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3-month Bond Option Strategies:

**An analysis of performance from 1998 to 2010 in the
South African market**

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**Submitted towards the M.Phil degree in Financial
Mathematics**

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Abstract

Due to the 2008 financial crisis, investors have become more risk averse in investing in equities and have increased their holdings in bonds as they are believed to be less risky. However, South African interest rates have been volatile over the past decade due to changes in the inflation rate. This has caused the returns of bond portfolios to be uncertain since bond prices are inversely related to interest rates. It is thus imperative to manage the interest rate risk inherent in bond portfolios so that institutional investors can achieve their mandates and targeted returns. There is not much literature or research in South Africa on the performance of bond option strategies which are used to hedge the interest rate risk inherent in bonds and this paper addresses this issue.

The objective of this study is to investigate the performance of bond option strategies over the period from 1998 to 2010 in the South African market so as to ascertain which option strategies would have performed better. A hypothetical South African government bond is used as an underlying and the performance all portfolios with an option overlay are compared to that of a bond-only portfolio. Risk-adjusted returns and cumulative performance are the basis used to compare the performance of different portfolios. Option strategies considered are protective puts, call spreads, put spreads, zero-cost collars and short fences. We found that the short fence portfolio outperformed all other portfolios including the bond-only portfolio and the call spread portfolio was the worst performer.

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1 Introduction

The objective of this paper is to examine the performance of a number of 3-month bond option strategies normally employed by South African institutional investors. This is to determine which strategies have yielded favourable results on an absolute and risk-adjusted returns basis. The methodology used is to buy a hypothetical government bond at the beginning of a 3-month period and also buy/sell an option strategy on the bond. The strategy is rolled over at the end of 3 months for the period under consideration. The bond-only portfolio is used as the benchmark portfolio for analysis. It was found that the portfolios performed differently on a cumulative basis when a different starting point was used and the short fence portfolio outperformed all other portfolios on a cumulative and risk-adjusted returns basis

One could argue that option strategies that performed better in the past may not perform in future as past and future economic conditions are different. However, the purpose of this study is to examine which 3-month rolling bond option strategies would have outperformed the bond-only portfolio. The period from 1998 to 2010 was chosen due to data availability and the different economic conditions that it covers including the 2008 financial crisis. The 2008 financial crisis does cover the stress period and it is thus fair to believe that the period under consideration does give an idea of what future economic conditions one should expect. Therefore, the analysis of the performance of bond option strategies would give an idea of how portfolios with a bond option overlay will perform under different economic conditions.

Over the past decade, interest rates and exchange rates have not been stable in South Africa which has led to the high volatility of the bond market. The volatility of the bond market is not as high as that of the equities market, but since institutional investors like pension funds have high holdings in bonds, it is important to hedge the interest rate risk inherent in conventional bonds. One should note that 6-month rolling option strategies will not be investigated in this paper although 6-month bond option strategies are employed in practice. This paper is concentrating on 3-month bond option strategies since 3-month bond options are more liquid than 6-month bond options in the South African market and widely used by asset managers as well as other investors such as hedge funds and pension funds. South African bonds are illiquid

which makes it difficult for investors to close-out their positions during adverse market movements.

The amount and timing of cash flows from conventional bonds is known in advance. However, the yield-to-maturity which is defined as the rate of interest that will make the present value of a stream of cash flows from conventional bonds equal to its market price changes through time as market conditions change. It is affected mainly by changes in interest rates which results into the volatility of bond prices. Note that the yield to maturity and bond prices are inversely related and changes in interest rate will result in changes to the yield-to-maturity of the bond. Other sources of volatility in bond prices are liquidity risk, credit risk and inflation risk. It is thus imperative to take measures to reduce the volatility of bond prices in order to enhance the performance of bond portfolios.

There are a number of different option strategies which have been incorporated in bond portfolios in order to enhance returns and protect the portfolio from adverse movements in interest rates. They enable investors to meet their objectives due to the flexibility of returns available as different option strategies alter the returns distribution in different ways. Option strategies induce non-linearity in the payoff of bond portfolios enabling investors to shift the risk-return profile of their portfolios in a desired way. Amenc et.al (2005) argued that institutional investors have a particularly strong preference for non-linear payoffs because of the non-linear nature of the liability constraints they face. For example, pension funds have pension liabilities which are uncertain in timing (as they may depend on mortality, longevity, disability and retirement) and amount (they may be linked to the performance of an index (equity index or consumer prices index)). In order to hedge the risks inherent in their liabilities, pension funds will hold a significant amount of bonds (both conventional and index-linked) amongst other asset classes such as equities. However, the bonds they hold are exposed to changes in the yield-to-maturity and may fall in value while their liabilities increase leading to a mismatch between assets and liabilities. Therefore, active bond portfolio management is required in order to better manage the risk in bond portfolios. There are a number of ways in which this can be done which includes using asset swaps, swaptions, bond futures options and

bond options. These strategies are also used by liability-driven investors such as life insurance companies. This study will focus only on bond option strategies employed by South African institutional investors as they are better understood and less complex relative to other strategies used.

Suppose an investor who holds a bond worth R100 expects the bond market to fall by 6 per cent in the next 3 months. The investor can protect the current value of the bond by buying a 3-month European put option (A put option is a derivative instrument which gives the right to the holder to sell the underlying asset at a specific price (called the strike price) at a certain time in the future) with a strike price of R100, i.e. an at-the-money put option. If the market does fall by 6 per cent or more, the investor can exercise the option at the strike of R100 and the total value of the portfolio will be R100 less the premium paid for the option. The option position is beneficial to the investor if the put option premium is less than R6 which is likely to be the case. The investor can fully or partially fund the premium by selling out-of-the money put or call options (A call option is a derivative instrument which gives the right to the holder to buy the underlying asset at a specific price at a certain time in the future). In this example, the investor has reduced downside risk whilst maintaining the upside potential of the bond price. This is the flexibility that options can bring into a portfolio and it leads to better risk management and performance of bond portfolios.

Option strategies enable investors to improve the performance of their portfolios in falling, rising and range-bound markets as the holder can exercise the options when optimal in the case of American options or at expiry for European options. Many portfolio managers use these option strategies to speculate instead of hedging (hedging is a financial transaction in which one asset is held to offset the risk of holding another asset) and in turn increase risk. The increase in risk is due to the gearing of portfolios with options and this is rewarded by an increase in returns. It is not clear which option strategies improves the performance of portfolios, bond portfolios in particular, since these strategies depend on market conditions. For example, a written call strategy which involves writing a call option and holding the underlying asset performs better if the market is falling since investors gain the premium as the

option expire out-of-the-money. A number of studies have been done investigating which strategies perform better than others on a risk-adjusted returns basis and most of them are based on stock portfolios. It is thus imperative to investigate which strategies are suitable for bond portfolios in South Africa. This paper will look at six commonly known option strategies which are protective puts, covered calls, call spreads, put spreads, short fence and zero-cost collars. Note that other option strategies may be employed by South African investors in bond portfolio management but these are beyond the scope of this paper.

The rest of the sections in this paper are organised as follows: section 2 is the literature Review, section 3 is a discussion of the South African market, section 4 is the Mathematical framework and tools used in the study, section 5 is the Methodology and Data, section 6 is the Results and Analysis and section 7 is the Summary.

2 Literature Review

Chen (2005) argued that the riskiness of the bond market has increased substantially due to increased correlation with the stock market, international bond markets and increased volatility of interest rates which has led to an increase in bond risk premiums. He forecasted bond returns in the German financial market where he presented a correlation matrix between long term bond returns in the UK, Canada, US, German and Japan. The increased integration of the international bond market has led to investors requiring more sophisticated methods to manage the financial risks in their bond portfolios. Foreign investors invest in emerging markets including South Africa in search of high yields. Therefore, the volatility South African government bond prices are affected by the demand and supply from foreign investors and the bond market is also correlated with the international bond market. This effect is not captured in the study but it does have an impact on the bond yields, yield volatility and the performance of government bonds.

The pricing of bonds has become more difficult in South Africa mainly due to the government bond yield curve not being liquid across maturities. The bond yield curve used in this study is assumed to be liquid. Macroeconomic news announcement and intervention of the Central Bank play an important role in the prices of bonds and have a significant effect in bond risk premiums. Interest rates in South Africa have been volatile over the past decade as the South African Reserve Bank implements its inflation targeting policy in order to control inflation which is one of the economic indicators that are very volatile. This results in bond prices being volatile as they are dependent on interest rates and South African investors need to manage this risk.

Bollerslev et.al (2000) investigated the intraday periodicity, long memory volatility and macroeconomic announcement effects in the US Treasury bond market using intraday US Treasury bond futures data provided by the Futures Industry Institute for the period January 1994 to December 1997. Amongst other findings, they found that macroeconomic news announcements constitute an important source of volatility in the bond market followed by PPI, employment costs and retail sales. Since international investors use the US Treasury bond yield curve as a benchmark curve to price bonds in other markets such as South Africa, these

macroeconomic news announcements have a significant effect on the volatility of bond prices in South Africa. Therefore, active bond portfolio management is important for South African bond investors as the sources of volatility in the bond market do not only come from local risk factors but from other international sources of volatility.

Ross (1976), Breeden and Litzenberger (1978) and Adritti and John (1980) as cited by Bookstaber and Clarke (1984) showed the increasing efficiency of financial markets as investors were able to meet their investment objectives due to the flexibility of returns available from investment strategies. One of the ways of meeting these objectives is through the use of options. Consider a protective put strategy which involves buying a put option and holding the underlying stock. The loss to the investor is capped at the exercise price of the option while the upside potential is unlimited which may be useful for portfolio managers who want to maintain their portfolio values at a specific level as they may be uncertain about future market conditions. This is further supported by Bollen (1999) when he argued that derivatives allow fund managers to reduce downside risk whilst preserving or enhancing the upside potential of portfolios.

Keating and Shadwick (2002) said that "It is a generally accepted fact that returns from investments are not distributed normally". A number of studies on the characteristics of the returns distribution found that characterising the distribution of returns solely by the first two moments may lead to wrong conclusions as higher moments inherent in investment portfolios are not accounted for. This is why the study also considers other risk-adjusted measures in measuring portfolios with a bond option overlay as the distribution of returns is not normal due their non-linear payoff. A written call strategy reduces the variance on the right-hand side of the returns distribution whereas protective puts reduce variance on the left-hand side. The mean return of written calls is increased by the premium received in writing the call option and the mean return of protective puts is decreased by the premium paid to buy the put. This will result in the written call strategy dominating the protective put strategy on a mean-variance basis which may be a wrong conclusion since higher moments are not taken into account. The results in this paper are contradicting the latter statement since the protective put strategy

dominated the written call strategy in terms of the mean, but not the variance. Bookstaber and Clarke (1984) did provide evidence supporting this argument when they used numerical methods to simulate two option portfolios and compared them using mean and variance. They also showed that traditional performance measures which depend on the first two moments of a returns distribution can lead to wrong conclusions as will be seen in the results on section 6. When these measures were developed they were based on the Capital Market Line (CML) which assumes the distribution of returns can be characterized by the first two moments but this may not be the case with option-based portfolios.

Lekkos and Milas (2001) performed a study to predict the excess returns in the UK (United Kingdom) bond market. In their study they explained the variability of excess returns (annual bond returns less one year T-bill yields) using the forward risk premium (the difference between the one year forward rates 2, 5, 7 and 10 years in the future and one year T-bill yields). Using monthly observations from January 1976 to August 2000 of discount UK bonds they found that the slope of the term structure of interest rates explains the dynamics of expected bond returns in the UK bond market. They also found that expected returns exhibit a regime switching behaviour according to the variation of the slope of the term structure of interest rates. A flat or downward sloping term structure is identified with periods of a recession and an upward sloping term structure is identified with periods of economic expansion. This shows that excess bond returns are predictable, however, the author used data of discount bonds in the UK market and returns were available across maturities. The predictability of excess bond returns in the South African market may be difficult since discount bonds are not available in South Africa (they may be stripped from conventional bonds) and the bond yield curve is not liquid across all maturities which may make the results unreliable. It is therefore important that option strategies are employed in order to better manage the risks inherent in bond portfolios as well as assess their performance over time as to ascertain which strategies performed better in the South African market.

Isakov and Morard (2001) investigated the performance of a global investment strategy proposed by Morard and Naciri (1990) which combines diversification and option strategies.

The investment strategy involves using an optimization algorithm to randomly select stocks to be hedged in a stock portfolio resulting in an optimal portfolio of hedged and unhedged stocks. Using data from the Swiss Exchange over the period from January 1989 to December 1996 they found that the written call strategy consistently improves the performance of stock portfolios even in the presence of transaction costs. However, when theoretical option prices (calculated using the Black and Scholes (1973) model) instead of observed option prices were used, the partially hedged stock portfolio did not outperform the unhedged stock portfolio. This is because observed prices are likely to be higher than theoretical prices because of the volatility skew and investor's risk aversion.

One should note that the results presented in this paper do not depend on the option pricing model used to price options as evidence from Bookstaber and Clarke's (1984) analysis of option portfolio strategies show that the shape of the returns distribution is not altered by any mispricing of options. For example, a written call strategy truncates the right hand side of the returns distribution since the call option will be called away if the stock price rises above the exercise price. The premium received in writing the call option will shift the returns distribution to the right because of a change in the investment base but the shape will remain unchanged. However, results from a study by Isakov and Morard (2001) showed that if observed prices are used then the shape of the returns distribution will not change as pointed above. These results are consistent with what was found in this study.

Goltz et.al (2006) performed a study on the use of derivative strategies for bond portfolios. One of their analysis involved investigating the performance of protective put option strategies where the underlying asset is bond futures and compares it to the bond futures in an asset management context. Simulation techniques were used to generate bond and option prices and they found that the protective put strategy dominated the bond futures strategy on a mean-variance basis and in terms of the Value at Risk (VAR) measure. A similar study to the one presented in this paper performed by Dugmore (2002) compared the performance of two portfolios: one with the R153 (the R153 is a South African government bond which expired on 31/08/2009) bond-only and the other with an option strategy on the R153 bond. He found that

all strategies investigated which included protective puts, zero-cost collars and call spreads (except those with a written put leg) provide better risk-adjusted returns than the underlying R153 bond only portfolio. These results are similar with the results found in this study however the call spread did not perform well as discussed in section 6 of this paper.

Amenc et.al (2005) showed how an option overlay strategy can be used to enhance the performance of bond portfolios while reducing risk using a bond rotation program. They showed that an option overlay portfolio enhances performance of bond portfolios in trend less market cycles. "These are typically difficult market environments for timing strategies," (Arnott and Miller (1996) as cited by Amenc et.al (2005)). Their objective was to analyse the performance of bond portfolios with an option overlay that will enhance performance during trend less market conditions while not impacting the portfolio's ability to generate excess returns in volatile market conditions. Furthermore, the returns of the portfolio with options were found to be greater than those without an option overlay in 90% of the months. The results above are consistent with the ones found in this study particularly the relative annualised returns and volatility of the two portfolios. The portfolio with options outperformed the portfolio without options on a risk-adjusted returns basis (it has a Sharpe ratio of 1.66 whereas the portfolio without options has a Sharpe ratio of 1.00) and cumulative returns basis (39.31 per cent versus 30.98 per cent).

Most of the literature considered above for different bond markets show that bond portfolios with an option overlay have performed very well relative to portfolios without options. Different option strategies were used and they all yielded favourable results. The South African market is different from other market since the bond option and bond market are not efficient as these products are traded over-the-counter. This means observed bond option implied volatilities are not readily available and there is no pre-defined way or models used by market players to determine implied volatilities. The illiquidity of the market makes it even more difficult to price these options and the next section does mention one of the methods used by the market to determine bond option implied volatilities. The next section will describe the South African bond and bond options market in more detail.

3 The South African Market

South African bonds and bond options are not very liquid and they are traded over-the counter (OTC). Therefore, the bond and bond option market are not efficient as prices of executed trades are not readily available to investors. The only prices available are those from market-makers whom show wide bid-ask spreads for bond options due to their illiquidity. Transaction costs are not standard as they will depend on the terms of the agreement between the two counterparties in a trade, but they are approximately one percent of the total value (price multiplied by number of units traded). There are both explicit and implicit costs and these depend on a trade by trade basis. This leads to the inefficiency of the bond and bond options market. There is no standard model used to price options and the bid-ask implied volatilities used in a trade is derived using different models. Since there are a few number of participants in the market, this also adds to the inefficiency.

When two counterparties enter into a bond option trade (e.g. one is buying a call option and the other is selling a call option) there is no exchange of premiums at outset as both counterparties are delta hedged and they will roll their positions over time in order to remain delta-hedged. It is the implied volatility that is traded (i.e. all-in volatilities or yield volatilities) and the bid-ask spread is wide due to the illiquidity of the options. There is a risk that the realised volatility of the bond will not be the same as that implied when two counterparties enter a transaction since bond option volatilities are not available. Therefore, investors hedge this implied volatility using swaptions. Swaptions are a good hedge since they do give an indication of what the market's expectation of the volatility in the future and they are very liquid as foreign banks are one of the major players in the swaptions market. This is mainly because of the large positions that they have in South African bonds and they need to manage their risks and earn the desired return.

A model is used to get the bond volatility from the swaption volatility. The underlying bonds are mainly the R157 and R186 and there is no market on other underlying South African government bonds such as the R207. Data on the bid-ask spread on implied volatilities is not readily available. The South African Reserve Bank does provide a volatility skew for bond

options on a monthly basis, but these are not useful as the given skew may be way off the market skew, hence, it is unreliable and should not be used for trading purpose.

There are 3 banks in the South African who are market-makers on bond options and all other players in the market are local. The four main players are hedge funds, pension funds, asset managers and banks. Most institutional investors in South Africa are restricted to “written” option positions, meaning bought calls or sold puts must be overlaid on cash, while sold calls and bought puts must be overlaid on the underlying asset. This ensures that an investor does not take on excessive risk by “gearing” the portfolio. One should note that relative to other developed countries or markets, the South African bond options market is still growing.

The standard day count convention of actual/365 is used in the analysis. At the end of April 2011, monthly statistics showed that volumes traded on government bonds were slightly above 3.3 million with a value of approximately R191 million. These are exchange-traded bond options that will expire within 12 months and the figures were taken from the Johannesburg Stock Exchange (JSE) website. Most of the trades are done over-the-counter mainly between the 3 banks that are making a market on bond options.

One feature of bonds is that they are traded in terms of their yield-to-maturity. The standard all-in price is calculated using a discounted cash-flow approach or the Bond Pricing Formula which was formulated by the Bond Exchange of South Africa for existing bonds on the market. This paper uses the discounted cash flow approach to price bonds. The South African bond yield curve is not liquid as only the R157 and R186 are mostly traded. Most participants in the bond market use different models of the bond zero curve that is used to price bonds. Alternatively, the yields of the liquid bonds are used and other tenors are interpolated.

Interest rate derivatives are priced using Black’s formula. For bond options, the option strike is quoted in terms of the spot yield. For example, if the option strike is quoted as x per cent of the spot yield then this converts to $(200-x)$ per cent of the current bond price. This is because of the inverse relationship between the bond price and its yield-to-maturity. The strike and the spot price in Black’s formula are not in terms of yield. Therefore, formula 3 in section 4 below needs to be used to convert from a bond or strike yield to a cash price. Bond yield volatilities are

determined in the swaption market whereas price volatilities are used in Black's (1976) formula. Therefore one needs to convert from yield volatility to price volatility using formula 6 in section 4 below. The reason why one has not used yield volatilities is because bond prices are non-linear functions of the yield, and hence, the yield volatility is not the same as the price volatility. There exists a software written by RiskWorX which allows for the pricing of American and European bond options on any of the bonds listed at the South African Bond Exchange.

The South African market had good returns year in 2010 due to low yields leading to investors earning capital gains. However, interest rates have been decreasing in order to stimulate the economy and this has led to foreign investors selling South African and thus pushing yield up. Since the government has a budget deficit, the yield curve is high and even higher than the swap curve. In January 2011, R7.5 billion left the country leading to yields going up. Inflation volatility in South Africa is high. This leads to the volatility in the bond market as investors incorporate expectations of inflation in bond yields. The volatility of inflation is caused by high commodity prices, food prices and exchange rate volatility. It is expected that the South African Reserve Bank will increase interest rates later in 2011 and bond yields will increase as a result. If this should transpire, now is not a good time to buy bonds as their capital value may decrease due to increasing yields. However, as yields go up they provide high fixed revenue income as coupon payments are in line with yields. Therefore, investors should understand their risk profile and know when to invest in bonds.

Due to the illiquidity of bond options, banks and hedge funds normally hold a portfolio of bonds and they hedge their positions using government bond index futures which are fairly liquid. Due to unavailability of data, this paper has not shown how the results contrast with that observed in the market. However, since a hypothetical government bond and bond option strategy are constructed, this should give an indication of what to expect from the market.

4 Mathematical Framework and a brief discussion of the tools used in the study

This section provides the mathematical formulas and tools used in this paper. The tools are provided to emphasise the difference in the pricing of bond options in the standard Black's (1976) formula as well as performance measures which take account of the distribution of returns.

4.1) Omega ratio

Shadwick and Keating (2002) formulated the Omega ratio which is the ratio of the probability weighted average gains to the probability weighted average losses of the portfolio. It takes account of all the distributional characteristics of a returns distribution, i.e. all higher moments, which makes it suitable for measuring the performance of option-based portfolios since they may not be normally distributed. De Wet et.al. (2008) commented that the Omega ratio makes no assumption about any moments of a returns distribution and it will give the same results as the Sharpe ratio if higher moments are statistically insignificant.

The evaluation statistic Omega is defined as:

$$\Omega(\tau) = \frac{\int_a^b (1 - F(x)) dx}{\int_a^{\tau} F(x) dx} \quad \text{where,} \quad (1)$$

$F(x)$ is the cumulative distribution of portfolio returns

τ is the return level threshold. A return level threshold of 15% per annum is used in this paper

a is the interval of the probability density function of returns where a is the minimum return and b is the maximum return of a portfolio's returns distribution

4.2) Maximum Drawdown

The maximum drawdown is the maximum drop in the value of a portfolio over a given period of time. It is used to measure the riskiness of portfolios as it quantifies the worst drop in the portfolio and it was formulated by Ismail et.al. (2003). Let V_t be the portfolio value process at

time t and P_t be its running maximum at time t . The drawdown D_t is defined as the drop of the portfolio from its running maximum:

Maximum Drawdown D_t is then defined as:

(2)

4.3) Bond pricing

In general, the fair value of a fixed-income security is the present value of a stream of cash flows it is expected to generate over its future lifetime. The formula used to calculate bond prices in this paper is:

(3)

P_t is the bond price at time t ,

C is the semi-annual coupon payment,

i is the time until the i^{th} coupon,

y_{tm} is the yield to maturity of the bond compounded semi-annually

N is the number of coupons payments left,

M is the face value of the bond and

T is time to maturity of the bond.

The bonds considered in this paper do not exist and thus do not have a yield to maturity. This means the bonds are generic/hypothetical and have not been traded in the South African market before. They are priced using the yield curve to discount its future cash flows. The South African bond yield curve over the 11.5-year period was used to calculate bond prices by

replacing ytm in formula 3 with the closing yield at time t. If the rates were not available for certain periods of a particular day, these are linearly interpolated from the yield curve on that particular day. Bonds are assumed to have a face value of R100 throughout the analysis. After getting the bond price using the yield curve, the yield to maturity of the bond is calculated as the yield that will make the bond price equal the present value of its future cash flows. The yield to maturity is calculated in order to get the spot yield; this will be used to get the strike yield since bond option strikes are quoted in terms of a percentage of the spot yield in South Africa. Formula 3 will be used to convert the strike yield to an all-in strike price (the exercise price of the option) by replacing ytm in formula 3 with the strike yield.

4.4) Bond Option Pricing

Black's (1976) formula is used to calculate bond options. The formula is as follows:

$$\text{and} \tag{4}$$

$$\text{where,} \tag{5}$$

$$\frac{F - C}{P} \left[\frac{1}{2} + \frac{d}{2\sigma} \sqrt{\frac{1 - e^{-2\sigma^2 T}}{2\sigma^2 T}} \right] N(d_1) - \frac{F - C}{P} \left[\frac{1}{2} - \frac{d}{2\sigma} \sqrt{\frac{1 - e^{-2\sigma^2 T}}{2\sigma^2 T}} \right] N(d_2)$$

is the forward price of the bond at time t

is the price of a European call option at time t,

is the price of a European put option at time t,

is the price of the underlying bond at time t,

C is the present value of coupons during the remaining life of the option,

N(x) is the cumulative standard normal distribution of x,

K is the strike price (cash) of the option which is calculated using the spot yield,

T is the maturity of the bond and t is the current time which makes (T-t) the time to maturity of the option,

r is the annual interest-rate for the period T-t

σ is the price volatility of the underlying bond at time t which is calculated using formula 6 below.

The formula used in Hull (2005:643) to change from yield to price volatility is as follows:

$$\sigma = \frac{MD}{1 + y} \sigma_y \quad (6)$$

σ is the price volatility,

MD is the modified duration,

y is the yield to maturity and

σ_y is the yield volatility.

The duration of a bond is calculated as:

$$D = \frac{\sum_{t=1}^n \frac{C}{(1+y)^t} + \frac{F}{(1+y)^n}}{P} \quad (7)$$

the parameters are the same as those defined above in the bond price formula and D is the Macaulay Duration of the bond. The modified duration (MD) is calculated as:

$$MD = \frac{D}{1 + y} \quad (8)$$

where y is the yield to maturity of the bond and n is number of coupons per year.

4.5) A brief discussion of option strategies employed in this study

4.5.1) Written Covered Call strategy

A call option gives the holder the right, but not the obligation to buy the underlying asset (a bond for the purposes of this paper) at a pre-specified price (called the strike price) at the pre-specified date (called the expiry date). The holder of a call option will benefit if bond prices increase to a level above the strike price. This is a bullish strategy since the holder is anticipating that prices will increase. Below is the profit and loss diagram for a covered call strategy, with a short call option strike price of K . The dashed line shows the profit and loss of the option before it reaches maturity. As maturity approaches the dashed lines move towards the solid line. At maturity the payoff profile of the option is shown by the solid line. Note that all diagrams below are not drawn to scale. The y-axis is the profit and loss and the x-axis is the bond price.

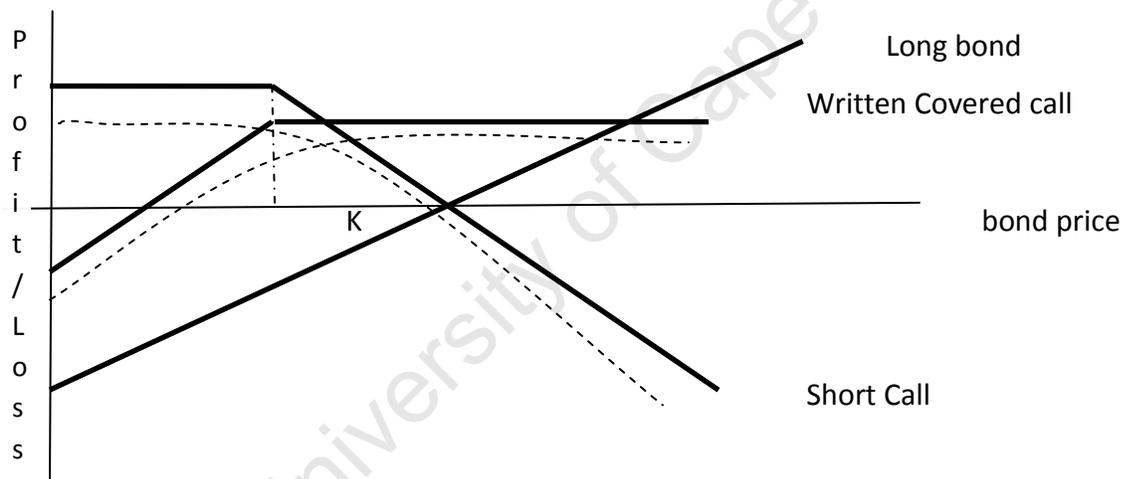


Figure 1.1: Profit and Loss diagram for a written call strategy

4.5.2) Protective Put strategy

A put option gives the holder the right but not the obligation to sell the underlying bond at an agreed strike price on a pre-specified date. This is a bearish strategy since the holder anticipates that prices will fall in the market. Below is the profit and loss diagram for a protective put option position. The dashed line and solid line shows the profit and loss before and at maturity respectively.

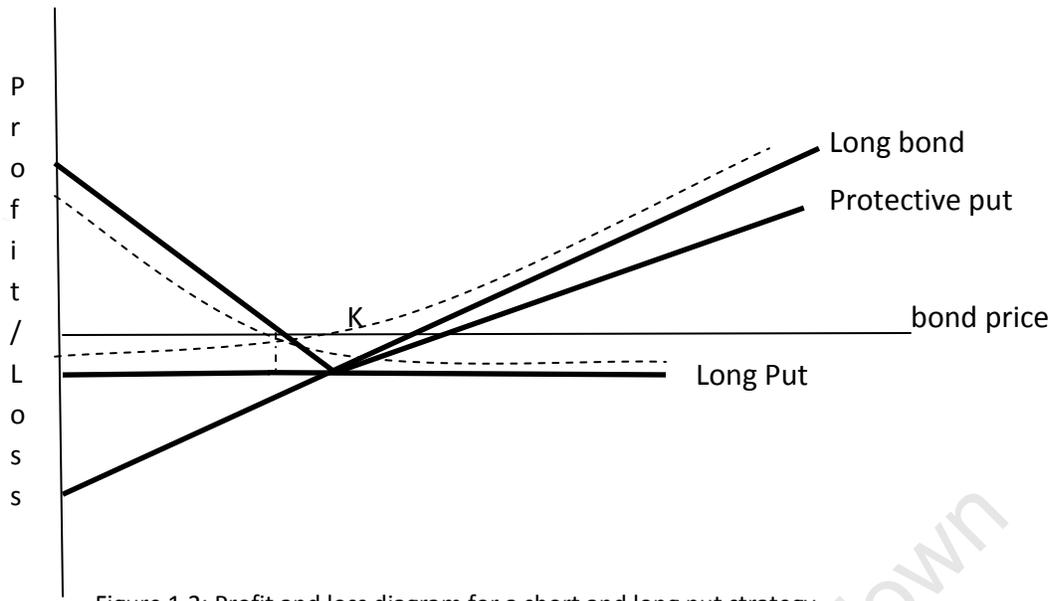
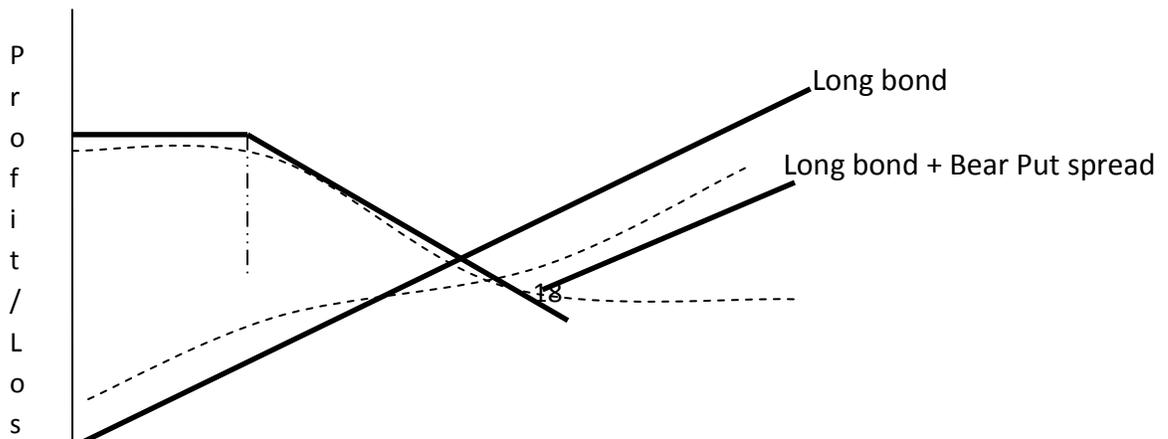


Figure 1.2: Profit and loss diagram for a short and long put strategy

4.5.3) Put Spread Strategy

A put spread can be created by buying a put option with a higher strike price (K_2) and selling a put option with a lower strike price (K_1). This strategy involves an initial cash outflow because the price of the option purchased is higher than the price of the option sold. This strategy is diagrammatically represented below. The use of dashed and solid lines is as described previously.



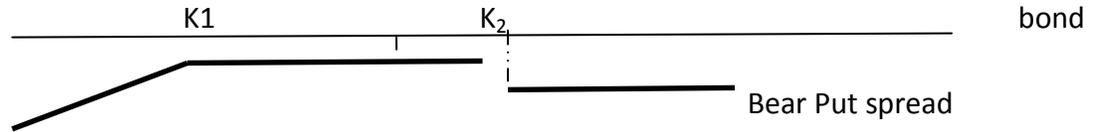


Figure 1.3: Profit and loss diagram for a put spread strategy

4.5.4) Zero-cost collar strategy

A Zero-cost collar can be created by holding the underlying asset, buying a put option with strike price K_1 and selling a call option with strike price K_2 . The strike price of the call option is chosen in such a way that the price of both the put and call options are equal. This strategy will therefore have zero initial cash flow. The strategy is represented diagrammatically below which includes the long bond. The use of solid and dashed lines is as described previously.

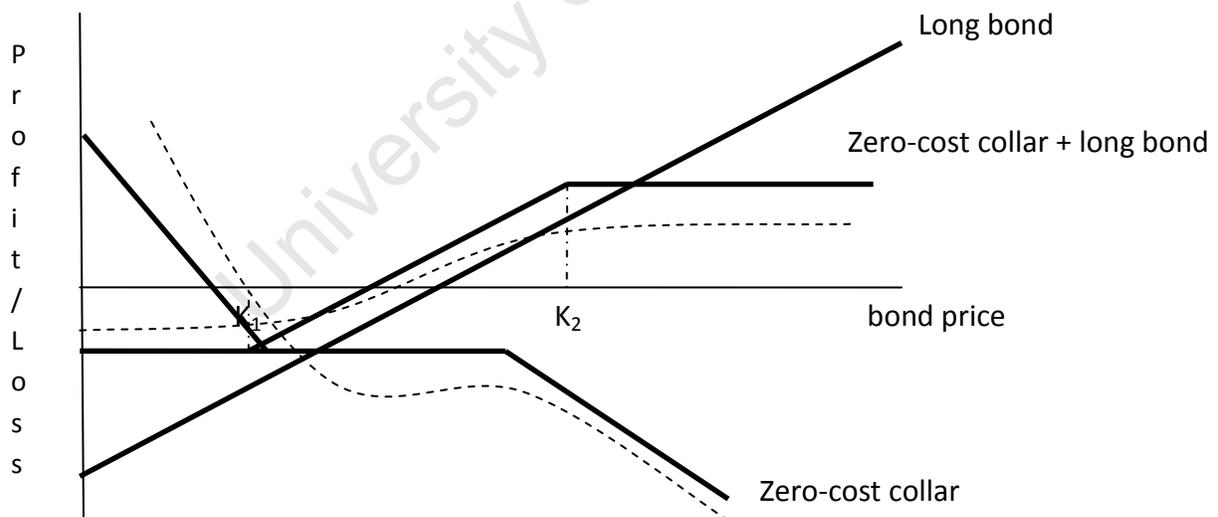


Figure 1.4: Profit and loss diagram of a Zero-cost collar strategy

4.5.5) Call Spread strategy

A Call spread can be created by buying a call option with at a strike price (K_1) and selling a call option with a higher strike price (K_2). This strategy involves an initial cash outflow because the

price of the option purchased is higher than the price of the option sold. This strategy is diagrammatically represented below. The use of dashed and solid lines is as described previously.

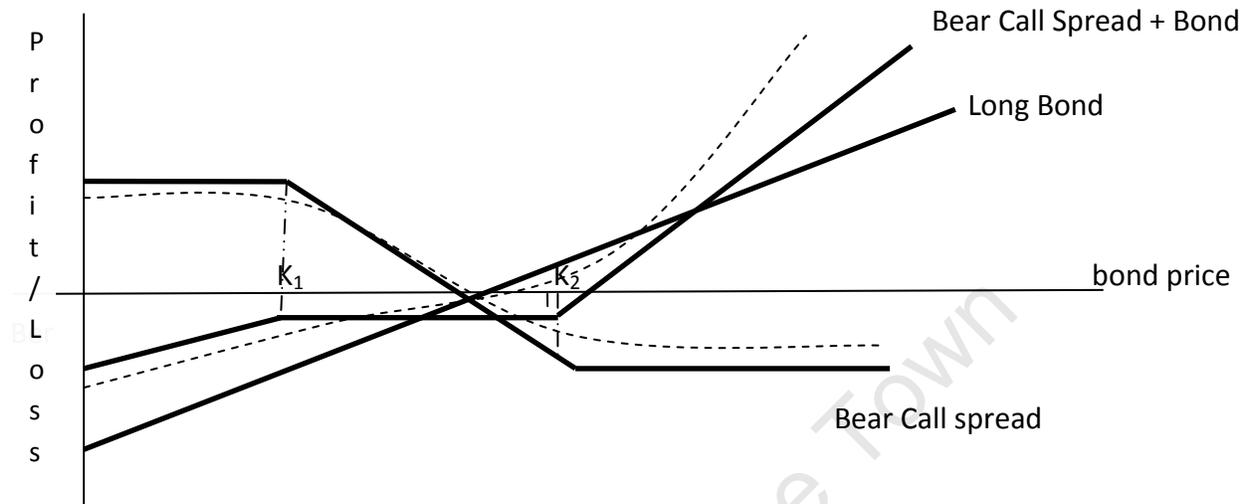
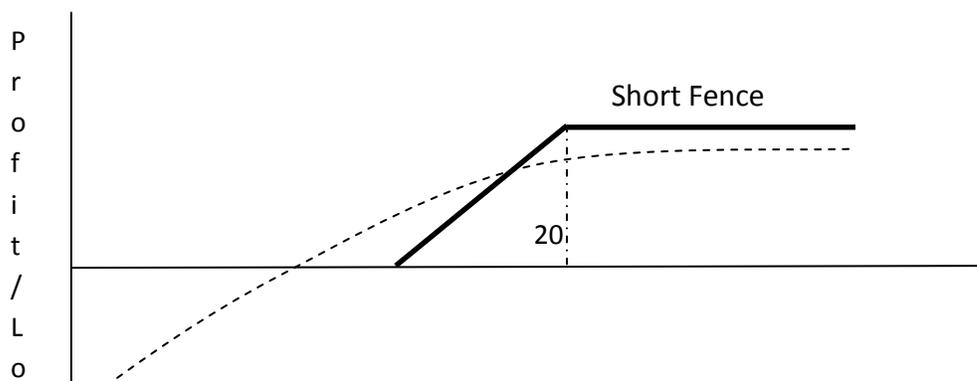


Figure 1.5: Profit and loss diagram for a put spread strategy

4.5.6) Short Fence strategy

A Short Fence can be created by a put spread, short call option at a price that will offset the cash outflow from the put spread and a long position in the underlying asset. Consider a portfolio consisting of a put spread (short put at strike yield K_1 and long put at strike yield K_2), a short call at strike yield K_3 where K_3 is chosen in such a way that the price of the call option offsets the initial cash outflow from the put spread, and a long position in the underlying asset. Note that $K_1 < K_2 < K_3$. The portfolio described above can be diagrammatically represented as below. The use of dashed and solid lines is as described above.



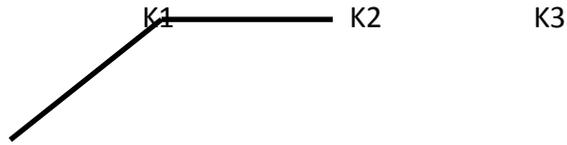


Figure 1.6: Profit and Loss diagram of a Short Fence strategy

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5 Methodology and Data

The objective of this paper is to analyse the performance of different 3-month bond option strategies over the period from 05 January 1998 to 06 July 2010 so as to ascertain which bond

option strategies would have performed better on an absolute and risk-adjusted return basis. Portfolios comprising of a hypothetical government bond with a coupon rate of 12% per annum payable semi-annually (the coupon rate was subjectively chosen and this does not have a significant impact on the results) and a 3-month option strategy (e.g. zero-cost collar) are constructed. The whole strategy (bond plus option overlay) is analysed and rolled every 3 months during the 12-year period. We assume that a new x-year bond (x is the term to maturity of the bond) is bought at the beginning of a 3-month period and an option strategy on the bond is taken (with all options expiring at the end of 3 months). After 3 months the position is rolled over, meaning the structure is re-priced and all proceeds are reinvested into the structure (proceeds resulting from the sale of the old x-year bond and the mark-to-market value of the old 3-month bond option strategy). A 3-month rolling strategy means that the hedged position is rolled (i.e. another hedge is put in place) once the options expire. For instance, a put option might be used to protect against downside risk. Once the put option expires at the end of 3 months, the position will be closed and the same position is taken again (with the strike at the same percentage level as before). All portfolios hold a long position in the underlying hypothetical government bond. We will consider 10-year and 5-year bonds in the analysis. We make the following assumptions:

- I. Options are traded at a price determined by Black's (1976) pricing formula for bonds, which is the convention in the local market.
- II. The bond market is liquid to ensure that bonds, call and put options are bought and sold at the price determined by formula 4, 5 and 6 respectively. This will not be true in the real world but it makes the analysis easier.
- III. We assume the implied volatility bid-ask spread is zero to make the analysis easier and practical, i.e. bid price is equal to the offer price.
- IV. We assume constant price volatility for all bond option strikes, i.e. there is no volatility skew.
- V. We assume there are no transaction costs including trading expenses. This makes the analysis more tractable. Therefore gross returns are reported in the results.

VI. A bond plus option overlay portfolio will be compared with a bond-only portfolio in order to determine which strategies would have performed better over the past 12 years.

We use daily data running 05 January 1998 to 06 July 2010 (3111 daily prices) provided by Cadiz Securities. Bond yields, modified duration and bond yield volatilities of South African government bonds were used to create a series of price volatilities used to calculate option prices. This was done since the hypothetical government bond has no historic data that can be used to price bond options. The assumption of zero bid-ask spread is used since we are constructing a hypothetical government bond and yield volatilities, modified duration and zero curves are those implied from the yields of benchmark South African government bonds, i.e R157 and R186.

The performance of the portfolios are analysed over the 12-year period using risk-adjusted performance in addition to the traditional measures such as the mean and variance. The most important performance that were used in deciding whether the option-based portfolio outperformed other portfolios were those that do not assume that the distribution is normal.

Since South African bonds are traded OTC, data availability was very limited. It is assumed that all bond options are European although they are American in the market. This enables us to use a closed form formula to value options whereas using American bond option prices would have required us to value the option using binomial trees or a closed form formula derived using Black's (1976) formula. This is beyond the scope of this paper.

6 Results and Analysis

The following subsections show the performance statistics and cumulative performance of different option strategies over the period from 05 January 1998 to 06 July 2010. One should note that the option strategies are for a 3-month period and are rolled over. The results below are based on a 10-year and 5-year bonds with a coupon rate of 12% per annum compounded semi-annually. The option portfolios are said to perform better if they outperform the bond-only portfolio on a risk adjusted returns and on a cumulative basis. The performance statistics are based on annualized returns over the period. The strike prices chosen for the bond option strategies are subjective and other strikes can be considered. The portfolios presented below were constructed as follows:

- I. Protective put: long a 95% strike put option and long underlying bond
- II. Put spread: long a 105% strike put option, short a 95% strike put option and long the underlying bond
- III. Call spread: long a 95% strike call option, short a 105% strike call option and long the underlying bond
- IV. Covered call: short a 105% strike call option and long the underlying the bond
- V. Zero-cost collar: long a 95% strike put option, short a k% call option and long the underlying bond. The strike percentage (k) is chosen in such a way that the price of both the put and call are equal resulting in zero initial outlay
- VI. Short fence: long a 105% strike option, short a 95% strike put option, short a k% strike call option and long the underlying bond. The strike percentage (k) is chosen in such a way that there is zero initial outlay.

6.1) Performance statistics and Cumulative Performance of all portfolios with an underlying 10-year bond

Table 1: Performance statistics of different option strategies on a 10-year bond over the period from 01/05/1998 to 06/07/2010

	protective put	put spread	call spread	Covered Call	zero cost collar	short fence	bond
Minimum return	-50.02%	-53.37%	-48.76%	-44.58%	-43.96%	-56.10%	-44.49%
Maximum return	118.33%	107.36%	88.02%	86.02%	95.53%	119.25%	92.93%
Mean return	6.20%	8.24%	4.70%	5.35%	7.25%	12.57%	5.29%
Standard Deviation	28.74%	34.79%	22.17%	24.92%	30.95%	45.51%	24.80%
Sharpe ratio	21.57%	23.68%	21.19%	21.46%	23.41%	27.62%	21.32%
VAR	-28.93%	-31.14%	-28.85%	-26.21%	-31.58%	-40.79%	-25.89%
Conditional VAR	-13.52%	-19.00%	-15.55%	-13.54%	-15.14%	-25.08%	-13.54%
Sortino Ratio	5.73%	6.36%	4.49%	5.28%	6.38%	8.01%	5.29%
Omega Ratio	0.55	0.70	0.58	0.58	0.62	0.74	0.55
Downside drawback	-0.50	- 0.53	- 0.49	- 0.45	- 0.44	- 0.56	- 0.44

From the table above, the short fence portfolio outperformed all other portfolios on a risk-adjusted returns basis since it had the highest average return (12.57 per cent), Sharpe ratio (27.62 per cent), Sortino ratio (8.01 per cent) and Omega ratio (0.74). However, the outperformance was due to the high risk of the portfolio since it had the highest standard deviation (45.51 per cent), VAR (40.79 per cent) and conditional VAR (25.08 per cent). The high risk of the portfolio is due to its exposure to both the upside and downside of bond price

movements (see Figure 1.6) since profits and losses on the portfolio are not capped. Bond prices were highly volatile over the period which led to high profits and losses on the portfolio. The short fence portfolio performed well on a risk-adjusted returns basis and its average return of 12.57 per cent per annum is well above the return on the underlying bond over the same period.

On a risk-adjusted returns basis, the call spread portfolio underperformed the bond-only portfolio since it had a lower Sharpe ratio (21.19 per cent versus 21.32 per cent), Sortino ratio (4.49 per cent versus 5.29 per cent). However, its Omega ratio was higher by 0.03. Since the Omega ratio is a better measure of performance than the Sortino and Sharpe ratio as it does not make any distributional assumptions (see section 4.1 above), it would not be unjustified to say that the call spread portfolio performed slightly better than the bond-only portfolio on a risk-adjusted returns basis. This could be due to one of three reasons; firstly, the higher Omega ratio could be due to the lower volatility of the portfolio as measured by the standard deviation of returns (22.17 per cent compared to 25.80 per cent of the bond-only portfolio). Secondly, one should note that this ratio is the ratio of the probability weighted average gains to the probability weighted average losses of the portfolio. Therefore, the low risk of the call spread portfolio may have led to fewer losses than the bond-only portfolio due to its lower risk. Thirdly, this could be due to losses being capped within the range of strike prices used for the call options in the portfolio (see Figure 1.5) as bond prices were range bound for most of the periods. As interest rates in the South African market move in cycles depending on the prevailing economic conditions, bond yields will thus be range bound as the South African Reserve Bank implements its inflation targeting policy. Hence, bond prices will be range bound most of the time.

One should note that, we have assumed that there are no transaction costs and the bid-ask spread is zero. As mentioned earlier in section 3 of this paper, this would not be true in the real world. The effect of transaction costs and bid-ask spread is beyond the scope of this paper due to data limitations. Furthermore, this will add more complexity as we might need two skew

volatility surfaces (bid and ask volatility surface) and transaction costs includes both explicit and implicit costs.

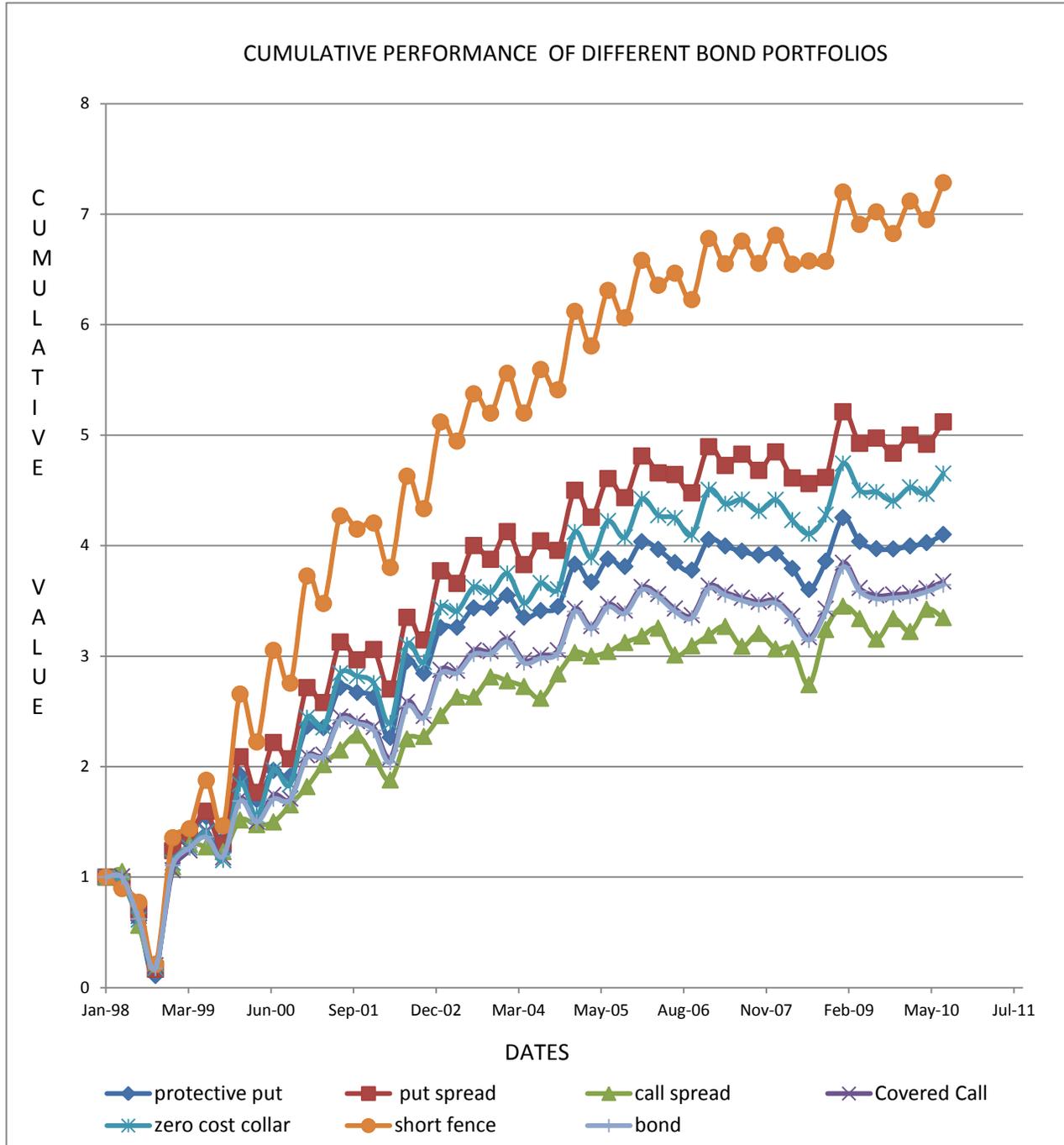


Figure 2: Cumulative performance of different option strategies on a 10-year bond over the period from 05/01/1998 to 06/07/2010

Figure 2 above shows the cumulative performance of different portfolios for the period under investigation. Cumulative performance shows how a portfolio would have performed, if an investor invested one rand from the beginning till the end of the period under consideration. All portfolios have more than tripled the amount of one rand that would have been initially invested. The short fence portfolio outperformed all other portfolios on a cumulative performance basis. This is consistent with what was observed in table 3 above when it outperformed all other portfolios on a risk –adjusted returns basis. All portfolios had negative returns during the first period which was mainly due to the fall in the bond price because of a coupon payment during the period and yields were increasing resulting in a decrease in bond prices. One would not have expected the protective put and zero-cost collar portfolios to fall as much as the bond-only portfolio since their losses are capped (see Figure 1.4 and 1.5). However, it should be noted that losses are capped at strike prices which are 95 per cent of the spot bond price for both portfolios. Therefore, when bond prices are falling but have not fallen more than 5 per cent, then they have not reached the protection level of the protective put and zero-cost collar portfolios, in this case losses are not capped.

The put spread portfolio has also outperformed all other portfolios except the short fence portfolio on a cumulative basis. The call spread portfolio underperformed all other portfolios including the bond-only portfolio which is also consistent with the results in table 3 above. It is assumed that an investor does not disinvest in the portfolio during the period.

The performance of these portfolios is dependent on what time period did we start investing in the portfolio. Figure 2 shows cumulative performance as of the beginning of 1998. We will examine how cumulative performance would be if one rand is invested in each of the portfolios at the beginning of 2005. This will show that investing in these portfolios depends on the timing of option strategies and they are dependent on bond prices, which are affected by changes in interest rates. Interest rates depend on prevailing economic conditions as mentioned previously and they have changed significantly over the last decade.

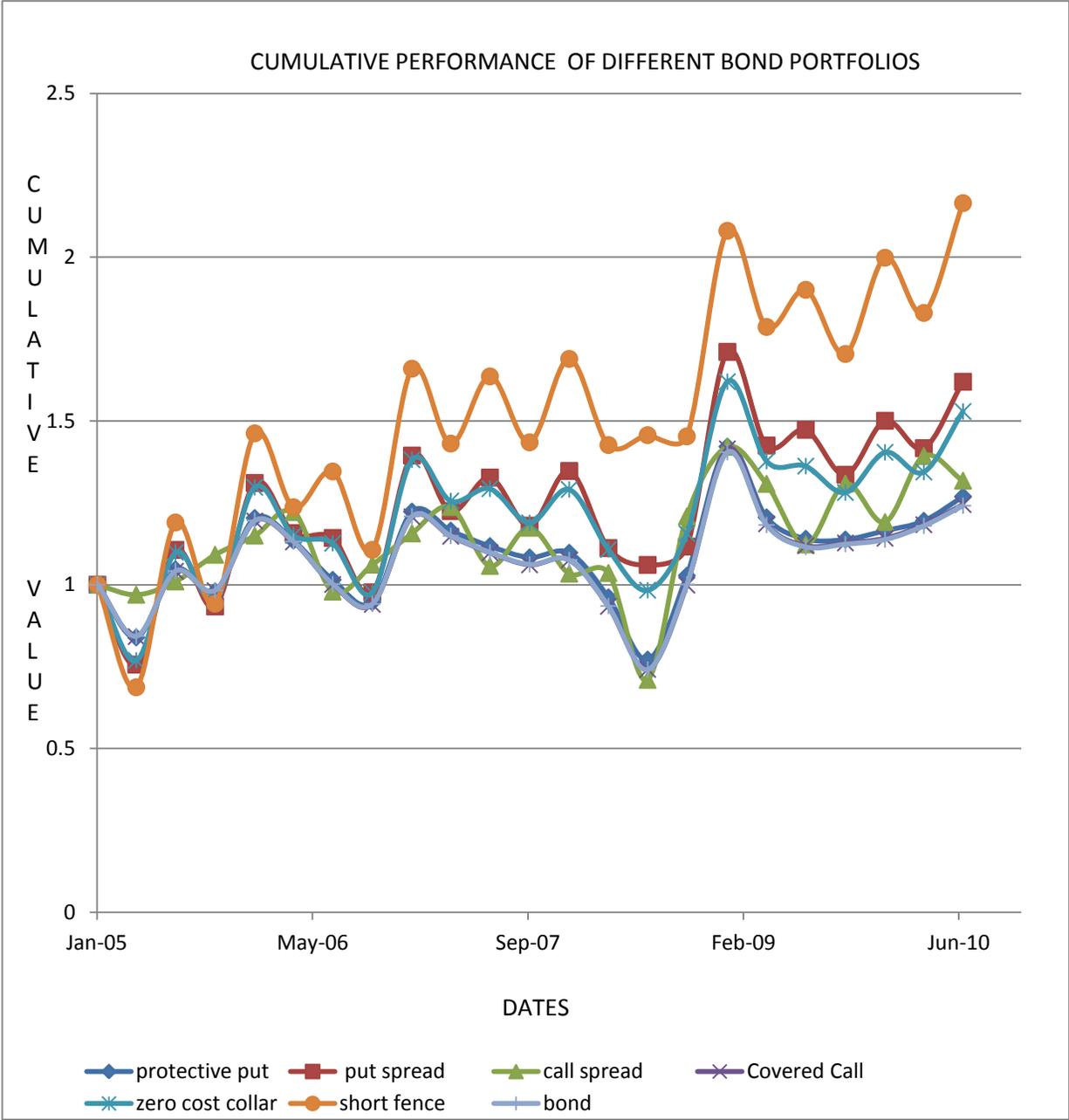


Figure 3: Cumulative performance of different option strategies on a 10-year bond over the period from 05/01/1998 to 06/07/2010

Figure 3 above shows the cumulative performance of all portfolios if an investor were to invest one rand at the beginning of 2005 in each of the portfolios until the middle of 2010. The performance of the portfolios is different from that observed in Figure 2 above. The short fence

portfolio has outperformed all other portfolios as previously observed. The call spread portfolio which underperformed all other portfolios on a risk-adjusted returns basis and cumulative basis as can be observed from table 3 and Figure 2 respectively, performed better than the bond-only and protective put portfolios. Therefore, cumulative performance of the portfolios is dependent on the time at which the investor starts investing in the portfolio. This will require investors to be able to time the market and the latter is one of interesting topics in Finance currently. Timing the market requires skills of asset managers as well as hedge fund managers whom are one of the players in the bond option market. Active bond portfolio management is important in order to be able to earn superior risk-adjusted returns since they enable investors to manage their portfolios effectively and keep risks as low as possible whilst maintaining the upside potential.

6.2) Performance statistics and Cumulative Performance of all portfolios with an underlying 5-year bond

Table 2: Performance statistics of different option strategies on a 5-year bond over the period from 05/01/1998 to 06/07/2010

	protective put	put spread	call spread	Covered Call	zero cost collar	short fence	bond
Min return	-45.50%	-43.21%	-43.26%	-40.57%	-38.70%	-40.16%	-37.27%
Max return	99.35%	57.81%	84.47%	62.56%	75.21%	70.82%	69.06%
mean returns	4.69%	5.34%	3.55%	4.47%	6.06%	8.33%	3.67%
Standard Deviation	23.92%	25.63%	19.22%	22.66%	26.74%	33.38%	19.35%
Sharpe ratio	19.60%	20.84%	18.46%	19.71%	22.68%	24.97%	18.96%
VAR	-22.82%	-26.50%	-22.43%	-24.28%	-26.75%	-31.33%	-21.20%
Conditional VAR	-12.48%	-16.53%	-14.54%	-13.70%	-17.00%	-21.94%	-10.37%
Sortino ratio	4.92%	4.96%	3.93%	4.60%	5.65%	6.41%	4.43%
Omega ratio	0.51	0.62	0.29	0.58	0.70	0.87	0.55
Downside drawback	-0.45	-0.43	-0.43	-0.41	-0.39	-0.40	-0.37

For completeness, we now examine how the portfolios would have performed if option strategies were on a 5-year bond as an underlying instead of a 10-year bond. The table above shows the performance statistics of all portfolios for the period 05 January 1998 to 06 July 2010. The short fence portfolio outperformed all other portfolios on a risk-adjusted returns basis as was observed in table 3 above. It also had the highest risk relative to other portfolios as can be seen by its high standard deviation (33.38 per cent), VAR (31.33 per cent) and conditional VAR (21.94 per cent). The call spread portfolio underperformed all other portfolios as previously observed.

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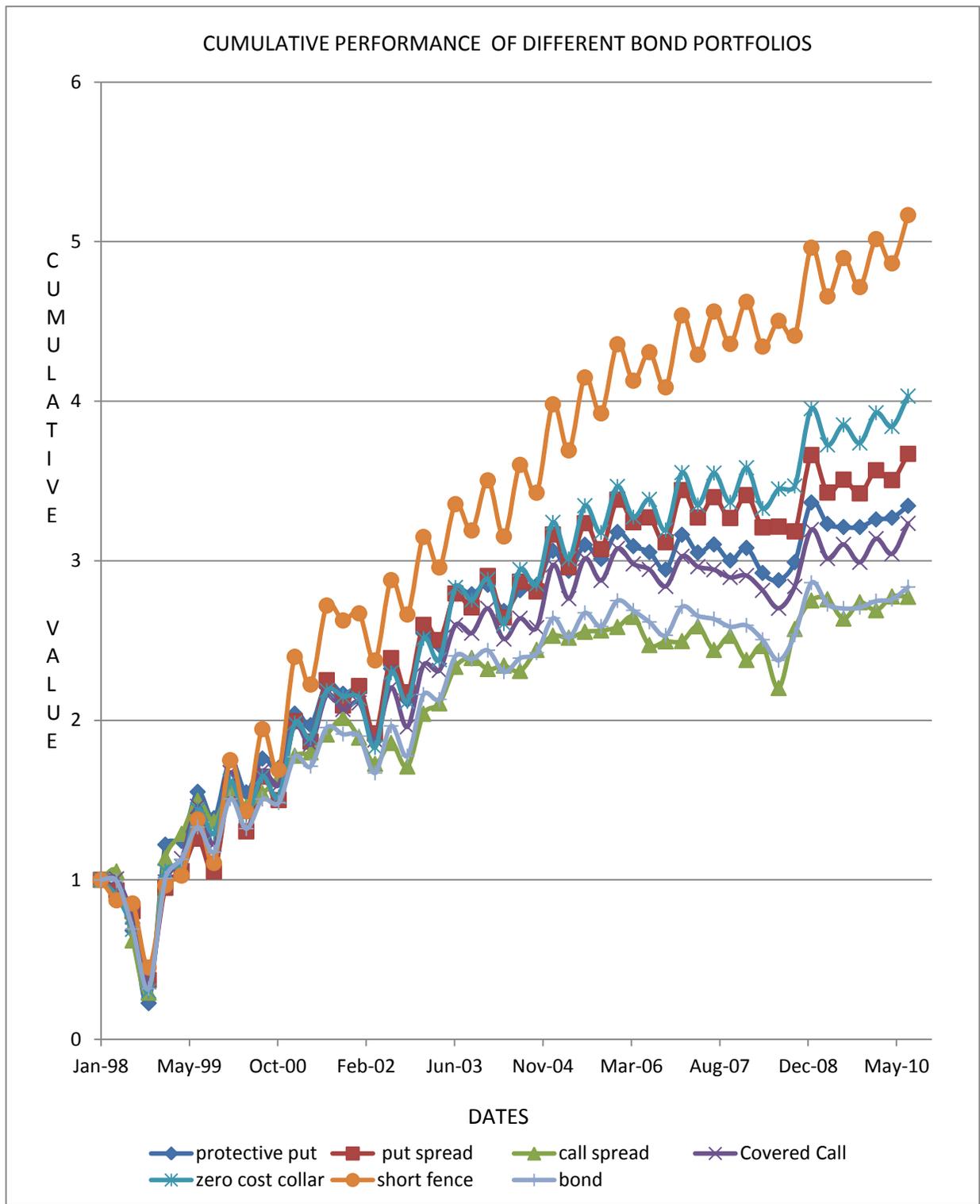


Figure 4: Cumulative performance of different option strategies on 5-year bonds over the period from 05/01/1998 to 06/07/2010

The cumulative performance of the portfolios in Figure 3 is different to that observed in Figure 2. However, the short fence and call spread portfolios did outperform and underperformed all other portfolios as previously observed respectively. The zero-cost collar portfolio outperformed the put spread portfolio when 5-year bonds are used as an underlying in the portfolio.

The results above are consistent irrespective of whether a 10-year or 5-year bond is used as an underlying in the option strategies. The short fence portfolio was the best performer whereas the call spread portfolio was the worst performer amongst all other portfolios. If cumulative performance is examined at the beginning of 2005, the short fence portfolio still performed better than all other portfolios on a cumulative basis and the call spread portfolio outperformed the put spread and bond-only portfolios.

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7 Summary

The objective of this paper is to analyse the performance of 3-month bond option strategies so as to ascertain which strategies would have outperformed the underlying bond over the period from 05 January 1998 to 06 July 2010. The methodology used is to buy a hypothetical government bond at the beginning of a 3-month period and also buy/sell an option strategy on the bond. The strategy is rolled over at the end of 3 months for the period under consideration. The bond-only portfolio is used as the benchmark portfolio for analysis.

Option strategies considered were the protective put, call spread, put spreads, covered calls and short fence. We found that the short fence outperformed all other portfolios including the bond-only portfolio on a risk-adjusted returns and cumulative basis whereas the call spread portfolio underperformed. Although the portfolios induce non-linearity in the payoff of bonds, this comes at a high risk as they add more volatility to the bond portfolios. This is seen by the high standard deviations of portfolios with an option overlay relative to a bond-only portfolio. Cumulative performance of portfolios depends on when the investor started investing in the portfolio as the performance of bond portfolios with or without options depend on prevailing economic conditions, particularly, changes in interest rates.

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