CHAPTER 1

INTRODUCTION

Barings Bank, one of the oldest British banks, went bankrupt in February 1995. A sum twice as large as Barings' capital was lost on the derivatives market by its futures trader, Nick Leeson. A year later, Daiwa Bank lost $1 billion, and a few months later, Sumitomo Corporation lost $1.7 billion in the copper market. In 1997, National Westminster Bank lost £90 million on options trading. In 1998, Long-Term Capital Management had to be bailed out due to its over-exposure in emerging markets. Several other companies worldwide have suffered large losses over the past few years because of their speculative trading in derivatives.

Since most of the losses in these cases were incurred as a result of derivative positions, these collapses caused great concern in financial markets over the world. Derivatives have now

been recognized as dangerous instruments. Nevertheless, there has been explosive growth in the derivatives market over the past 25 years. This growth is related to the fact that the trade volume of derivatives is usually much higher than that of the underlying instruments. Notwithstanding various losses by banks and funds which have failed to manage the financial risk adequately, derivatives can be successfully used to hedge or reduce financial risk *or* to create highly leveraged speculative positions in the market. According to the office of the Controller of the Currency (OCC) (Dashtidar, 2000:11), in the third quarter of 1999, the notional value of derivatives held in US commercial banks rose to a record high of $35.7 trillion. One of the most dominant forms of derivatives is interest rate contracts, representing 79% of all activity.

This study concentrates on the South African fixed income market, where the bond market ranks as one of the most liquid emerging bond markets in the world, with a daily turnover in excess of R40 billion (www.bondex.co.za). The South African fixed income market ranks in size in the top 25 fixed income markets in the world and ranks second in terms of market turnover related to market size (www.bondindex.co.za).

1.1 Aim of the study

The enormous impact of derivatives in the financial world necessitates the use of accurate valuation and risk-forecast models. The aim of this study is to focus on the South African fixed income market and evaluate current models and procedures. In order to add value, alternatives are proposed where necessary.

All valuation models depend on certain assumptions and therefore have certain limitations.

However, many participants in the derivatives markets use a 'black box' approach, without realizing the consequences of applying an inappropriate model. Both the awareness of risk and the challenge of making a profit encourage traders to take positions that correspond to their appetites for risk. As a trader, one soon realises the benefit of having more accurate valuation models which enable one to take on more risk with greater confidence. A better understanding of the pricing model, the risk and variables involved gives traders more confidence which, in turn, allows them to take bigger positions.

When one realises how imperfect models are, choosing a viable valuation method becomes difficult. It is for this reason that the study analyses the existing models and procedures used in the South African fixed income market, and, where applicable, tries to find an alternative. Throughout the study there is an attempt to reconcile the knowledge obtained by means of theoretical research with the practical problems experienced in the market.

Although many academics and practitioners have developed methods for valuing and managing interest rate instruments and derivatives, little work has been done with regard to the specific characteristics of the South African fixed income market. The aim of this study is to address certain inefficiencies experienced in the South African fixed income market in the area of term structure analysis and bond option valuation.

1.2 The term structure of interest rates

Since the fixed income market is entirely based on the term structure of interest rates, it remains the most important input in the pricing of any fixed income derivative security. (It also influences other derivatives, as it determines the discount factor for discounting the expected payoff.) Analysing the yield curve is thus a very important aspect of decision-

making for managers of fixed income portfolios and hedge funds. The yield curve contains information about future market expectations of interest rates. An essential aspect for managing or trading fixed income instruments is to understand the derivation of a zero-coupon yield curve, a swap curve and a forward curve.

In South Africa, where only coupon bonds are traded, the Johannesburg Stock Exchange (JSE) Actuarial Yield Curve has been conventionally accepted as the benchmark yield curve. This curve is available on a daily basis and is seen as the South African yield curve. It is, however, merely a fit through the yield-to-maturities of South African government bonds. It can be seen as an approximation to a par-bond curve, although the bonds are *not* par-bonds. A zero-coupon yield curve gives a homogeneous function of yield against term-to-maturity.

The South African bond market trades mainly in coupon bonds, and little or no data is available for zero-coupon instruments. Thus it is necessary to do bootstrapping. This is, however, a time-consuming process. When one uses this method every day, one becomes convinced that there has to be a quicker and more efficient way to get the same, or even better results. An iterative bootstrap method was therefore developed. It starts with a first guess for the zero-coupon yield curve and then converges to the actual zero-coupon yield curve. Since the publication of this method in *RISK* (Smit & Van Niekerk, 1997), the technique has been used by several practitioners and academics both locally and internationally.

1.3 The bond option market

The South African bond options market is largely driven by the over-the-counter (OTC) market. The options are mainly American options which can be early-exercised. The importance of understanding the risk characteristics of an option and realizing their profit

potential serves as an incentive to search for alternative ways of valuing options in order to use all opportunities to optimize profits. Using the Black model (Black, 1976), which was developed for commodity futures, was clearly insufficient.

This study discusses the theory underlying the most popular bond option pricing models, and concentrates on the Hull-White model (Hull & White, 1990). The numerical solution of the Hull-White model applied to South African OTC bond options is discussed in depth. The reasons for choosing the Hull-White model are the following:

- It incorporates mean reversion of interest rates.
- It determines the pull-to-par effect analytically.
- It is exactly consistent with the initial term structure of interest rates.
- It incorporates the early-exercise value of American options.
- It addresses implicitly the risk of a change in the cost-of-carry.

The Hull-White model has had to be adjusted for its application to South African bond options, as these options are traded on the yield-to-maturity of the bond, rather than the price. Because the numerical solution to the Hull-White model uses the current term structure of interest rates as an input, the zero-coupon curve is used as an input. Although the options are American, holders of these options seldom early-exercise them, since it is generally believed that the time-value is lost if one does so. The conditions in which OTC bond options are early-exercised, are therefore discussed in more detail.

The complexity of the Hull-White model encouraged the development of a simplified model for exchange-traded options (see Chapter 7). The new model could also stimulate bond option trade on the South African Futures Exchange (SAFEX), a market which is illiquid at present. An exchange-traded bond option has no short-term risk-free rate component, as the underlying

instrument is the bond future, and interest is earned on the margin account. Therefore, instead of using the short-rate or the price of the bond as the stochastic variable, it is possible to assume that the *yield-to-maturity* of the bond follows a Brownian motion. A pricing model for options on the future yield of a bond is in many ways similar to the Black model (see Chapter 5). However, the yield-based model addresses most of the disadvantages of the Black model.

1.4 Structure of the study

The study is structured as follows: Chapter 2 discusses the most important concepts of the valuation of derivative securities. In order to understand the valuation of derivative securities sufficiently, it is necessary also to have a good grasp of the concepts of arbitrage, martingales and partial differential equations. The remainder of the study is divided into two fields of research: first, the term structure of interest rates (Chapters 3 and 4) and, second, bond option valuation models (Chapters 5, 6 and 7).

Chapter 4 aims to develop an improved bootstrapping method in order to obtain a zero-coupon yield curve. A yield curve gives the relation between the yield of a fixed income investment and its term. The zero-coupon yield curve is the basis for pricing all vanilla products (bonds, swaps, forward swaps, etc.) in the fixed income market and serves as an important input in pricing bond options using a no-arbitrage model.

Chapter 5 then discusses several existing bond option valuation models. In Chapters 6 and 7 there is an attempt to improve on existing methods to value South African bond options. In Chapter 8 there is a summary of the findings, followed by conclusions and recommendations.