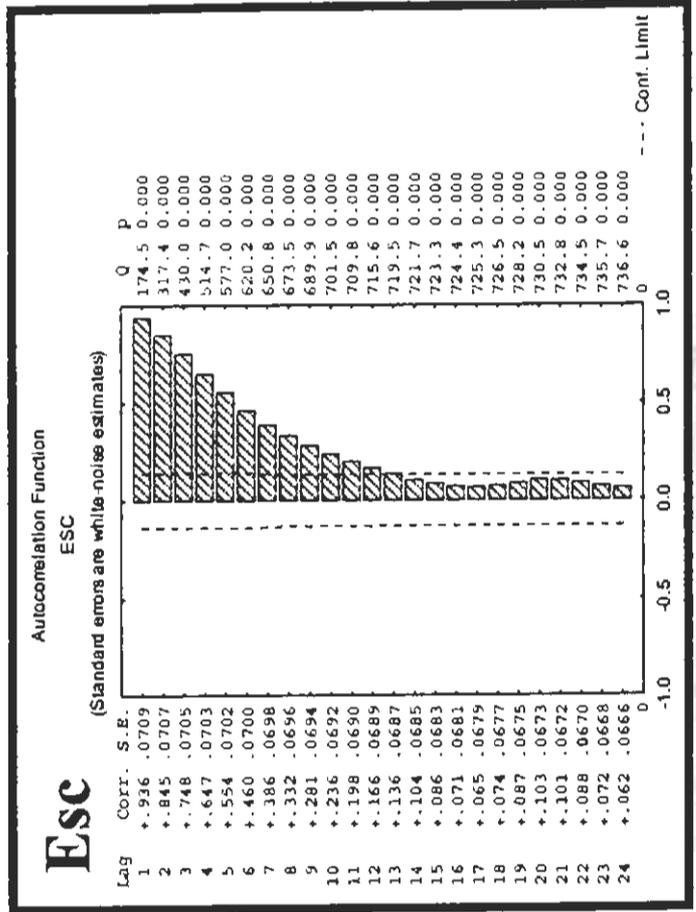
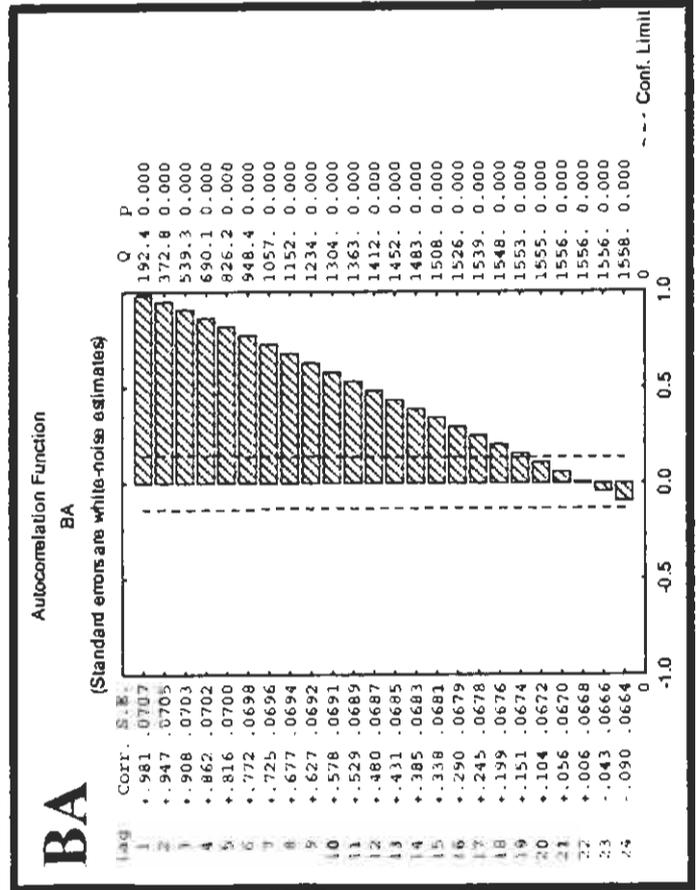
THE SAMPLE AUTOCORRELATION AT LAG  $k$   
DENOTED BY  $r_k$  IS:

$$r_k = \frac{\sum_{t=b}^{n-k} (z_t - \bar{z})(z_{t+k} - \bar{z})}{\sum_{t=b}^n (z_t - \bar{z})^2}$$

where  $\bar{z} = \frac{\sum_{t=b}^n z_t}{(n-b+1)}$

# SAC

- STATIONARY IF SAC CUTS OFF OR DIES DOWN FAIRLY QUICKLY
- NONSTATIONARY IF SAC DIES DOWN EXTREMELY SLOWLY



## 2. SAMPLE PARTIAL AUTOCORRELATION FUNCTION (SPAC)

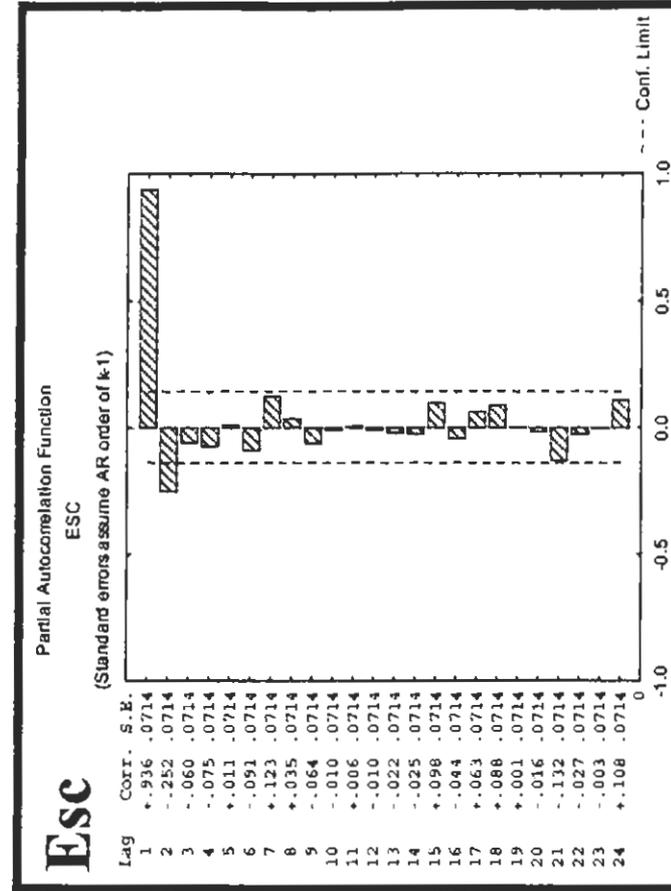
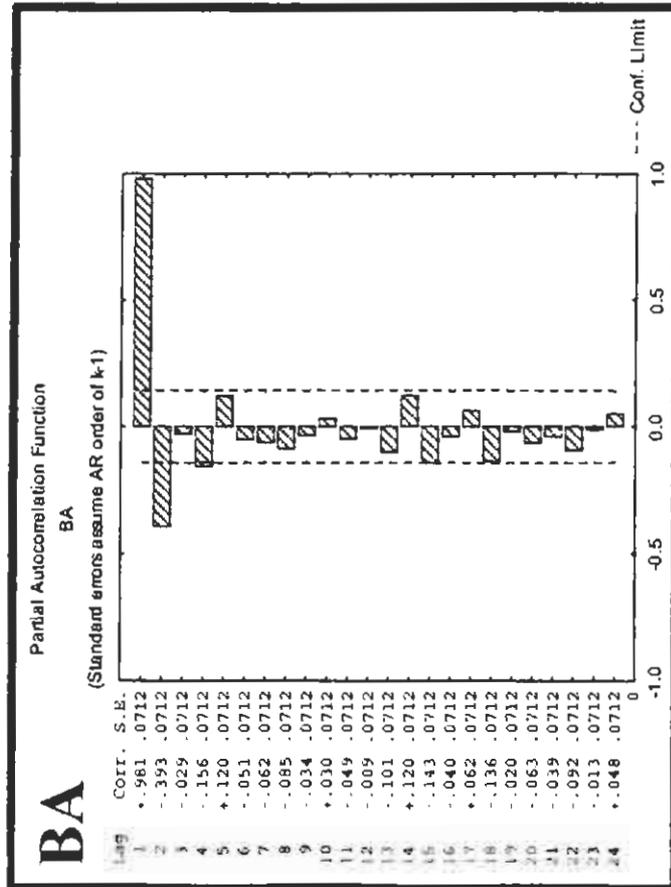
THE SAMPLE PARTIAL AUTOCORRELATION AT  
LAG  $k$  DENOTED BY  $r_{kk}$  IS:

$$r_{kk} = \begin{cases} r_1 & \text{if } k = 1 \\ \frac{r_k - \sum_{j=1}^{k-1} r_{k-1,j} r_{k-j}}{1 - \sum_{j=1}^{k-1} r_{k-1,j} r_j} & \text{if } k = 2, 3, \dots \end{cases}$$

$$r_{kj} = r_{k-1,j} - r_{kk} r_{k-1,k-j} \quad \text{for } j = 1, 2, \dots, k-1$$

# SPAC

- LAG AT WHICH THE SPAC CUTS OFF



- CUTS OFF AFTER LAG 2 →

## SECOND-ORDER AUTOREGRESSIVE MODEL

$$z_t = \delta + \phi_1 z_{t-1} + \phi_2 z_{t-2} + a_t$$

where

$\phi_1$  and  $\phi_2$  are unknown parameters relating  $z_t$  to  $z_{t-1}$ ,  $z_{t-2}$   
 $a_t$  is a random shock

and  $\delta = \mu(1 - \phi_1 - \phi_2)$



### 3. CONDITIONS FOR STATIONARITY

$$\phi_1 + \phi_2 < 1$$

$$\phi_2 - \phi_1 < 1$$

$$|\phi_2| < 1$$

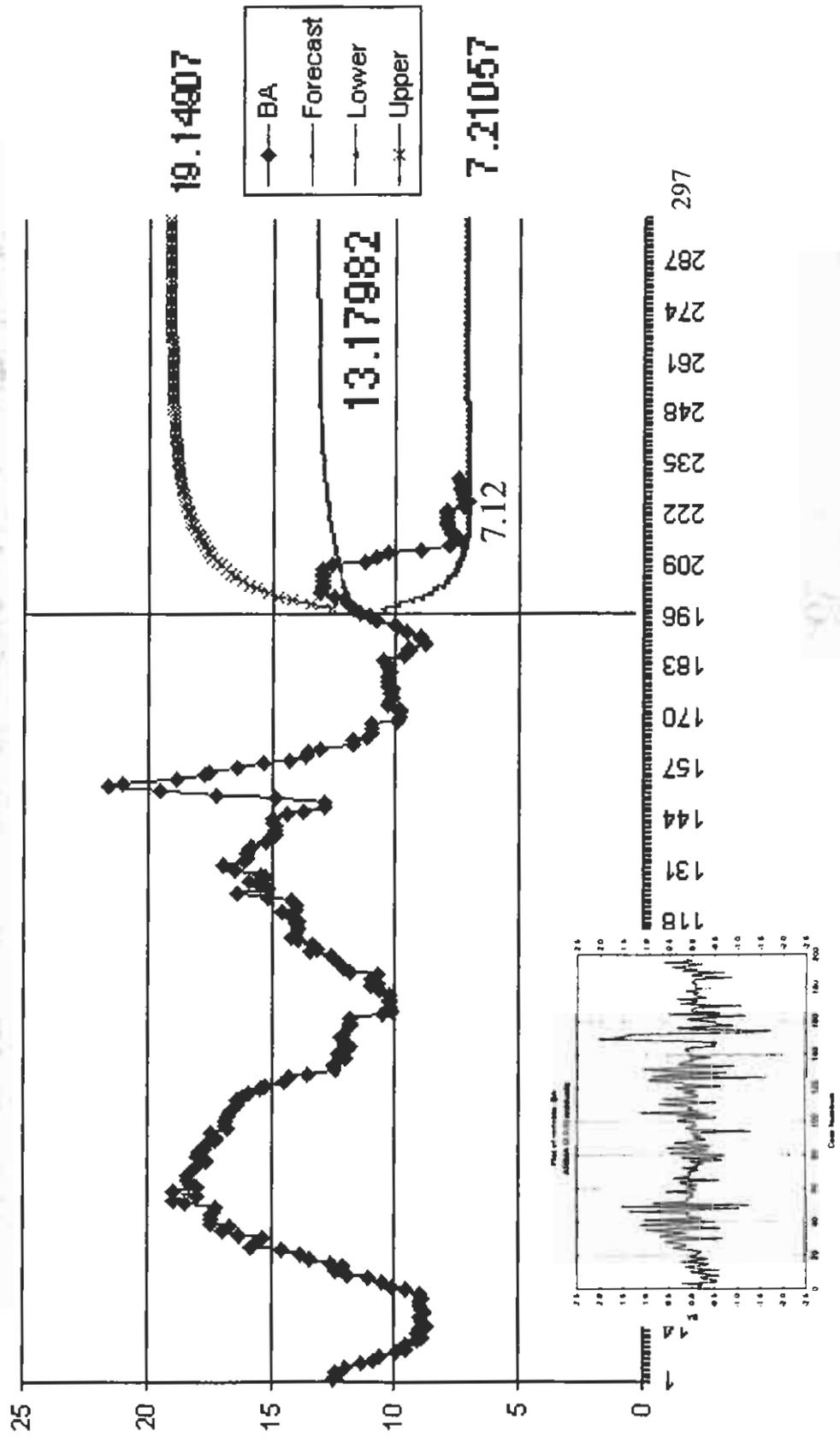
BA			
p(1)	1.3758		
p(2)	-0.4032		
1	$1.3758 + (-0.4032) = 0.9726$		which is <1
2	$(-0.4032) - 1.3758 = -1.779$		which is <1
3	$ -0.4032  = 0.4032$		which is <1

Esc			
p(1)	1.2782		
p(2)	-0.3377		
1	$1.2782 + (-0.3377) = 0.9405$		which is <1
2	$(-0.3377) - 1.2782 = -1.6159$		which is <1
3	$ -0.3377  = 0.3377$		which is <1

**SATISFIED**

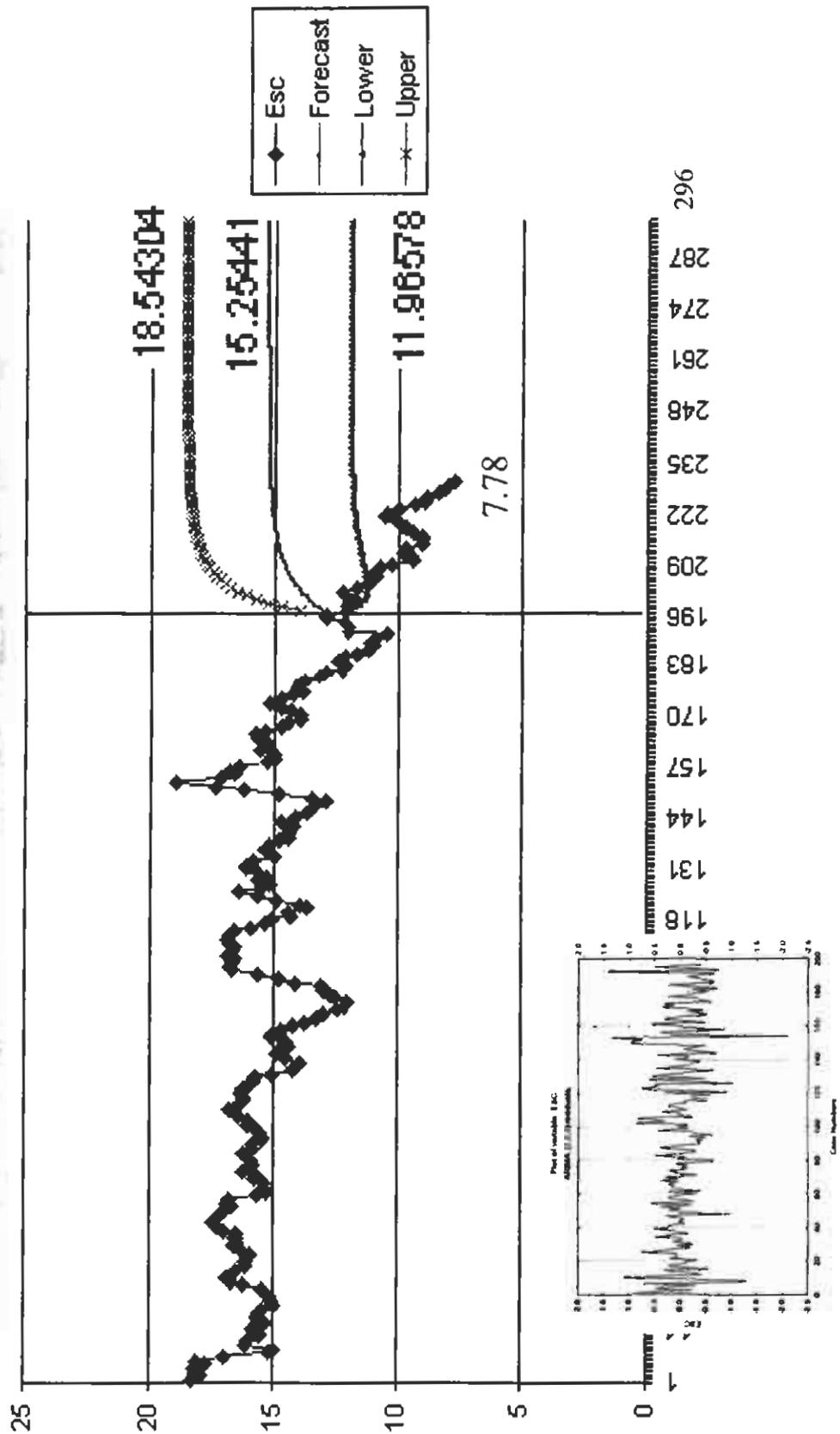
# FORECASTING WITH AR(2) MODELS

## BA



# FORECASTING WITH AR(2) MODELS

Esc



# VOLATILITY MODELS

2.2.

## MODELS WITH LIMITS

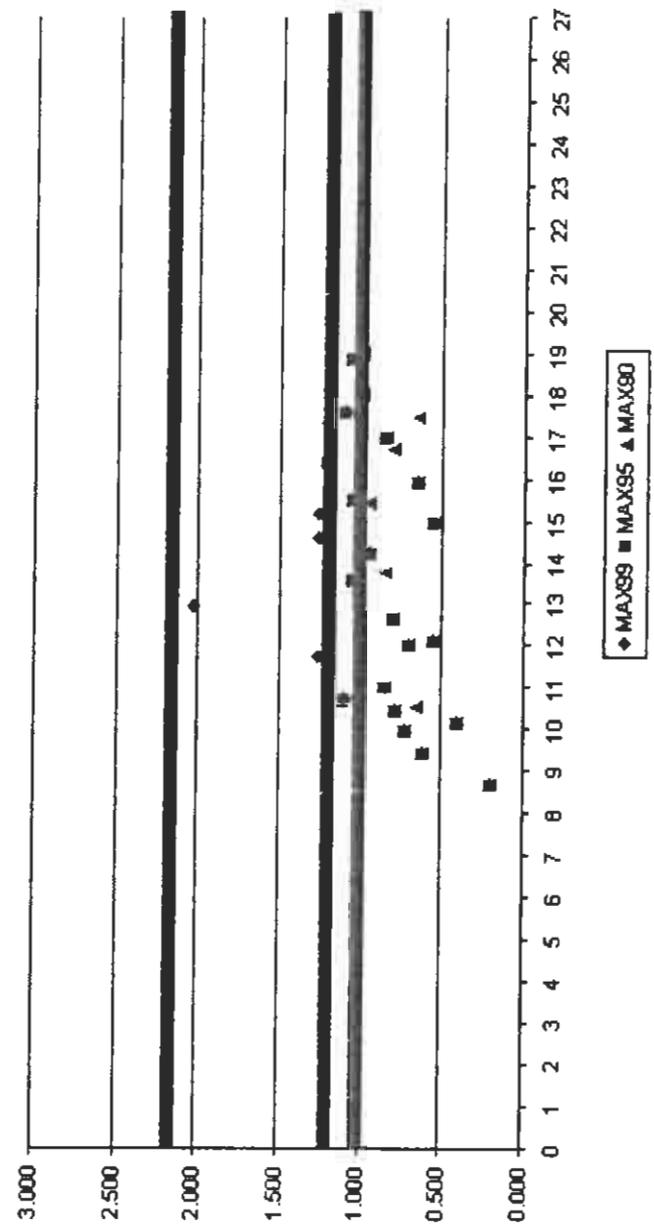
- **LONGER-TERM FORECASTING – INTERVALS**
- **STAND AT A POINT**
  1. USE ALL DATA AVAILABLE BEFORE THE POINT
    - BACK CASTING AT OTHER POINTS
  2. USE ONLY 60 VALUES (5 YEARS) BEFORE THE POINT

## VOLATILITY MODELS

- PREDICT USING ABSOLUTE VALUE FIRST DIFFERENCES
- CREATE INTERVALS OF
  - 99%
  - 95%
  - 90%
- WHEN EXTREME VOLATILITY IS EXPECTED
- WHEN NORMAL VOLATILITY IS EXPECTED
- BASE CASE
- SET LIMITS

# ABSOLUTE VALUE 1<sup>ST</sup> DIFFERENCES

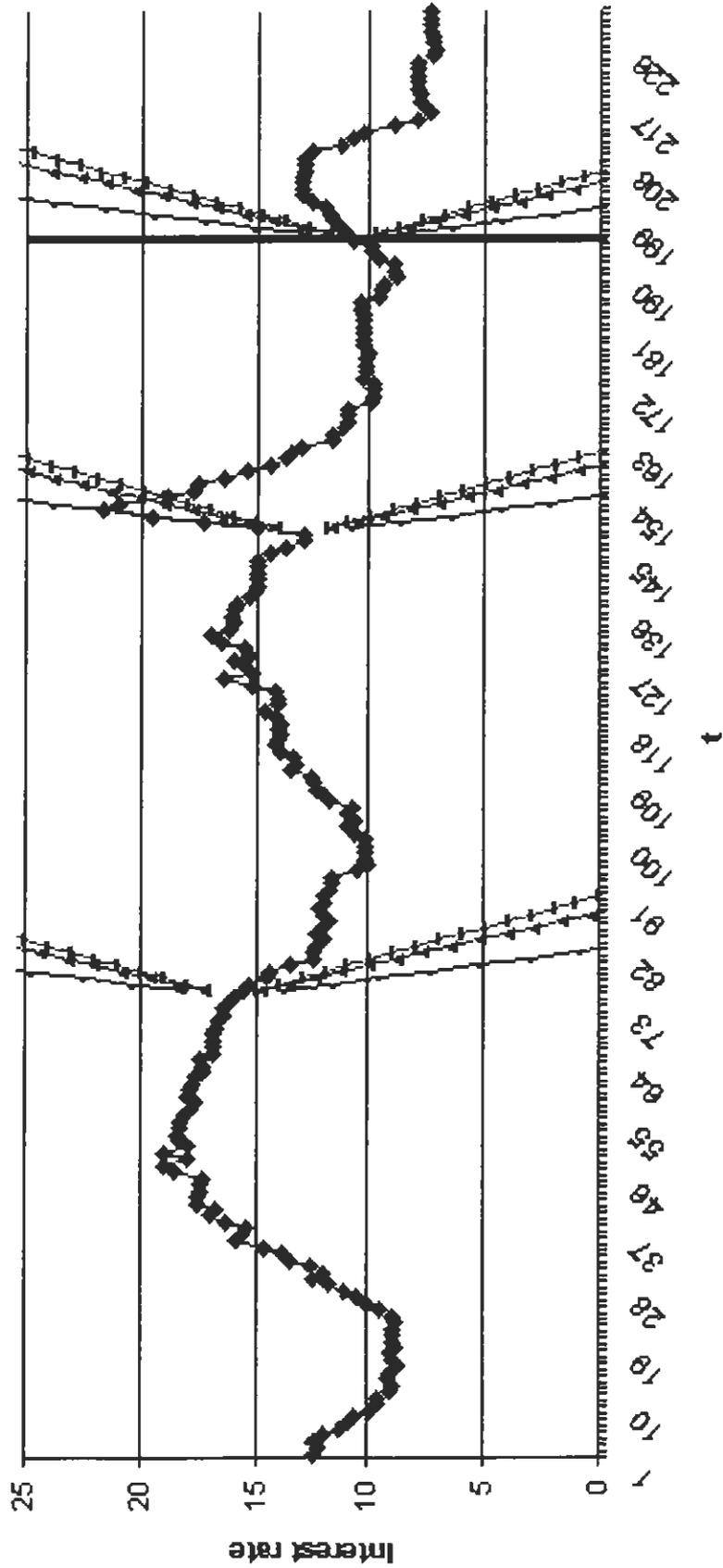
- 99% - REMOVE TOP 1% (2 VALUES)
- 95% - REMOVE TOP 5% (10 VALUES)
- 90% - REMOVE TOP 10% (20 VALUES)



# EXAMPLE: BA EXTREME VOLATILITY

## 1. USING ALL DATA BEFORE POINT

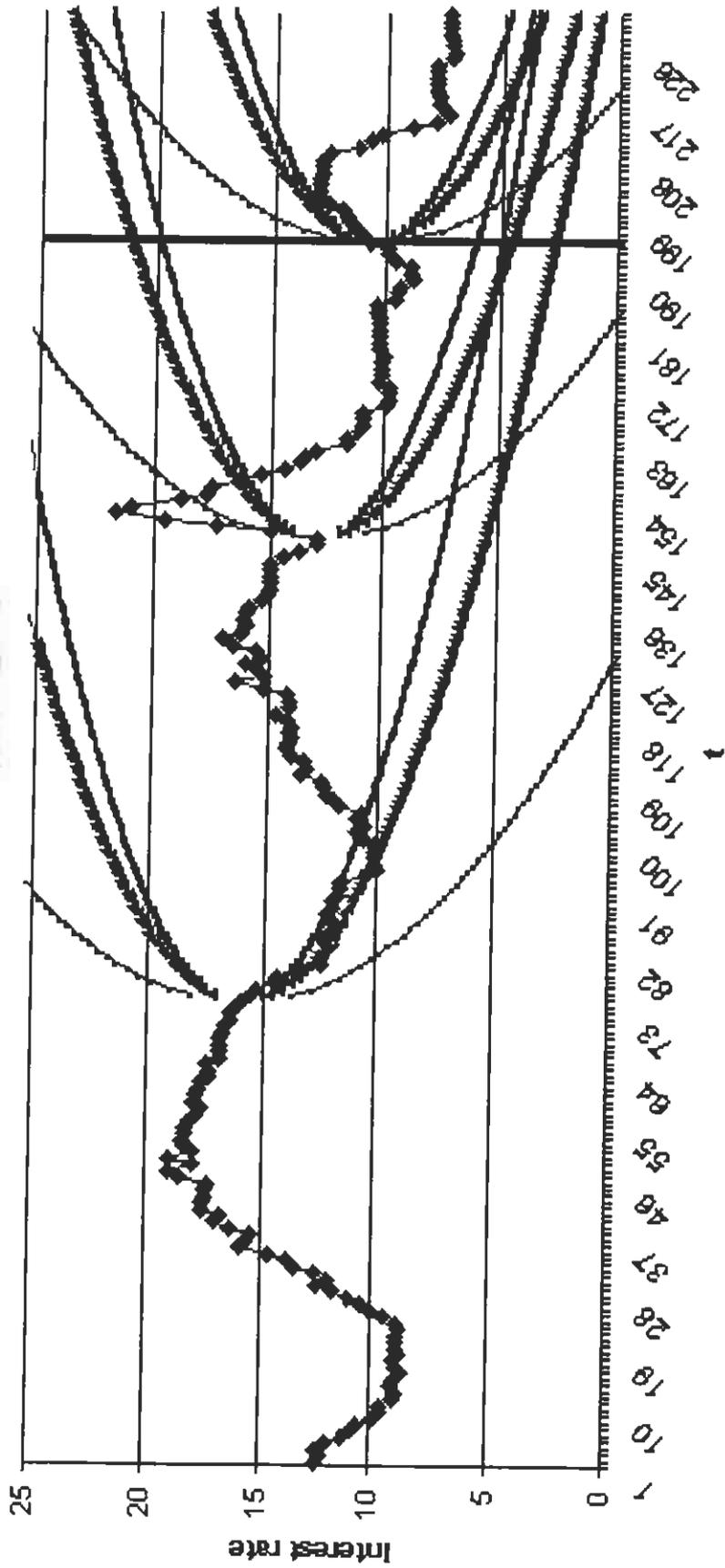
196



# EXAMPLE: BA NORMAL VOLATILITY

## 1. USING ALL DATA BEFORE POINT

196



## LIMITS BASED ON

$$\bar{x} \pm t \times S$$

where  $\bar{x}$  is the average or mean of the data being used

- $t$
- 99%: CRITICAL VALUE 2.576
  - 95%: CRITICAL VALUE 1.960
  - 90%: CRITICAL VALUE 1.645

$$s = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}}$$

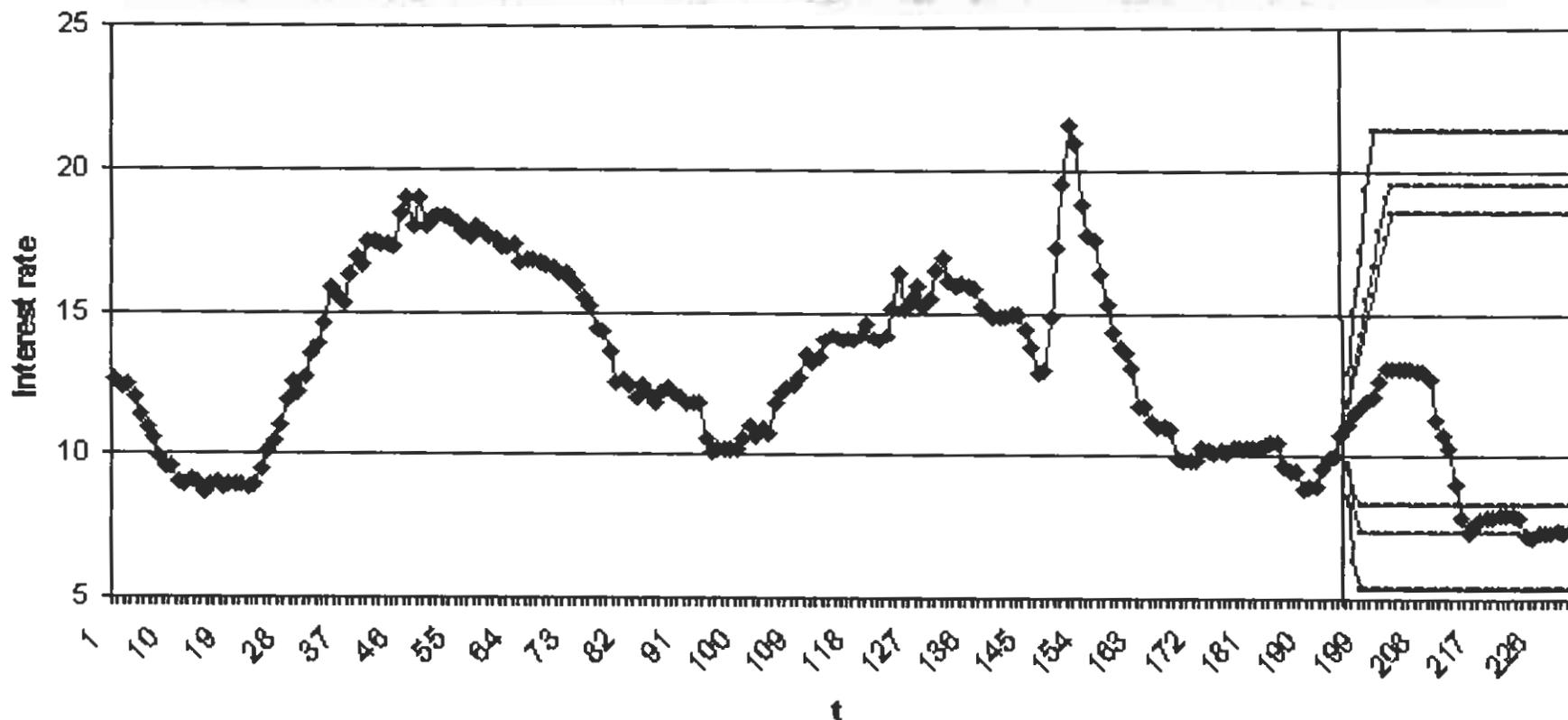


# EXAMPLE: BA EXTREME VOLATILITY

## 1. USING ALL DATA BEFORE POINT

196

LIMITS

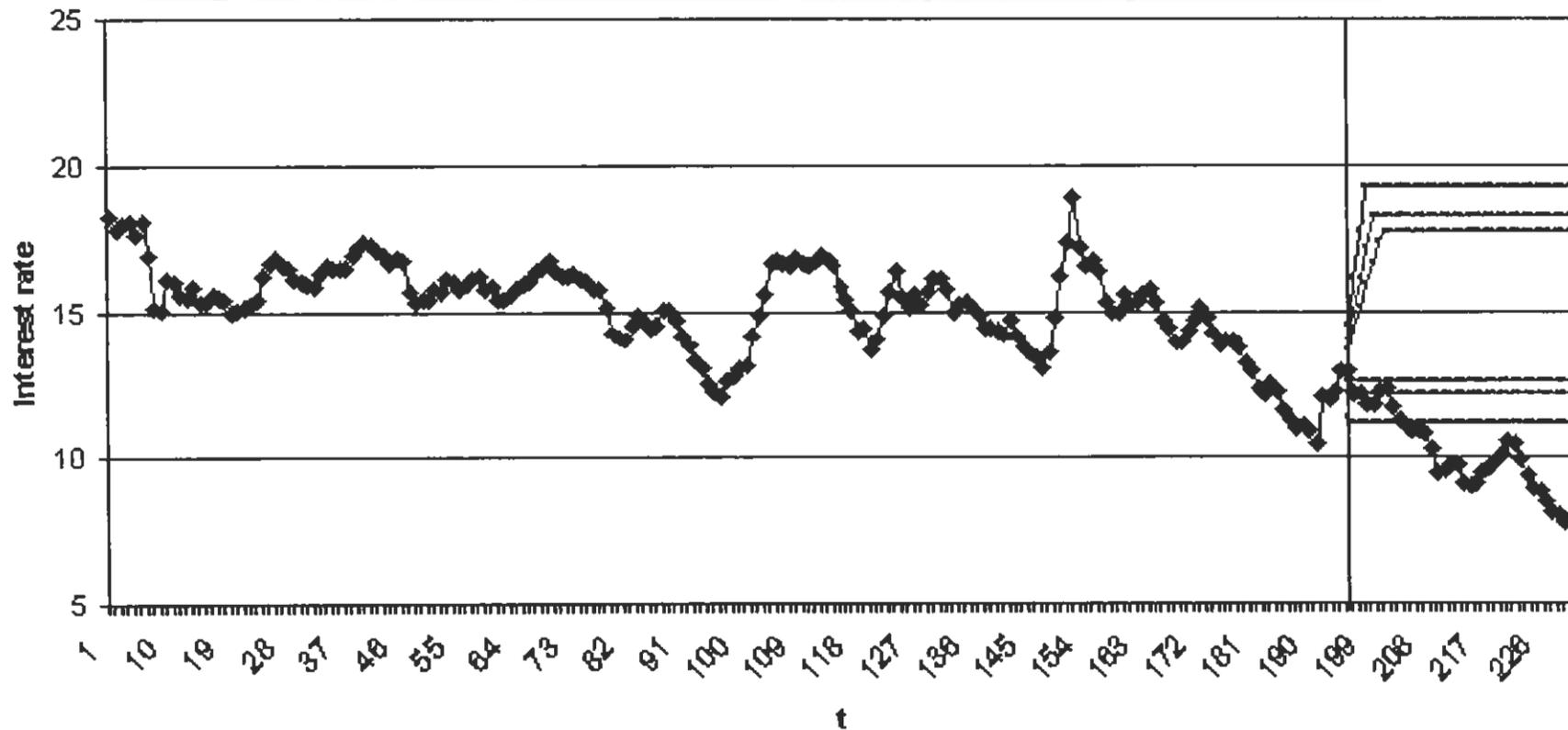


EXAMPLE: Esc EXTREME VOLATILITY

**1. USING ALL DATA BEFORE POINT**

196

LIMITS

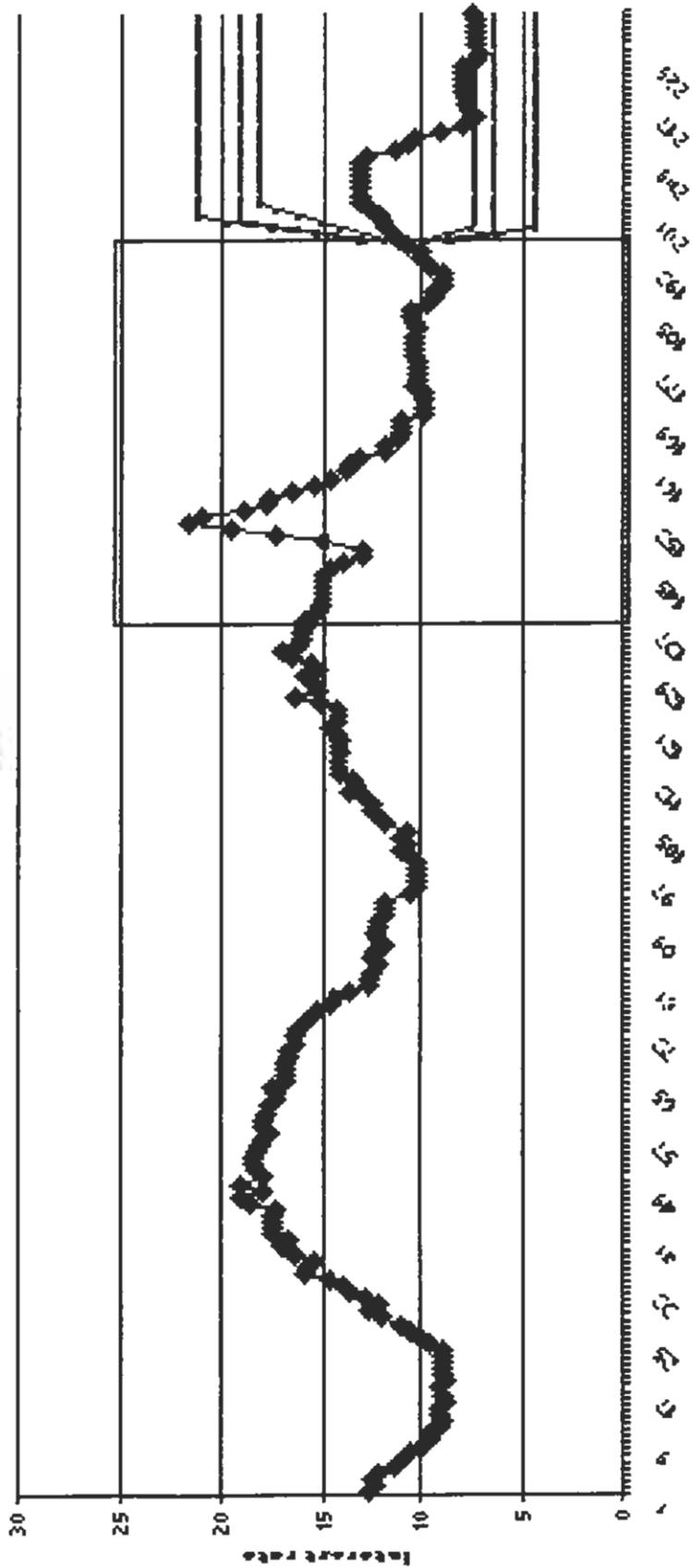


EXAMPLE: BA EXTREME VOLATILITY

**2. ONLY 60 VALUES BEFORE POINT**

196

LIMITS

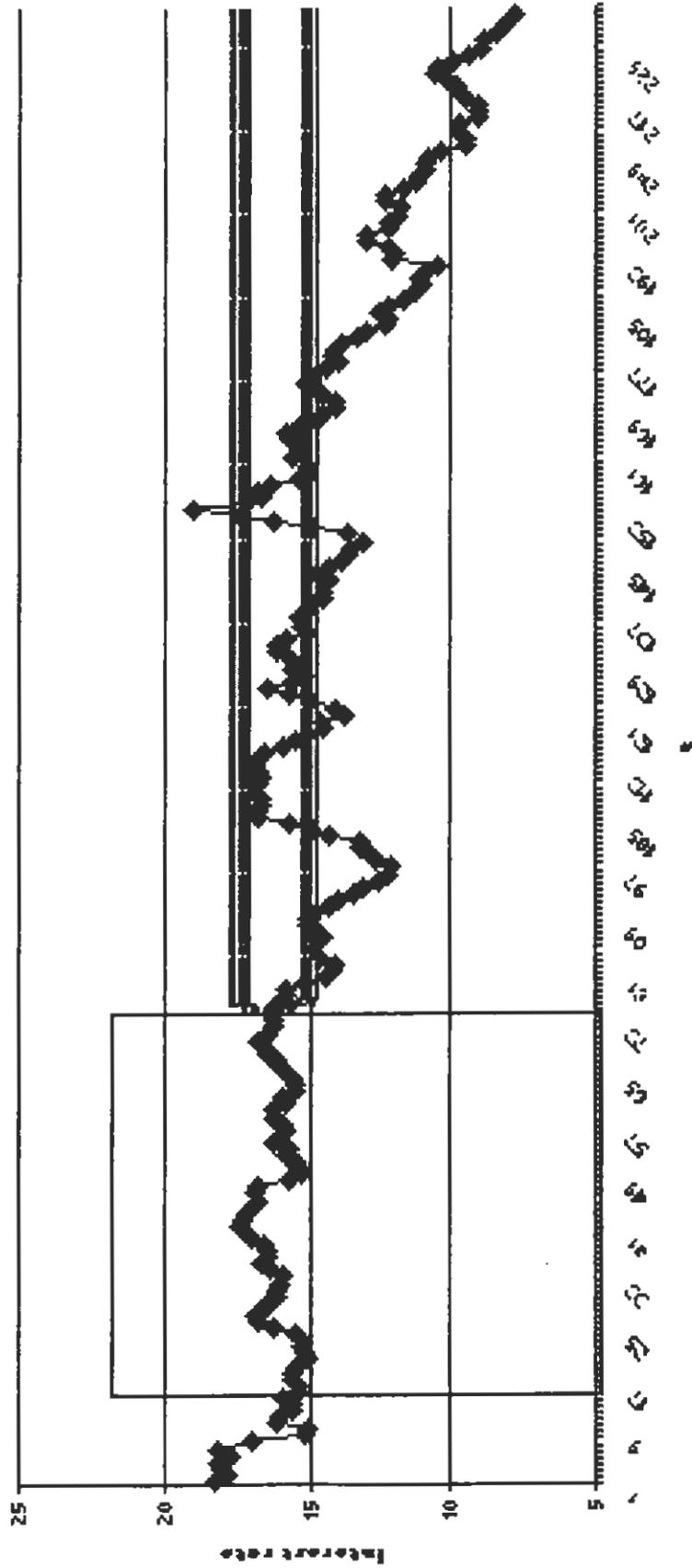


EXAMPLE: Esc EXTREME VOLATILITY

**2. ONLY 60 VALUES BEFORE POINT**

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LIMITS



# LIMITS AT THE DIFFERENT POINTS

## SUMMARY TABLES

BA	Point	Lower Limit	Upper Limit	Size of Interval	Esc	Point	Lower Limit	Upper Limit	Size of Interval	
197	196	99%	5.38	21.43	16.05	196	99%	11.17	19.24	8.07
		95%	7.30	19.51	12.21		95%	12.14	18.28	6.14
		90%	8.28	18.53	10.25		90%	12.63	17.78	5.15
60	74	99%	5.83	24.09	18.26	60	99%	14.58	17.65	3.07
		95%	8.01	21.91	13.89		95%	14.95	17.28	2.33
		90%	9.13	20.79	11.66		90%	15.14	17.09	1.96
	148	99%	8.43	18.65	10.23		99%	11.51	18.32	6.81
		95%	9.65	17.43	7.78		95%	12.32	17.50	5.18
		90%	10.27	16.80	6.53		90%	12.74	17.09	4.35
	196	99%	4.32	21.06	16.74		99%	9.68	18.62	8.94
		95%	6.32	19.06	12.74		95%	10.75	17.55	6.80
		90%	7.35	18.04	10.69		90%	11.29	17.00	5.71

- DETERMINE THE PERCENTAGE OF DATA THAT LIES INSIDE THE INTERVAL
- CONSIDER THE TABLES AND GRAPHS AS A WHOLE

# VOLATILITY MODELS

## CONCLUSIONS

- LONG-TERM MODELS – INTERVALS
- TWO TYPES OF MODELS:
  1. BOX-JENKINS AR(2) MODELS
  2. MODELS WITH LIMITS
- EACH TYPE OF MODEL HAS ADVANTAGES / DISADVANTAGES

# VOLATILITY MODELS

## CONCLUSIONS

- CONSIDER THE DATA BEING USED
- CONSIDER THE AMOUNT OF DATA:
  - ✓ AVAILABLE
  - ✓ NEEDED – MORE IS NOT ALWAYS BETTER

# GENERAL CONCLUSIONS

- WHAT WORKS FOR ONE MODEL MAY NOT WORK FOR ANOTHER
- OTHER METHODS AND MODELS
- ANALYSE THE RESULTS AS A WHOLE



**THE END**

**A PRESENTATION BY:**

**HELENA FERNANDES**

**N7053**

## CHAPTER 3 APPENDIX

### 1.

One of the ALCO's functions is to produce an integrated strategy, which operates on both sides of the balance sheet. Many banks focus on the gap between interest-sensitive assets and interest-sensitive liabilities in assessing their rate exposure (gap analysis). Other banks go beyond the simple analysis and construct a model of the bank's asset and liability structure line by line. From this, Falkena and Kok (1991:11) observe, the ALCO is then able to compute the effects on earnings, of projected changes in interest rates or various funding strategies.

### 2. Measuring Interest Rate Risk With GAP

Unexpected changes in interest rates can alter a bank's profitability significantly. A bank's interest rate risk has to do with the volatility in net interest income relating to changing interest rates. Interest rate changes raise or lower net interest income, depending on the cash flow characteristics of a bank's assets and liabilities as well as on the existence of embedded options.

### 3. Link Between GAP and Net Interest Margin (NIM)

Instead of GAP or GAP ratio, a better risk measure "relates the absolute value of a bank's GAP to earning assets" (Koch & Macdonald, 2003:305). The greater this ratio, the greater the interest rate risk<sup>1</sup>. This ratio has the additional advantage of being able to be directly linked to variations in NIM. Koch and Macdonald (2003:305) state that specifically, management may determine a target value for GAP in light of specific risk objectives stated in terms of a bank's target NIM.

Risk assessment, in conjunction with expected interest rates, imposes policy limits on an acceptable GAP where the general relationship, according to Koch and Macdonald (2003:306) is:

$$\frac{\text{Target GAP}}{\text{Earning assets}} = \frac{(\text{Allowable \% change in NIM}) (\text{Expected NIM})}{\text{Expected \% change in interest rates}} \quad (\text{Eq. A1})$$

<sup>1</sup> As mentioned before, in this context, risk is associated with the volatility in net interest income. The use of absolute value shows that the sign of GAP indicates whether net interest income rises or falls when rates change in a specific direction. It does not influence the volatility of net interest income.

Evidently, a bank's effective GAP and net interest margin are closely linked. Ideally, banks should identify the amount of net interest income at risk if interest rates change. Instead of doing this directly through earnings sensitivity analysis, many banks limit the size of GAP as a fraction of assets, which indirectly limits the variation in net interest income, as Koch and Macdonald (2003:306) explain.

#### 4. An Immunised Portfolio

Banks may choose to target variables other than the MVE in managing interest rate risk. Indeed, banks may use duration analysis to stabilise numerous different variables reflecting bank performance. For example, many banks are interested in stabilising the book value of net interest income. This may be done for a one-year time horizon using the following duration gap measure, from Koch and Macdonald (2003:331):

$$DGAP^* = MVRSA(1 - DRSA) - MVRSL(1 - DRSL) \quad (\text{Eq. A2})$$

Where

MVRSA = cumulative market value of RSAs

MVRSL = cumulative market value of RSLs

DRSA = composite duration of RSAs for the given time horizon;  
Equal to the sum of the products of each asset's duration with the relative share of its total asset market value

DRSL = composite duration of RSLs for the given time horizon;  
Equal to the sum of the products of each liability's duration with the relative share of its total liability market value

As Koch and Macdonald (2003:332) state, if DGAP\* is positive, then the bank's net interest income will decrease when interest rates decrease and increase when rates increase. If DGAP\* is negative, then the relationship is reversed. Interest rate risk is eliminated only when DGAP\* is zero.

#### 5. Interest Rate Risk: Trading Exposure<sup>2</sup>

Trading exposure refers to the sensitivity of *present values* of money market and capital market instruments (debt instruments and related derivatives) to changes in current interest rates. It is yet another concern of the treasury management that falls under the supervision of the ALCO. According to Cade (1997:160), this refers to:

<sup>2</sup> Trading exposure is the risk affecting financial instruments.

- Asset portfolios of treasury bills, government and corporate bonds, debt securities, certificates of deposit, commercial paper and other instruments held for purposes of trading, investment or liquidity
- *Liabilities* in the form of “short” (oversold) positions
- Included by association are “repos” (repurchase agreements), “reverse repos” and interest-sensitive derivative contracts in general

Where the interest rate on the principal or underlying instrument is fixed (that is, it does not float in line with current rates), the present value will usually adjust inversely whenever rates change. A rate increase causes a capital loss, a rate decrease brings a capital gain. Cade (1997:161) points out that these losses and gains “have to be recognised in the bank’s books in respect of all tradable instruments that are marked to market” (in other words, regularly revalued at market prices).

Interest-related trading exposes a bank to losses or gains due to price changes in the assets (or liabilities) concerned. Therefore, the risk could be classified under the category of price risks. The Basle regulatory regime merges them all under “market risks”. Others assign to interest rate risk only those impacts that are directly and solely attributable to interest rate changes. A single financial instrument may combine several different types of risk. Cade (1997:161) mentions that the way to deal with a case like this is to unbundle the risks and manage each separately, according to its basic rules.

Interest-related trading exposure can be measured and managed by a ladder and gapping methodology. However, this traditional approach suffers from problems of rigidity and imprecision. Modern banking “prefers two superior and complementary techniques” (Cade, 1997:161) with a view to keeping revaluation losses within bounds, namely:

1. **Open position sensitivity analysis** – which looks at the sensitivity of present values to movements in a benchmark interest rate (sometimes called a “factor”). It corresponds to open position risk as described under structural exposure;
2. **Value at risk** – which measures the statistical volatilities of the chosen “factors” themselves. Cade (1997:161) explains that by combining an assessment of the volatility of the factor with the sensitivity of the instrument to changes in that factor, it can be estimated, with a stated level of confidence, how much money is likely to be lost within a given timescale of holding that instrument. This monetary estimate is known as *value at risk* (or VAR). At portfolio level, VAR provides a single number

representing potential losses arising (over the chosen timescale) from the “disparate levels of risk inherent in the bank's diverse trading positions” (Cade, 1997:162).

VAR analysis recognises yield curve risk and basis risk implicitly, in addition to open position risk. Cade (1997:168) states that the technique offers a platform for:

- Stress-testing and formulation of portfolio policy
- Delegation of trading sub-limits
- Capital allocation and performance measurement

It raises a number of technical problems. Yet, value at risk seems to be gaining increasing acceptance amongst regulators in Basle as well as others, as a basis for “determining bank capital requirements in respect of trading risks” (Cade, 1997:162). Indeed, it appears to be a vital tool.

#### 1. Trading exposure: Open position sensitivity analysis

The calculations used in duration and interest rate elasticity are relevant in this section. As mentioned, interest rate elasticity (represented by the Greek letter delta) measures “the rate of change in the present value of a financial instrument or a portfolio in response to a specified change in factor interest rates” (Cade, 1997:162).

The basic equation below is used to establish the approximate percentage by which the present value of a portfolio will fall if factor interest rates rise by 1%:

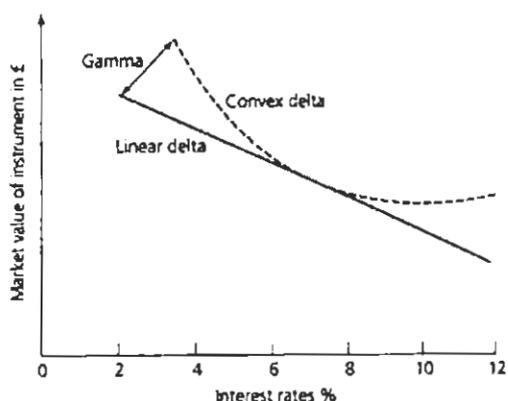
$$\text{Delta \%} = \frac{-\text{Duration}}{1 + \text{yield to maturity}}$$

An example from Cade (1997:162) is: if duration is two years and yield to maturity is 7% per annum, then:

$$\begin{aligned}\text{Delta \%} &= \frac{-2}{1 + 0.07} \\ &= -1.87\%\end{aligned}$$

This means that a 1% rise in factor interest rates will cause a fall of approximately 1.87% in the present value of the portfolio. Conversely, the effect of a 1% fall in interest rates is a rise of approximately 1.87% in the present value.

When delta is plotted as a trend line on a chart, rarely is it constant and traces a straight line (consistent with the formula above). Usually, delta is variable and follows a curved path. This is due to a mathematical effect known as “convexity”, better known in the market as “gamma”. Gamma measures any change in delta (that is, in interest rate elasticity) as it moves up and down the scale. Figure<sup>3</sup> A3.1. serves as illustration:



**Figure A3.1. Diagram illustrating interest rate elasticity and gamma.**

Since delta is not usually linear (constant), the simple, duration-based equation gives only an approximate answer (which may be sufficient for some portfolios but for others not). The formula does not provide detailed information on the sensitivities of specific positions within the portfolio.

A more precise methodology exists. It “uses zero-coupon pricing to value cash flows off the factor yield curve” (Cade, 1997:163). This consists of flexing the factor interest rate by one basis point (one-hundredth of 1%) at chosen intervals along the curve, one at a time, while keeping the remaining rates the same. This is done in order to derive a series of “notional revaluations of positions” (Cade, 1997:163), which allows for many modelling permutations.

The sensitivity measurement is expressed in industry in a convenient module known as “present value of a basis point” (PVBP or PV01 for short). In other words, how much

<sup>3</sup> From Cade (1997:163).

present value the portfolio stands to lose (or gain) for each basis point movement in interest rates.

Once the bank has a means of measurement, it will want to contain the sensitivities within acceptable bounds. Duration-based methodology makes use of *delta-hedging* – “limiting the organic sensitivities by writing derivative contracts with opposite positioning” (Cade, 1997:164). However, artificial hedging is bought at the expense of increasing the bank’s counterparty credit exposures.

Lastly, the portfolio should contain a *spread of issuer names* (20 or more) in order to minimise *specific risk*. This is the potential for decline in credit ratings, making the sensitivities worse.

## 2. Trading exposure: Value At Risk

Value at risk analysis provides the basis for an estimate of revaluation losses that the bank may incur on a specified portfolio over a given time horizon. Cade (1997:164) explains that the technique involves compiling statistical distributions of daily movements in the factor interest rates that underpin the prices of the instruments in the portfolio, often going as far back as five years.

By combining factor volatility with instrument sensitivity, the bank can obtain a picture of the likely price volatility of each instrument that it is holding. Thereafter, figures can be aggregated (using *variance/ covariance matrix* methodology or alternative *historical simulation*)<sup>4</sup> to show the volatility of the portfolio as a whole. There are recognised technical problems in quantifying covariances in VAR analysis.

The end result may be plotted in the form of a distribution curve on a histogram. A “normal” bell-shaped curve is used. However, since VAR focuses on loss rather than gain and therefore, confines its attention to the left-hand side of the curve, the mathematics are slightly different from usual. Now, 1.65 standard deviations cover 95% of the loss distributions, two standard deviations cover roughly 97.5% of the loss distributions and three standard deviations account for nearly 99.9%.

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<sup>4</sup> Cade (1997:164) mentions that practitioners employ these methods in order to “achieve a lower overall risk estimate than would otherwise emerge from a linear summation based on individual volatilities in isolation”.

From this, it can be concluded that within a chosen short period of trading:

- We are 95% confident that losses in the value of the portfolio will not exceed Rx
- We are 97.5% confident that they will not exceed Ry
- We are 99.9% confident that they will not exceed Rz

in an escalating series of amounts. The “value at risk” in these formulations is the potential loss of Rx or Ry or Rz (or the corresponding amount at any other confidence interval on the curve).

The corollary is that:

- In one case out of twenty, the losses probably *will* exceed Rx
- In one case out of about fifty, they probably *will* exceed Ry
- In one case out of a thousand, they probably *will* exceed Rz

The problem is that the formula does not reveal by how much (let alone when). There is, therefore, a need to “probe the extremes” (Cade, 1997:165) by stress-testing.

### **Stress-testing**

In-house practice in the trading area of a bank will try to keep *historical volatility* rolling forward, reflecting daily revaluations of the asset portfolio. The problem is that past volatility is, at best, a guide. It cannot encompass all future possibilities. It is perhaps because of this, that regulatory authorities are reluctant to rely on historical trading statistics. Any bank that has chosen to adopt a VAR approach to trading will, therefore, want to go beyond the history and subject its portfolio to rigorous stress-testing.

Stress-testing involves simulating a continual series of unusual scenarios which are inspired by many sources of rate shift extremes. Banks try to come up with the worst thing that could happen to their book and supplement their inventions with “Monte Carlo” techniques (which generate streams of random rate projections and permutations).

The results of stress-testing have an important influence on portfolio management policies and decisions. They also have an influence on the VAR sub-limits that are delegated to separate trading books or desks.

### **Problems with value at risk**

Cade (1997:166/167) mentions that VAR has certain technical difficulties, for instance:

1. There are many ways to measure volatility. Therefore, uncertainties lie in:

- What should be the "moving window" of statistical distributions (a few days, several years)
  - Whether all observations should count equally, or whether more recent experience should be given extra weighting (and if the latter, there are concerns about it producing big jumps in perceived volatility and VAR);
2. Professional opinion is divided on the "mathematical validity" of some aspects of the VAR aggregation process. In addition, the phenomenon of basis risk shows that correlations are inherently unstable – they change over time and may break down in extreme conditions when they are needed the most;
  3. The "normal" bell-shaped curve which is best for standard deviation treatment is rarely obtained. Where the statistical distribution is significantly skewed, alternative mathematical techniques must be employed to estimate risk probabilities. In the financial markets, the distribution tends to be more *leptokurtic*<sup>5</sup> than asymmetric. This problem can be addressed in part by using a GARCH<sup>6</sup> model, which assigns a weighting to current market volatility in relation to previous time periods.

Even if these technical problems can be solved, there is still the question of where the analysis should be centred. That is, whether a 95% confidence interval should be used or whether a higher standard should be used.

The potential loss represented by VAR is understated if (as is common) the costs of liquidating and/ or hedging that position are left out. The act of liquidation may, itself, move prices further "against the bank" (Cade, 1997:168).

Evidently, value at risk is not without its technical or conceptual difficulties. Nevertheless, Cade (1997:168) suggests that it represents the banking industry's best efforts to deal with the challenge of volatility.

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<sup>5</sup> As Cade (1997:167) explains it, a leptokurtic distribution "has longer/ fatter tails and a higher peak than a normal distribution, reflecting a higher incidence of extreme values, particularly in short term intervals of measurement".

<sup>6</sup> Generalised Autoregressive Conditional Heteroskedasticity.

$$4.4.1.3. \quad Y'_{t+1} = Y_t \times \left( \frac{Y_t}{Y_{t-1}} \right)$$

◆ **Procedure and Findings – Naive Models: 1.3.**

Table A4.1. below is an example of a portion of the table that was created and used in Excel to represent the third naïve model used in this study. It contains the same column headings as the first two models and shows the first five rows of data. The structure of this model differs from the second naïve model in column D – the column where the model is represented.

For this third naïve model,  $Y'_{t+1} = Y_t \times (Y_t / Y_{t-1})$  which means that, once again, the previous as well as the current actual values are needed to make a prediction. Therefore, the first forecast will start at t=3 and not t=2. This can be seen in the table.

...	B	C	D	E	F	G	H
9	t	Y <sub>t</sub>	Y'_{t+1}	e <sub>t</sub> =Y <sub>t</sub> -Y'_{t+1}	Prediction	Actual	Direction
10	1	12.55					
11	2	12.3					
12	3	12.45	12.05	0.395	Down	Up	0
13	4	12	12.60	-0.602	Up	Down	0
14	5	11.3	11.57	-0.266	Down	Down	1

***Table A4.1. Representative portion of the table used in Excel, depicting the first few rows of the third naïve model using the BA data set. The criteria for the "Direction" remains the same as for the first and second naïve models. The rows start at 9 purely because there was other information or text on the worksheet where the work was done in Excel.***

Once the **Prediction** and **Actual** results are obtained (in the same way as for the first two naïve models), the **Direction** may be found and subsequently, the total number of correct direction predictions for this model.

The formulae used in the other columns is similar to the ones used in the previous two naïve models and a sample can be seen in Table A4.2.

...	B	C	D	E	F
9	t	$Y_t$	$Y'_{t+1}$	$e_t = Y_t - Y'_{t+1}$	Prediction
10	1	12.55			
11	2	12.3			
12	3	12.45	=C11*(C11/C10)	=C12-D12	=IF(D12>C11;"Up";IF(D12<C11;"Down";"Constant"))
13	4	12	=C12*(C12/C11)	=C13-D13	=IF(D13>C12;"Up";IF(D13<C12;"Down";"Constant"))
14	5	11.3	=C13*(C13/C12)	=C14-D14	=IF(D14>C13;"Up";IF(D14<C13;"Down";"Constant"))

G	H
Actual	Direction
=IF(C12<C11;"Down";(IF(C12>C11;"Up";"Constant")))	=IF(F12=G12;1;0)
=IF(C13<C12;"Down";(IF(C13>C12;"Up";"Constant")))	=IF(F13=G13;1;0)
=IF(C14<C13;"Down";(IF(C14>C13;"Up";"Constant")))	=IF(F14=G14;1;0)

**Table A4.2.** Representative portion of the table used in Excel, showing some of the formulae used to create the third naive model for the BA data set. The table is represented in two parts due only to page constraints.

$$4.4.2.1. \quad Y'_{t+1} = \frac{Y_t + Y_{t-1}}{2}$$

◆ **Procedure and Findings – MA Models: 2.1.**

Table A4.3. is a representation of part of the empirical work that was created in Excel that depicts the first MA model. Only the first four columns and first five rows of data (t=1 to t=5) are shown.

...	B	C	D	E
8	t	$Y_t$	$Y'_{t+1}$	$e_t = Y_t - Y'_{t+1}$
9	1	12.55		
10	2	12.3		
11	3	12.45	12.43	0.025
12	4	12	12.38	-0.375
13	5	11.3	12.23	-0.925

**Table A4.3.** Representative portion of the table used in Excel, depicting the first few rows of the first moving average model using the BA data set. Column D shows "the model".

The biggest difference between all the models is how they are represented (in column D). For this model, the average of two values are needed to make the first prediction. Therefore, the first prediction starts (as it did in the second and third naive models) at t=3.

The **Prediction**, **Actual** and **Direction** columns work the same as they did for the naïve models.

A sample of the formulae used to create the model is shown in Table A4.4.

...	B	C	D	E
8	t	$Y_t$	$Y'_{t+1}$	$e_t = Y_t - Y'_{t+1}$
9	1	12.55		
10	2	12.3		
11	3	12.45	$= (C10 + C9) / 2$	$= C11 - D11$
12	4	12	$= (C11 + C10) / 2$	$= C12 - D12$
13	5	11.3	$= (C12 + C11) / 2$	$= C13 - D13$

**Table A4.4. Representative portion of the table used in Excel, showing some of the formulae used to create the first MA model for the BA data set.**

All the 1s (correct match between the direction of **Actual** and **Prediction**) are added up and divided by the number of comparisons to find the percentage of correct direction predictions for this model.

$$4.4.2.2. \quad Y'_{t+1} = \frac{Y_t + Y_{t-1} + \dots + Y_{t-m+1}}{m}$$

◆ **Procedure and Findings – MA Models: 2.2.**

Experiments were conducted with various values for  $m$ . The same procedure that was applied to the previous models was followed for these MA models. Once the **Predicted** and **Actual** values had been found, the **Direction** was determined. Thereafter, all the matches (1s) were added for each  $m$  and divided by the respective number of comparisons.

Table A4.5. (a) is a sample of the model that was created in Excel to represent the second moving average model. The table (column D in particular) shows the model applied to the BA data set when  $m=5$ . This means that the average of five values is needed to make a prediction. Table A4.5. (b) shows some formulae that were used.

...	B	C	D	E
8	t	$Y_t$	$Y'_{t+1}$	$e_t = Y_t - Y'_{t+1}$
9	1	12.55		
10	2	12.3		
11	3	12.45		
12	4	12		
13	5	11.3		
14	6	10.85	12.12	-1.270
15	7	10.55	11.78	-1.230

(a)

...	B	C	D	E
8	t	$Y_t$	$Y'_{t+1}$	$e_t = Y_t - Y'_{t+1}$
9	1	12.55		
10	2	12.3		
11	3	12.45		
12	4	12		
13	5	11.3		
14	6	10.85	=SUM(C9:C13)/\$B\$13	=C14-D14
15	7	10.55	=SUM(C10:C14)/\$B\$13	=C15-D15

(b)

**Table A4.5.** Representative portion of the table created in Excel, depicting (a) the first few rows of the second moving average model for the BA data set with  $m=5$  and (b) some of the formulae that were used to create the model.

#### 4.4.3.1. Single Smoothed

◆ **Procedure and Findings – Exponential Smoothing Models: 3.1.**

Table A4.6. shows some formulae that were used to create the first exponential smoothing model. Reference is made to the following cells, where the values in them are: Cell H5 = 0.9; Cell J5 = 0.1; Cell L206 = 195.

...	B	C	D	E	F
8	t	$Y_t$	$Y'_{t+1}$	$e_t = Y_t - Y'_{t+1}$	$e^2$
9	1	12.55			
10	2	12.3			
11	3	12.45	=SUM(C9:C10)/B10	=C11-D11	=(E11)^2
12	4	12	=(H\$5)*(C11)+(\$J\$5)*(D11)	=C12-D12	=(E12)^2
13	5	11.3	=(H\$5)*(C12)+(\$J\$5)*(D12)	=C13-D13	=(E13)^2
...	...	...	...	...	...
205	197	11.4	=(H\$5)*(C204)+(\$J\$5)*(D204)	=C205-D205	=(E205)^2
206					=SUM(F9:F205)
207					SSE
208					=F206/L206
209					MSE

**Table A4.6.** Representative portion of the table used in Excel, showing some of the formulae used to create the first exponential smoothing model for the BA data set with  $\alpha=0.9$ . The MSE is found in cell F208.

#### 4.4.3.2. Double Smoothed

◆ **Procedure and Findings – Exponential Smoothing Models: 3.2.**

Below is a sample of the formulae that were used.

...	E	F	G
3	Alpha 1	1	=1-F3
4	Alpha 2	0.2	=1-F4

...	B	C	D	E	F
8	t	Yt(data)	Y't(single)	S''t(double)	S''t-S''t-1(bt)
9	1	12.55	=C9	=C9+\$F\$4*(C9-D9)	
10	2	12.3	=\$F\$3*C10+\$G\$3*D9	=E9+\$F\$4*(D10-E9)	=E10-E9
11	3	12.45	=\$F\$3*C11+\$G\$3*D10	=E10+\$F\$4*(D11-E10)	=E11-E10
12	4	12	=\$F\$3*C12+\$G\$3*D11	=E11+\$F\$4*(D12-E11)	=E12-E11
...	...	...	...	...	...
206					
207					
208					
209					

...	I	J	K
8	Forecast	Real e	Real e <sup>2</sup>
9			
10	=D9+(D9-E9)+F9	=C10-I10	=J10^2
11	=D10+(D10-E10)+F10	=C11-I11	=J11^2
12	=D11+(D11-E11)+F11	=C12-I12	=J12^2
...	...		...
206			=SUM(K9:K205)
207			SSE
208			=K206/P206
209			MSE

**Table A4.7. Representative portion of the table used in Excel, showing some of the formulae used to create the second exponential smoothing model for the BA data set with  $\alpha_1=1$  and  $\alpha_2=0.2$ . The table is represented in two parts due only to page constraints.**

For this particular example, Cell P206 (used to work out the MSE) has the value 196. It is the number of comparisons between "Prediction" and "Actual".

However, as with all previous models, the second exponential smoothing models were modified to accommodate the maximum number of comparisons that were determined for the second MA model (when  $m=3$ : 194 for the BA data set and 193 for the Esc data set). For all combinations of the alphas, then, the table below is a sample of the results:

Comparing BA						3.2.	Comparing Esc					
$\alpha_1$	$\alpha_2$	MSE	M	C	PCD		$\alpha_1$	$\alpha_2$	MSE	M	C	PCD
0	0	10.7333	102	194	52.58%		0	0	10.7983	87	193	45.08%
	0.1	10.7333	102	194	52.58%			0.1	10.7983	87	193	45.08%
	0.2	10.7333	102	194	52.58%			0.2	10.7983	87	193	45.08%
	0.3	10.7333	102	194	52.58%			0.3	10.7983	87	193	45.08%
	0.4	10.7333	102	194	52.58%			0.4	10.7983	87	193	45.08%
	0.5	10.7333	102	194	52.58%			0.5	10.7983	87	193	45.08%
	0.6	10.7333	102	194	52.58%			0.6	10.7983	87	193	45.08%
	0.7	10.7333	102	194	52.58%			0.7	10.7983	87	193	45.08%
	0.8	10.7333	102	194	52.58%			0.8	10.7983	87	193	45.08%
	0.9	10.7333	102	194	52.58%			0.9	10.7983	87	193	45.08%
	1	10.7333	102	194	52.58%			1	10.7983	87	193	45.08%
0.1	0	11.0159	62	194	31.96%		0.1	0	7.7430	102	193	52.85%
	0.1	2.1800	63	194	32.47%			0.1	0.9625	89	193	46.11%
	0.2	1.9072	61	194	31.44%			0.2	0.8378	84	193	43.52%
	0.3	2.1891	68	194	35.05%			0.3	0.8448	92	193	47.67%
	0.4	2.4433	69	194	35.57%			0.4	0.8768	95	193	49.22%
	0.5	2.6404	69	194	35.57%			0.5	0.9111	94	193	48.70%
	0.6	2.7928	69	194	35.57%			0.6	0.9424	93	193	48.19%
	0.7	2.9129	70	194	36.08%			0.7	0.9696	95	193	49.22%
	0.8	3.0095	71	194	36.60%			0.8	0.9930	95	193	49.22%
	0.9	3.0887	71	194	36.60%			0.9	1.0131	95	193	49.22%
	1	3.1546	71	194	36.60%			1	1.0304	95	193	49.22%
...	...	...	...	...	...		...	...	...	...	...	...
1	0	11.4235	78	194	40.21%		1	0	11.0059	101	193	52.33%
	0.1	3.7633	110	194	56.70%			0.1	1.4826	93	193	48.19%
	0.2	1.8225	120	194	61.86%			0.2	0.9930	104	193	53.89%
	0.3	1.1753	117	194	60.31%			0.3	0.7485	103	193	53.37%
	0.4	0.8689	111	194	57.22%			0.4	0.6034	109	193	56.48%
	0.5	0.6966	109	194	56.19%			0.5	0.5101	111	193	57.51%
	0.6	0.5904	109	194	56.19%			0.6	0.4472	111	193	57.51%
	0.7	0.5216	109	194	56.19%			0.7	0.4033	112	193	58.03%
	0.8	0.4757	111	194	57.22%			0.8	0.3720	114	193	59.07%
	0.9	0.4447	113	194	58.25%			0.9	0.3494	114	193	59.07%
	1	0.4239	110	194	56.70%			1	0.3330	115	193	59.59%
		MAX 11.4235			61.86%				MAX 11.0059			59.59%
		MIN 0.3018			6.19%				MIN 0.2246			2.07%
		M = Matches							M = Matches			
		C = Comparisons							C = Comparisons			
		PCD = Predict Correct Direction							PCD = Predict Correct Direction			

(a)

(b)

**Table A4.8.** Table showing a sample of the results obtained from applying combinations of values for  $\alpha_1$  and  $\alpha_2$  to the second exponential smoothing model using (a) the BA data set and (b) the Esc data set.

4.5. Summary

BA								
Model			PCD	MSE	s	RSFE	MAD	TS
1.1.	-	-	6.19	0.3508	0.5923	-1.0500	0.3939	-2.6659
1.2.	-	-	56.70	0.4247	0.6517	0.1800	0.4495	0.4005
1.3.	-	-	56.70	0.4295	0.6553	-4.4669	0.4500	-9.9264
2.1.	-	-	34.02	0.5766	0.7594	-1.6650	0.5007	-3.3250
2.2.	$m = 3$		38.14	0.8263	0.9090	-2.4833	0.5995	-4.1421
3.1.	$\alpha = 0.1$		37.11	3.8427	1.9603	-20.9984	1.6264	-12.9111
	$\alpha = 0.4$		36.60	0.8966	0.9469	-3.7927	0.6580	-5.7641
	$\alpha = 0.6$		37.63	0.5763	0.7591	-2.0309	0.5106	-3.9775
	$\alpha = 0.9$		35.57	0.3831	0.6190	-1.1248	0.4097	-2.7457

(a)

Esc								
Model			PCD	MSE	s	RSFE	MAD	TS
1.1.	-	-	2.07	0.2402	0.4901	-5.1300	0.3563	-14.3971
1.2.	-	-	60.10	0.3330	0.5771	-0.2100	0.4092	-0.5132
1.3.	-	-	30.05	0.3377	0.5811	-3.2889	0.4089	-8.0438
2.1.	-	-	35.75	0.3740	0.6116	-7.5900	0.4544	-16.7032
2.2.	$m = 3$		39.38	0.5072	0.7122	-10.4267	0.5231	-19.9308
3.1.	$\alpha = 0.1$		49.22	1.2319	1.1099	-55.4607	0.8659	-64.0471
	$\alpha = 0.4$		40.93	0.5023	0.7088	-13.5542	0.5143	-26.3528
	$\alpha = 0.6$		39.90	0.3567	0.5973	-8.6182	0.4419	-19.5029
	$\alpha = 0.9$		38.34	0.2577	0.5076	-5.5962	0.3716	-15.0578

(b)

**Table A4.9. Summary table of the tracking signals (excluding exponential smoothing models) for (a) the BA data set and (b) the Esc data set. The standard deviation also shown is abbreviated as s.**