PRICING OF SINGLE STOCK FUTURES OPTIONS IN SOUTH AFRICA

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ABSTRACT

“JSE tops all single stock futures markets” (Business Report, July 13, 2007). The Johannesburg Securities Exchange’s (JSE) single stock futures market is the largest in the world. This research investigates the forecasting abilities of implied volatility models for South African single stock future options and warrants. Furthermore, the pricing premiums between the two derivative instruments are investigated, as this presents a potential arbitrage opportunity for the market makers of the warrants.

Historical volatility is used as a comparative forecast method to the implied models. The calculated historical and implied volatilities are compared retrospectively to the realised volatility to ascertain which forecasting methodology is superior. Inter-bank implied volatility for single stock futures options is compared to implied volatility for warrants with the same underlying shares to determine pricing premiums.

The simple historical volatility model is shown to be a better forecast of realised volatility for both derivatives. Warrants are charged at a significantly higher premium than what the market makers, amongst themselves, are willing to pay for the same underlying shares with single stock futures options.

DECLARATION

I, Brian Cameron declare that this research report is my own, unaided work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the University of the Witwatersrand, Johannesburg. It has not previously been submitted for any degree or examination to this or any other university.

Brian Cameron

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DEDICATION

This work is dedicated to my wife Celia, and sons Troy and Ross for making the sacrifices that enabled my sustained commitment to this project.

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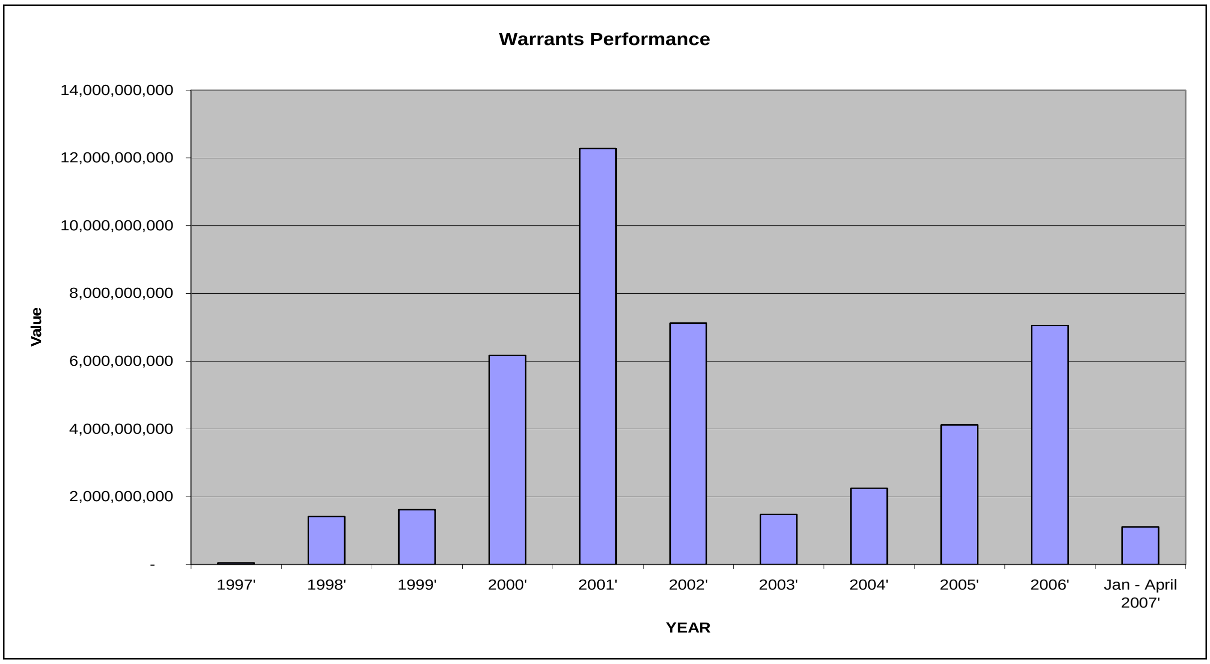
CHAPTER 1 : INTRODUCTION AND BACKGROUND

1.1 <u>CONTEXT OF THE STUDY.</u>

“JSE tops all single stock futures markets” (Business Report, July 13, 2007). The Johannesburg Securities Exchange’s (JSE) single stock futures market is the largest in the world. In the first quarter of 2007 over 44 million derivative contracts were traded on the new exchange. The single stock futures and options on futures market has grown in leaps and bounds since its inception in 1999.

The warrants market by contrast, which emerged in 1997 in South Africa, went through a rapid growth phase and later tapered off. It appears to be once again trending upwards. (Figure 1 below). This market established growth as a financial instrument offering the ‘man on the street’ investor an opportunity to benefit from gearing with access to some of the major blue chip stocks without having to lay out large sums of capital to gain the same exposure.

Figure 1 Warrants trades by volume (JSE 2007)



Apostolellis and Maxwell (2002) conducted the first research into warrants markets in 2000. At that stage the growth in the markets from 1997 had been substantial. The market at the time could be considered to be in a growth phase which since 2000 has become even more sizeable with some 300 warrants currently being offered (there were only ± 100 in 2000). The market, however, appeared to peak with R 12 Bio worth of trade in 2001. In 2004 trade again increased. Figure 1 shows the trend in the warrants market since it's inception.

In addition to the warrants as a derivative, the South African Futures Exchange (SAFEX) launched the Single Stock Futures (SSF) market in 1999. In a manner the warrants and the futures are competing instruments that offer greater gearing for investors. In September 1999 SAFEX also introduced options that could be taken on the Single Stock Futures. The market for options on SSFs has also grown dramatically and can be considered a competing type of instrument to the warrants.

The issuers of warrants are the market makers providing the liquidity for trade, and have a large degree of control over the markets, as described in the work by Koorts and Smith (2002). Subsequent to the launch of the options on the SSF by SAFEX, an opportunity for warrant issuers came to light. They now had a mechanism to issue the warrants and take a position on the same underlying by buying the SSF option. This provides an opportunity for the issuers to realise the difference in the volatility between the warrants that they sell and the volatility on the options for the same underlying. In essence it provides the issuers of warrants with an opportunity to profit by trading the volatility difference between the instruments. This is not a risk free profit as there is risk for the writers of the options in that they have to delta hedge the warrant and fund the margin requirements on the futures, which is open to basis risk. The cost associated with listing warrants is higher than the costs for the SSFO due to listing costs, compliance requirements and having to be a member of the exchange.

Apostolellis' (2000) research at the time was conducted shortly after the Single Stock Future Options (SSFO) came on to the market and was not considered as a comparative benchmark in terms of the overpricing of the warrants.

1.2 PURPOSE OF THE STUDY

The purpose of this study is to determine:

Whether there has been an improvement in the premium pricing of warrants since the research in 2000

Whether there is a correlation between the issue of warrants for various underlying stocks and the options available on the single stock futures option markets

To establish if issuers gain an opportunity by trading the volatility of the SSF options against the volatility of the warrants.

1.3 PROBLEM STATEMENT

The purpose of this research is to establish if implied volatility models are superior in their forecasting ability of future volatility when compared with a simple historical volatility model for the pricing of SSFO and Warrants in South Africa (SA), and also if there is a significant pricing premium between the two derivative instruments.

1.3.1 Sub Problems.

To establish which methodology provides better forecasting when pricing SSFO as listed on SAFEX: the Black Implied volatility model or a simple historical volatility model.

To establish which methodology provides better forecasting when pricing South African Warrants as listed on the JSE: the Black Scholes Implied volatility model or a simple historical volatility model.

To compare the pricing premiums of the warrants and SSF options for the same underlying equity.

1.4 DELIMITATION AND LIMITATIONS

The study will be limited to the South African market and to the limitations with respect to data acquisition. Warrants in particular are issued by registered financial institutions. These institutions themselves as issuers are the market makers, and therefore provide the liquidity. Data such as the open interest for warrants is not published.

Volatility is a function of the price of an option when using the option pricing models. Traders pricing the option they want to sell or buy may use historical data in the estimation of volatility as and input into these models. This may be in the form of a blend of moving averages, mean absolute deviations or standard deviation. The comparison of historical volatility with the models is therefore auto correlated to a degree.

1.5 SIGNIFICANCE OF THE STUDY

The significance of the study is a review of the current warrants market now that is has matured and has been operational for almost 10 years. The former research by Apostolellis in 2000 was done when the market was in an emerging stage and had been operational for only three years.

The launch of alternative geared investment products such as the SSF options provides a new area of research that has not been considered in the SA market before. The comparison of the volatility (and hence the pricing premiums) between the SSF options and the warrants will highlight potential opportunities for warrant issuers at the expense of the retail investor.

The pricing of options is an area of research that has had extensive attention and yet there are still no definitive answers. Volatility forecasting has become a requirement in terms of corporate governance; the Basle Accord in 1996 essentially makes it compulsory for financial institutions around the world to use it as a risk management tool. (Poon & Granger, 2003). Policy makers these days use market estimates of volatility as an indicator of the financial markets and economy. These compliance based forecasts are evaluations of the risk of the underlying asset classes and not the risk of the equity derivatives themselves. The topic of this research is focussed on the pricing premiums for equity derivatives specifically. In the context of the governance requirements these derivative instruments may form part of the risk management strategies employed for compliance.

It is possible by considering the liquidity of the markets and by evaluating the dynamics between the futures, options on futures and the warrant market, to identify whether there are any indicators that could lead one toward a trading strategy. Tavakkol (2000) considers the cross correlation between the S&P options and the underlying S&P futures contracts and determines that a momentum trading strategy can be implemented since the option implied volatilities are predictable.

1.6 ASSUMPTIONS

The influence of trading strategies cannot be accounted for since the details of the trades are not known.

Daily closing prices are assumed to be the traded price for the transactions on the day.

CHAPTER 2 : LITERATURE REVIEW

2.1 SSF OPTIONS AND WARRANTS ON THE JSE.

The difference between an SSF option and a warrant is the fact that the warrants are options that are listed on the stock exchange rather than on the futures market. The underlying in each is different one being a stock as underlying the other a future. Furthermore warrants are only options issued with the underlying being a particular equity or basket of equities. The underlying for an option can be any item, and can range from gold or maize to equities.

Single Stock Futures Options (SSFO) are options as issued by SAFEX on futures contracts. These futures contracts are issued for various equity based stocks, as well as for some of the indices on the JSE. One can then buy an option, a ‘call’ in the case where one speculates that the price of the future will rise before the expiry of the futures contract, and a ‘put’ in the case where one expects the price to drop.

SSFO and warrants in the context of the South African markets are therefore very similar instruments since they are both derivatives with underlyings that are based on equity stocks. The only difference is the issuing authority. In the case of warrants the issuers are banks. The SSFO are intended to be traded openly by the members of SAFEX, however to date the issuers are primarily banks and large institutions such as the insurance companies. Furthermore due to the fact that banks are the market makers for warrants an important difference is that one cannot short a warrant, whereas the option on a future can be shorted. The limitations on shorting warrants are largely due to credit requirements. SAFEX manages this situation through the close monitoring of the margin requirements which need to be fulfilled on a daily basis.

There is also a difference in the trading mechanism between the SSFO and the warrants. In accordance with the requirements of a futures contract an initial margin and the daily margin need to be maintained as the common requirement.

Conceptually if you bought a put option on both a future and stock of the same name for the same period and the stock did not move at all, the warrant would be worthless at maturity but the option on the single stock future would not be so, it would have accrued the risk free interest rate over the period.

The efficiency of this options market has not previously been evaluated and the fact that the market makers for the retail warrants market use it as a hedge makes for an interesting research topic.

2.2 OPTIONS, OPTIONS ON FUTURES AND WARRANTS PRICING.

2.2.1 Options.

An option gives the holder the right but not the obligation to buy or sell an asset by a certain date for a certain price. The most common option pricing model is that of Black and Scholes (1972). This model is based on the following assumptions:

The stock price corresponds to a log normal model and the volatility and expected returns are constant.

There are no transaction costs or taxes

There are no dividends on the stock.

There are no riskless arbitrage opportunities.

Trading is continuous

Investors can borrow or lend at the same risk free rate

The risk free rate is constant

The formulae for pricing options with the Black Scholes is as follows:

For a call option: $c = S_0 N(d_1) - Ke^{-rT} N(d_2)$

For a put option: $p = Ke^{-rT} N(-d_2) - S_0 N(-d_1)$

Where $$d_1 = \frac{\ln(S_0 /) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(S_0 / K) + (r - \sigma^2 / 2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

c = current call option price (cents)

p = current put option price (cents)

S_0 = current stock price (cents)

K = strike price (cents)

T = time to expiry (years)

r = risk free rate (%)

σ = volatility of the stock price (%)

The function $N(x)$ is the cumulative probability function for the standardised normal variable.

The other conventional pricing model is the binomial model as developed by Cox, Ross and Rubenstein (1978). This model is based on a lattice model.

Assume S_o is the price of the underlying asset, and the option price is f. If the time to maturity is T and the asset price during this period can move up or down from S_o to a new level, $S_o u$, or down to $S_o d$ (u>1;d<1). The values of u and d (i.e. the amount the share price moves to a higher level or a lower level) are actually determined by the volatility of the stock.

$u = e^{\sigma\sqrt{\Delta t}}$ (the martingale probability.)

$$d = \frac{1}{u}$$

where σ = the volatility

Δt = the length of one time step on the tree

For a risk neutral situation the probability of the price movement is :

$$p = \frac{a-d}{u-d}$$

Where $a = e^{r\Delta t}$

r = risk free rate

p = risk neutral probability

This risk neutral probability is used to value the option at each point in the binomial tree, working backwards from a stock price that could be either above or below the stock price. The differential at each node between the stock price and the strike price is the value of the option, unless it is ‘out of the money’, in which case the value of the option is zero.

2.2.2 Options on Futures.

Options on futures contracts are in effect no different to the common options contracts; the only difference is that the underlying asset is a futures contract instead of a commodity or stock. These types of options are a tool for investors as portfolio insurance and are often utilised by large institutional investors. A futures option is the right, but not the obligation to enter into a futures contract at a certain future price by a specified date.

There are a number of reasons for the popularity of futures options as opposed to standard options; the main reason according to Hull (2000) is the liquidity. Furthermore a futures price is known immediately whereas a spot price for a share may not be readily available. Futures on commodities are also easier to trade than the commodities themselves and most futures options are settled in cash since many are exercised prematurely. Market efficiency is also cited as a reason that these options are favoured.

Hull (2000) suggests the use of the Black model rather than the Black-Scholes model for the pricing of Futures options. This assumes that the futures prices behave in the same way as a stock paying a dividend yield at the domestic risk free rate.

The formulae for pricing future options with the Black model is as follows:

For a call option, c: $c = e^{-rT}\left[\ F_0 N(d_1) - KN(d_2)\ \right]$

For a put option, p: $p = e^{-rT}\left[\ KN(-d_2) - F_0 N(-d_1)\ \right]$

Where $$d_1 = \frac{\ln(F_0 / K) + \sigma^2 T / 2}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(F_0 / K) - \sigma^2 T / 2}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

c = current call option price (cents)

p = current put option price (cents)

F_0 = current futures price (cents)

K = strike price (cents)

T = time to expiry (years)

r = risk free rate (%)

σ = volatility of the stock price (%)

The function $N(x)$ is the cumulative probability function for the standardised normal variable.

Ramaswamy and Sundaresan (1985) conducted research into the valuation of options on futures contracts. The findings specifically relate to the significant implications of the interest rates that are applied to the valuation methodology; they demonstrate that a stochastic interest rate produces more reliable results than a constant interest rate, as is normally applied if the Black methodology is used. According to them the valuation of these options differs from the valuation of common options in two ways. The futures price needs to be determined as a function of the underlying, and even when the underlying does not pay dividends it may be optimal to exercise the option prematurely.

Research into the efficiency of the futures options markets by Ball and Tourous (1986) indicates that for the three markets considered, the Deutsche Mark futures option on the Chicago Mercantile Exchange, the Gold futures option contracts on the Commodity Exchange of New York and the sugar futures option traded on the New York Coffee, Sugar and Cocoa Exchange there were very few opportunities for riskless arbitrage and that the markets were efficient. They investigate the relationship between the volatility of futures prices and the time to maturity of the underlying futures contract and find no conclusive trend, but determine that the volatility does vary systematically with the time to maturity.

Shastri and Tandon (1986) conducted research into the efficiency of the market for options on the S&P 500 and German Mark futures. In contrast to the findings by Ball and Torous (1986) they find that the market prices deviate substantially from the model prices. The model is based on the Black model and the model derived by Geske and Johnson which prices the assets as a sequence of compound options.

Poon & Granger (2003) studies indicate that specifically for options on futures, Amin and Ng (1997), Edey and Elliot (1992) and by Fung and Hsieth (1991) establish that the forecasting power of implied is significant for interest rate futures. For commodities Day and Lewis (1992), Claessens (1995), Marten and Zein(2002) and Szakmary (2002) find that implied volatility is a superior indicator according to Poon & Grangers studies.

The common Black and Binomial option pricing methodology that is used for the pricing of stock options can be applied to futures options.

2.2.3 Warrants

Warrants are options in the definition of the warrants as traded on the JSE. The difference between these options and conventional options is the fact that they are limited to the shares as traded on the JSE and the period of the options is generally six months. The pricing models for warrants can be any of the conventional methodologies as applied to normal options, i.e. Black-Scholes or binomial methodologies as described above. Apostolellis and Maxwell (2002) used the conventional Binomial model for their research into the JSE warrants markets.

2.3 OTHER MODELS

Following the development of the Binomial lattice models there has been the development and research into trinomial trees by Boyle (1986). Baule and Wilkens (2004) attempted to refine the binomial model and make it what they call “lean”. In an attempt to simplify the numerical efforts required to calculate these models. They derived a lean method that produces results without a loss of accuracy.

Branger (2004) uses “cross-entropy” as a new methodology and Foster and Whiteman (2006) use Bayesian prediction and Entropy in some of the more recent methodologies. Foster and Whiteman(2006) claim that the Bayesian techniques account for two additional aspects which other conventional models omit: the ability to integrate out what they call “estimation risk” and they are able to incorporate any non-sample information that may arise from an informative prior.

The Jump diffusion models have also seen development recently with the Lévy process which is a new area of focus for option pricing as a form of stochastic model. A Lévy process according to Huang and Wu (2004) is a continuous time stochastic process with independent stationary increments. These processes include jump processes and they specifically use the framework of time changed Lévy processes so that there are a number of jump diffusion stochastic volatility models that can be generated. They conducted research using these models for the S&P 500 index options and they determine that the high frequency jump structures always outperform the low frequency Poisson jump specification. They also establish that the stochastic volatility can be related to two sources; the instantaneous variance of the diffusion component and the arrival rate of the jump component.

There are numerous option pricing models. The primary issue in option pricing irrespective of which methodology is used is the forecasting of volatility since this is the only unknown. The forecasting of volatility can be further split into two broad categories, option based models and time series based models (Poon & Granger, 2003). In their definition the time based data is considered to be that which utilises historical information, whereas the option base is a reverse calculated volatility or implied volatility.

Within these two categories there are also a number of different models that can be used, ranging from Autoregressive Conditional Heteroskedasticity (ARCH) and Generalised Autoregressive Conditional Heteroskedasticity (GARCH) to stochastic models. These are all discussed in the following sections.

The simplicity of the Black Scholes model is an attractive feature. Arnold, Nixon and Shockley (2003) develop simple tables using MS Excel™ for the pricing using Intrinsic Standard Deviation (ISD) as an input. Tavakkol (2000) also uses the simplified Black Scholes model for the research into determining correlations between futures and options and establishing a momentum based trading strategy. Recent research in the South African markets by Apostolellis and Maxwell (2002) used the binomial model and Koorts and Smith (2002) use the simple Black Scholes pricing model in their research. In this research the Black and Black Scholes model will be used due to its simplicity and to facilitate the ease of computation considering the large sample of data analysed.

2.4 VOLATILITY.

According to Poon & Granger (2003) “Volatility is the most important variable in the pricing of derivative securities.” In order to price options one needs to know the volatility of the underlying asset.

In the options world “vol” or volatility is the actual terminology used by traders instead of the price of an option. This is due to the fact that the vast majority of traders use the Black Scholes model and based on this model four out of the five inputs can be considered to be observable: time to maturity, the strike price, the risk free rate, and the current price of the underlying asset. Volatility is the only exception.

All option pricing models are dependent on one common variable, volatility. This variable is forecast in many different manners and there have been many different publications, models and studies to try and establish a consistent model to forecast future volatility. In essence the majority of these are based on using the deviations or variation in the stock or underlying returns. These methods range from using historical volatility of standard deviations through to what is known as intrinsic standard deviation (ISD). Volatility is often referred to as standard deviation or variance.

Ederington and Guan (2006) conducted research into the measurements of historical volatility from Historical Standard Deviation (HSD), they find that adjusted mean absolute deviation produces a better measure of forecast future volatility than historical standard deviation and is as good as the complex GARCH methodology.

Shastri and Tandon (1986) conducted their test work in numerous different markets and over various periods. They produce results that show that another shortcoming to HSD as a forecast of future volatility is the fact that the deviation and variance are functions of a squared return deviation which is disproportionately responsive to outliers. The only case where the model is not sound is when the markets differ significantly from normality and a test for this must be conducted.

There are many differing opinions on the sample period to be used when using HSD and how far one would need to go back to derive a reasonable predictor. Figlewski (1997) suggests that historical standard deviation is best measured over a longer period than the forecast horizon. The time to maturity was identified by Bekkers (1981), Ball and Tourous (1986), Figlewski (1993) and Yu and Chen (2002) as being a key factor influencing the pricing of options. Yu and Chen (2002) study the impact of strike prices, time to maturity, volatility and the risk free rate on warrant pricing and establish that there are biases induced by these variables.

Ederington and Guan (2006) confirm the findings by Figlewski (1997) in their research. Traditional texts such as Hull (2000) recommend using daily data over the most recent 90-180 days; however as a rule of thumb a period that is the same as the forecast period can be used.

They evaluate the differences between using the Historical Standard Deviation and the Implied Standard Deviation and the findings are that HSD produce larger estimates of volatility than the ISD. They find that the HSD biases the model toward overvaluation on long maturity options, and that the reverse is true for the short term maturity options. What is significant in the research is that they find that the models for both implied and historical volatility deviate from the market prices, but that the mispricing of the options is related to the degree to which the option is ‘in’ or ‘out’ of the money, and the time to expiration.

Apostolellis and Maxwell (2002) compared the predictive abilities of HSD and ISD for realised standard deviation and found that HSD was a better predictor than ISD. Similarly Day & Lewis (1992), Lamoureux & Lastrapes (1993) and Canina & Figlewski (1993) also found the ISD to be biased.

There are many considerations such as the forecast periods considered that have a great influence on these predictive abilities. Using Hull’s (2000) rule of thumb may not be the most appropriate measure. Findings by Figlewski (1997) and Ederington and Guan (2006) suggest that when using HSD longer periods are more appropriate.

Ederington and Guan (2006) highlight some shortcomings with HSD as an estimator of future volatility. They state that the HSD only considers the informational content of past returns and there is no accounting for any other possible influential information and HSD also assumes an equal weighting of all past squared return deviations dating back to a random date and ignores any observations prior to that date.

Engle (2004) developed the ARCH and GARCH models to respond to the latter problem. The GARCH models make use of a weighting to take increase the influence of the more recent data. It is assumed this would have more information about the immediate future than the older data. The GARCH models are complex and there is no clear indication that they produce more accurate results.

Poon & Granger (2003) have compiled what is probably the most comprehensive evaluation of the forecasting performance of various volatility models. They evaluated the results from 93 published papers on the topic taking into consideration the various methodologies, applications and empirical findings. They compare all outcomes of the publications and provide details as to the performance of the various models. Poon & Granger (2003) report that out of the 93 publications HSD was found to be on a par with the complex GARCH models. ISD outperformed all other models which confirms the findings of Ederington and Guan (2006).

Huang and Chen (2002) however compared various stochastic models, the Hull and White model, GARCH and Exponential Generalised Autoregressive Conditional Heteroskedasticity (EGARCH) with the Black Scholes model using both HSD and ISD as inputs to the times series and Black Scholes and Hand White models. In all cases they demonstrate that the HSD was found to be the least accurate. The Hull and White model using ISD as an input outperformed the GARCH, Exponential Autoregressive Conditional Heteroskedasticity (EARCH) and Black Scholes models.

According to Engle (2001) the ARCH and GARCH models were developed to model what is considered to be problematic with some of the assumptions with the traditional variance models. In standard least squares models one of the conditions is that the variances should be constant. This is often not the case, and if variances are significant then the results from the standard least square analysis could be considered unreliable.

This situation is known as heteroskedasticity, and in the GARCH and ARCH models the heteroskedasticity is the variance one attempts to model. More specifically in the financial sector these models for heteroskedasticity have been developed to deal with time series data such as stock prices over time in an attempt to determine and measure volatility.

Huang and Chen (2002) make a comparison of the Hull and White Stochastic Volatility model with Black Scholes model. The dataset was rather limited only considering 10 covered warrants traded on the Taiwan Stock Exchange (TSE). The empirical results indicate that the Stochastic Volatility model using implied volatility out-performs the others in predicting warrants prices. They use both time series and implied volatility in the research. For the time series approach they use three models including the historical volatility, the GARCH model and the EGARCH models.

Lehar, Scheicher and Schittenkopf (2002) conducted similar research comparing three methodologies, Constant volatility, GARCH and Stochastic Volatility models using the FTSE 100 option prices. The data set used was comprehensive consisting of 65,549 option contracts traded on 1210 days. Their finding opposes Huang and Chen (2002) in that they find that GARCH dominates Stochastic Volatility. However they do find that Stochastic Volatility is better than Black Scholes which is complimentary to Huang and Chen.

Tavakkol (2000) uses volatility spread in his research. He makes use of implied volatility to determine the price pressures in the option markets. Chiu, Lee, Lin and Chen (2005) use a modified GARCH model, the bivariate GARCH, in their study of the Warrants markets in Taiwan, a similar type of research where they were looking for leading relations between the options markets and the underlying.

Koorts and Smith (2002) investigated the mechanics of the warrants markets in South Africa and specifically evaluated it from the issuer's perspective. They conducted empirical analysis on the warrants pricing using implied volatility data.

In terms of some of the newer mathematical modelling applications Blynski and Faseruk (2006) use neural network methodologies and make comparisons to the Black Scholes model using both historical and implied volatility. Blynski and Faseruk (2006) use simple neural networks and find they are better than Black Scholes with historical data. When using implied volatility the Black Scholes outperforms the simple neural network method. They further develop a hybrid neural network model with implied volatility and this is found to be a better predictor than the Black Scholes model. They acknowledge that the use of neural networks by the average investor is limited. In order to construct the models one needs enormous amounts of data that may not be easily accessible to all.

Poon & Granger (2005) in their comprehensive evaluation of volatility forecasting literature have demonstrated that Implied volatility is a better indicator than historical volatility. The table below is an excerpt from Poon & Granger's (2005) research into the various methodologies. It indicates that the Implied volatility is the superior indicator, followed by Historical volatility and then the GARCH methodologies.

Table 1 Summary of outcomes from 66 studies on volatility forecasting methods (Source : Poon & Granger , 2005).

Comparison Outcome	Number of Studies	Percentage of Studies
HISVOL > ARCH	22	56
ARCH > HISVOL	17	44
HISVOL > ISD	8	24
ISD > HISVOL	26	76
GARCH > ISD	1	6
ISD > ARCH	17	94
SV > HISVOL	3	
SV > ARCH	3	
ARCH > SV	1	
ISD > SV	1	

Hypothesis 1.

Ho: Implied Standard Deviation (ISD) for volatility of options traded on the JSE Single Stock Future Options are not better predictors of Realised Standard Deviations (RSD) than Historical Standard Deviations (HSD) of the underlying futures.

Hypothesis 2.

Ho: Implied Standard Deviation (ISD) for volatility of warrants traded on the JSE is not a better predictor of Realised Standard Deviations (RSD) than Historical Standard Deviation (HSD) of the underlying shares.

2.5 PRICING PREMIUMS AND COMPARATIVE STUDIES.

Apostolellis and Maxwell (2002) conducted a study on the pricing efficiency of the warrants on the JSE. The research highlighted the overpricing of the warrants as issued in the South African markets. Apostolellis used the Australian markets as a benchmark and found that the South African markets were overpriced, as to a lesser extent were the Australian markets.

Previous research in comparisons of warrants and options has been done by Chan and Pinder (2000), Hanke and Pötzelberger (2002) and more recently Chiu, Lee, Lin and Chen (2005) and Bartram and Fehle (2007). Chan and Pinder (2000) conducted research into the systematic overpricing of warrants relative to options in the Australian markets. Hanke and Pötzelberger (2000) and Bartram and Fehle (2007) considered European warrants. The research of Chan and Pinder (2000) and Chiu, Lee, Lin and Chen (2005) is most significant because warrants in the Australian and Taiwanese markets are the same derivative instruments as the warrants issued in the South African markets.

Warrants in the US and Europe differ from the Australian and South African warrants. In the South African and Australian/Taiwanese warrants there is no effect on the capitalisation of the company if the warrants are exercised, whereas in the US and Europe additional shares are actually issued upon exercising the warrants, and the warrants are issued by the company itself. In the Australian and South African markets warrants are just another form of option that are issued by market makers for stocks on the relative securities exchange.

Chan and Pinder’s (2000) research considered two major items, namely: tests for systematic differences in the pricing between options and warrants, and secondly, the development of a model for the relative difference between the two securities. Chan and Pinder (2000) find that for the period January 1997 to June 1998 warrants were systematically overpriced relative to options when matched on the basis of the underlying.

Hanke and Pötzelberger (2002) considered the effects of the warrants issuance on the stock price of the issuing company and the subsequent impact on the options written on the same underlying. Bartram and Fehle (2007) considered the liquidity of the markets and the resulting impact on competitiveness.

Koorts and Smith (2002) investigated the mechanics of the warrants markets in South Africa and specifically evaluated this from the issuer’s perspective. Their research is again significant since it considers the warrants in the definition of a warrant in the South African context. They conducted empirical analysis on the warrants pricing using implied volatilities and considered issues such as liquidity, the impact that the market makers have on the pricing and the degree to which issuers can manipulate the markets.

Other research that has recently been conducted in the context of the South African markets is the study by Fedderke and Joao (2001). They investigated the relationship between stock index futures markets and the underlying markets specifically with respect to price discovery. They establish that the futures markets are not as ideally efficient, due to fact that the market is thin and does not trade as frequently as the spot markets. The main finding is that price discovery takes place in the futures markets rather than the spot markets and that the futures markets lead the spot markets.

Shastri and Tandon (1986) in their research into the options on futures contracts develop a trading strategy to exploit their findings of pricing deviations between the models and the markets by testing for efficiency in the markets.

In a comparison between futures markets and options markets Tavakkol (2000) discovers a momentum type trading behaviour that can be applied to the options markets. He conducted a comparison between the S&P options and S&P futures contacts using implied volatility spreads to determine trends. He establishes that the option implied volatilities can be predicted. Momentum trading can be explained as the impact of the trade behaviour in the one market influencing the behaviour in another. In the case of his research he finds that the returns of the futures lead movements in the options markets for up to three months.

Chiu, Lee, Lin and Chen (2005) investigated the lead-lag relationship between warrants and the underlying stocks in the Taiwanese markets. The empirical results did not show any leading relation of the warrants markets over the underlying. The evaluation, however, of the relationship between the volumes traded in warrants markets and the influence on returns on the underlying, highlighted a significant positive correlation. In essence they find that “warrant trading volumes influence the returns of the underlying stocks” (2005, 42). Furthermore in an extension to the research they determine a relationship between volatility and the volumes traded in the warrants markets.

In the South African environment Fedderke and Joao (2001) attempted to establish if there was any informational content in the price on the futures markets that could be used and compared to the spot market prices. In efficient market theory there should be little or no content and the prices in both markets should in theory be the same. A trading strategy for arbitrage could be established if there is the potential to exploit mispricing between the two markets. The results are opposite to that of Chiu, Lee, Lin and Chen (2005) in that they find the derivatives markets lead the spot markets. .

Hypothesis 3

Ho: The difference between the Implied Standard Deviation (ISD) and Realised Standard Deviation (RSD) on the Single Stock Futures Options (SSFO) is not significantly larger than the corresponding difference in the warrants market for the same underlying asset, indicating that there is no evidence of overpricing of SSFO relative to the warrants.

CHAPTER 3 : HYPOTHESES

3.1 HYPOTHESIS 1.

This is a T-test for mean difference of a paired sample:

$$H_0 : \mu_1 = \mu_2$$

Ho: Implied Standard Deviation (ISD) for volatility of options traded on the JSE Single Stock Future Options are not better predictors of Realised Standard Deviations (RSD) than Historical Standard Deviation (HSD) of the underlying futures.

$$H_a : \mu_1 \neq \mu_2$$

Where : μ_1 = mean difference of (ISD – RSD) for the SSFO

: μ_2 = mean difference of (HSD – RSD) for the SSFO

3.2 HYPOTHESIS 2.

This is a T-test for mean difference of paired samples:

$$H_0 : \mu_1 = \mu_2$$

Ho: Implied Standard Deviation (ISD) for volatility of warrants traded on the JSE are not better predictors of Realised Standard Deviations (RSD) than Historical Standard Deviation (HSD) of the underlying shares.

$$H_a : \mu_1 \neq \mu_2$$

Where : μ_1 = mean difference of (ISD – RSD) for the warrants

: μ_2 = mean difference of (HSD – RSD) for the warrants

3.3 HYPOTHESIS 3

This is a T-test for mean difference of two samples

$H_0 : \mu_1 = \mu_2$

Ho: The difference between the Implied Standard Deviation (ISD) and Realised Standard Deviation (RSD) on the Single Stock Futures Options are not significantly larger than the corresponding difference in the warrants market for the same matched underlying asset, indicating that there is no evidence of overpricing of SSFO relative to the warrants.

$H_a : \mu_1 \neq \mu_2$

Where : μ_1 = mean difference of (ISD – RSD) for the SSFO for the same underlying asset with the same time to maturity

: μ_2 = mean difference of (ISD – RSD) for the warrants for the same underlying asset with the same time to maturity

CHAPTER 4 : METHODOLOGY

4.1 APPROACH

The research has two main elements that will focus on methodology. In the first instance there is the issue of determining which volatility data produces the most accurate forecast of future volatility, historical or implied. The second component of the research is to establish if there is a premium pricing difference when comparing the warrants to that of the Single Stock Futures Options. Elements of the methodology adopted by Chan and Pinder (2000) are used as a basis. Chan and Pinder (2000) conducted research into the relative pricing differences between options and Warrants in the Australian markets. They made comparisons between options and warrants with the same underlying stock or asset.

4.2 POPULATION

The sample population consists of the option contracts that have been written on the JSE SSF options market from inception to August 2007. The population comprises both put and call options that have been written in this period, however does not include index options.

The sample population for the warrants research is the warrants contracts that have been issued on the JSE from June 2006 to August 2007. The population contains both put and call warrants that have been written in this period and excludes index based warrants.

4.3 SAMPLE SIZE AND SELECTION

4.3.1 Single Stock Future Options

There are 10727 observations in the sample as collected from the SAFEX website for the SSF options written from inception to August 2007, accounting for all put and call options. Liquidity is a key component of efficient markets. Within this data there are share codes that had been traded only twice in the nine year period. These are clearly not representative of a liquid market. The sample for this research was selected by considering the liquidity of the market and evaluating which share codes were most frequently represented within the data. The ten most frequently represented shares are selected to make up the final sample for this research. This resulted in a sample with 4584 observations.

A further 18 observations had missing information from the source files from SAFEX, these transactions were also removed reducing the sample to 4566 transactions. Within this sample there are a number of duplicate transactions. The reason for this duplication is that there was a limit on the individual transaction values, especially in the inception years, so for large trades these were split into a number of identical smaller trades. Duplicate transactions would result in a higher proportion of volatility results that would be identical and would skew the analysis. The duplicates were removed and the subsequent sample set has a total of 3615 observations.

Put and Call Options are different instruments and need to be analysed independently. The sample was therefore split dependent on the option type, i.e. a put or a call. Table 2 provides the details of the final sample.

Table 2 Single Stock Future Options sample set

Share Code	Calls	Puts		Share Code	Calls	Puts
AGLQ	285	185		IMPQ	231	146
AMSQ	166	101		MTNQ	143	123
BILQ	173	126		RCHQ	186	133
GFIQ	150	154		SOLQ	447	301
HARQ	103	151		TKGQ	202	109

4.3.2 Warrants

There are 16279 observations in the data as collected from the JSE DE01 and DR01 files for the warrants from June 2006 to June 2007 accounting for all European put options and both American and European call options.

The sample for the warrants is constructed by selecting the same ten underlying shares that make up the sample from the SSFO. These shares are selected specifically to support the analysis in Hypothesis 3 where a comparison of the premiums between the two instruments is conducted for the matching underlying shares. This resulted in a sample of 7632 observations. These observations account for 80.7% of the volumes traded, and are therefore considered representative.

A further 489 observations had missing information from the source files from the JSE, and were also removed reducing the sample to 5162.

All put options on the JSE warrants markets are European style options. Call warrants offer both American and European styled options. The American call options are more popular accounting for 98.4 % of the sample. The 89 European option observations were excluded from the sample for this research. The options were split dependent on the option type, i.e. a put or an American call. Table 3 outlines the final make-up for the warrants sample.

Table 3 Warrants sample set

Share Code	Calls	Puts		Share Code	Calls	Puts
AGL	463	107		IMP	106	175
AMS	369	241		MTN	537	240
BIL	639	220		RCH	267	129
GFI	901	291		SOL	701	325
HAR	608	97		TKG	482	137

4.4 SAMPLING METHODOLOGY

4.4.1 Single Stock Future Options

The entire sample set as described in section 4.3.1 is used in the analysis for Hypothesis 1, the comparison of the predictive abilities of the RSD and the ISD and the RSD and the HSD.

a) TIME VALUE

The option has a time value and an intrinsic value.The time value decays as the time to maturity gets less due to the exponential relationship. Bekkers (1981), Ball and Touros (1986), Figlewski (1997) and Yu and Chen (2002) evaluate the impacts of time to maturity on volatility. In this research the methodology as used by Figlewski (1997) is employed. The abovementioned sample is broken into maturity groups with overlapping intervals as specified by Figlewski (1993) to investigate the impact of time to maturity on the volatility. Table 4 below outlines the sample make-up:

Table 4 Sample set (i) by maturity group

Maturity group (i)	Days to Expiration	Number of Obs (Calls)	Number of Obs (Puts)
1	7-35	142	98
2	29-63	295	218
3	57-98	680	493
4	85-127	690	511

b) INTRINSIC VALUE

The impact of the “moneyness” of the options is also evaluated. “Moneyness” is defined as how far “in the money “or how far “out of the money” an option is. Another methodology for evaluating “moneyness” is a plot of implied volatility of an option as function of the strike price; this is know as the volatility smile. According to Hull (2000) equity options display less of a smile and more of a skew. The skew indicates that for low strike prices the options implied volatility is higher. Both Figlewski (1997) and Yu and Chen (2002) evaluate the impact of “moneyness” on volatility. The same methodology used by Figlewski (1997) is applied in this research. The main sample set is also broken into intrinsic value groups, using the same intervals as Figlewski (1997).

The intrinsic value intervals are defined by the difference between the spot of the underlying and strike price of the option. Table 5 below outlines the intrinsic value groups and the sample make-up:

Table 5 Sample set J by intrinsic value group.

Intrinsic Value group (j)	Intrinsic Value	Number of Obs (Calls)	Number of Obs (Puts)
1	-20 to -15.01	160	30
2	-15 to -10.01	224	63
3	-10 to -5.01	348	134
4	-5 to -0.01	537	289
5	0 to 5	156	276
6	5.01 to 10	75	177
7	10.01 to 15	33	129
8	15.01 to 20	18	85

4.4.2 Warrants.

The entire sample set as described in section 4.3.2 is used in the analysis for Hypothesis 2, the comparison of the predictive abilities of the RSD and the ISD and the RSD and the HSD.

4.4.3 Premiums

For the comparison of the premiums between the two derivative instruments the sample consists of matched underlying assets that are being traded in the same period.

There are many different trading strategies in the options markets and these attract different premiums dependent on the nature of the trade. As an example an institution that holds the underlying stock may want to hedge, an investor may seek opportunity with an outright call option, or banks may be using a straddle strategy. In order to extract a pure form of implied volatility from the SSFO, (i.e. a volatility that does not have any transaction costs built into it) the transactions that are inter-bank transactions are identified and used as the base. For an observation to be identified as an Inter-Bank transaction, it has to fulfil all of the criteria listed below:

Both the put and call have the same underlying future

Both the put and call are traded on the same date

Both the put and call have equal strike prices

Both the put and call have the same time to maturity

Both the put and call have the same number of contracts on each leg of the trade.

These transactions typically have minimal built in transaction costs and are an indicator of the price that the banks are willing to pay against the volatility at the time. The corresponding warrants matching the underlying equity, and with maturities that overlap in time have been identified. The implied volatility is extracted from the prices to determine the premiums charged. The premium is calculated by a comparison of the differential between the realised and implied standard deviations.

The sample on the warrants side of the trade consists of the call style options from the entire sample set as described in section 4.3.2. This sample covers the period June 2006 to June 2007.

The inter bank sample from the SSFO includes all call legs from the inter bank transactions that traded between June 2006 and June 2007. This resulted in a total sample of 148 observations. Table 6 below outlines the number of observations for the inter-bank transactions from the overall data set as described in section 4.3.1 for each individual share code.

Table 6 Inter-bank Transactions sample set

Share Code	IB Calls		Share Code	Calls
AGLQ	22		IMPQ	14
AMSQ	4		MTNQ	24
BILQ	16		RCHQ	12
GFIQ	14		SOLQ	12
HARQ	14		TKGQ	12

Since there are only a limited number of inter-bank observations and the corresponding number of warrants observations is much higher, the sample for the warrants data is also selected randomly matching the number of observations for the corresponding SSFO observations. This matching avoids unequal variances in the analysis.

4.5 DATA COLLECTION

4.5.1 Single Stock Future Options Data

a) DATA COLLECTION

The data was sourced from the SAFEX equity derivatives website by collecting the xlt. daily stats files. For the period there are 2520 daily .xlt files, these were downloaded and the data was imported into a database.

The files contain all the derivatives traded on SAFEX, index options, futures and options on futures. The first step was to isolate the futures and options that are written on the futures. The files contain the Mark To Market (MTM) data so even if an instrument is not traded on the day it is still listed. A data entry point in the “Conts”, ”Deals” and “Value” field indicated that there was a trade on that particular day. The associated futures data was also collected on the day of the trade. The following data was collected for each contract:

Option code

Underlying futures code

Strike price

Date of issue

Date of expiry

Type of option (put or call)

Issue price

Daily closing prices

Daily volumes

Daily bid ask spreads

Daily closing prices for the futures over the equivalent period of the option

4.5.2 Warrants Data

In 2000 Apostolellis obtained the detailed trading data for the warrants from MacGregors. During the course of this research it became apparent that the data for the warrants is no longer available from the vendors. Following a special request and for a fee, the data for the period June 2006 to June 2007 was obtained directly from the JSE. A larger sample would have been prohibitive in terms of cost and time to analyse. The data is identified as the DE01 and DR01 product files which the JSE issues to the vendors on a daily basis. The transactions are recorded in the DE01 file and the warrant data in the DR01 file. The data has been imported into a database and the traded transactions have been matched with the warrant data in MS Excel™. The DE01 file has a field that identifies if the instrument traded on the day and this was used to identify trades. The following data was collected for each warrant:

Warrant code

Underlying code

Strike price

Date of issue

Date of expiry

Type of warrant (American/European and if a put or call)

Issue price

Delta (cover ratio)

Daily closing prices

Daily volumes

Daily bid ask spreads

4.5.3 Underlying shares data

The data for the underlying shares was collected from Sharenet, which included daily close prices and the dividend payouts. The daily close values are corrected for dividend payouts and used in the calculation of the historical and realised volatilities.

4.5.4 Risk free rate data

The risk free rate is sourced by Bloombergs. The Johannesburg Inter Bank Acceptance Rate (JIBAR) daily close values are used and matched on a daily basis to the relevant option trade when calculating the implied volatility in the Black, Black-Scholes and Binomial models.

4.6 RELIABILITY AND VALIDITY

“The validity of a measurement instrument is the extent to which the instrument measures what it is intended to measure” (Leedy & Ormrod, 2005:92), and the reliability refers to the ability of the measurement instrument to produce consistent results under static conditions. (Leedy & Omrod, 2005).

4.6.1 Internal Validity

Internal validity refers to the ability of the researcher to draw accurate conclusions from the findings taking into considerations other relationships.

The methodology has been used in similar research under different circumstances and therefore the research methodology is considered to contribute to the internal validity.

The time to maturity and “moneyness” of an option are other relationships that may affect the volatility calculations. These relationships are evaluated independently to establish the impact if any on the findings.

The liquidity of the markets is a factor that has an impact on the pricing premiums; the sample has, however, been rationalised based on the liquidity by selecting the top 10 most traded options.

4.6.2 External Validity

External validity refers to the extent to which results from a specific study can be generalised or extrapolated to other similar environments or time frames.

The fact that there are numerous dynamics associated with a specific stock market makes the generalisation of the results to other markets questionable. The methodology adopted, however, could be utilised for similar comparative studies in other markets since the intent of the findings is closely associated with the determination of a forecasting ability of specific methodologies.

One method of improving external validity is by using a representative sample. Another method is replicating previous research in another context (Leedy & Ormrod, 2001). This research topic itself was borne from the previous research and methodologies by Apostolellis (2000) which is now being applied to a different time frame and a different market instrument. The findings may be useful for future time frames outside the periods considered.

4.6.3 Reliability.

Reliability refers to the consistency of results within a study (Leedy & Ormrod, 2001). The data selection and the methodology that is applied ensures that the results are generated from a consistent model.

The Derivigem® software package as provided with the book by Hull (2005) "Fundamentals of Options and Futures" is used to model the implied volatilities in MS Excel™. The Black model is considered to be the base model for the pricing of futures and has been used. To check the accuracy the Binomial model is used to compare the results. The results from both are accurate to within 2 decimal points.

In terms of reliability with the analysis, non-parametric tests are also conducted to confirm results where T-tests have been carried out and furthermore regression analysis is used as an alternative evaluation technique to confirm the T-test results.

The fact that the data is time based and linked to a dynamic market, implies that there could be factors that would affect the accuracy of the results. The methodology utilises the necessary statistical techniques to determine the consistency itself, and based on levels of significance and the selection of confidence level criteria, the inaccuracies are limited.

4.7 DATA ANALYSIS.

4.7.1 Implied Standard Deviation

a) SINGLE STOCK FUTURE OPTIONS

The Implied Standard Deviation (ISD) is calculated for each option using the price from the value of the transactions from the SAFEX daily data reports.

The ISD is calculated using the Black formula. The Derivagem® MS Excel™ add in formula's were used for the calculations from Hull (2000).

The formulae for pricing future options with the Black model are as follows:

For a call option $c = e^{-rT}\left[\ F_0 N(d_1) - KN(d_2)\ \right]$

For a put option $p = e^{-rT}\left[\ KN(-d_2) - F_0 N(-d_1)\ \right]$

Where $$d_1 = \frac{\ln(F_0 / K) + \sigma^2 T / 2}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(F_0 / K) - \sigma^2 T / 2}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

c = current call option price

p = current put option price

F_0 = current futures price

K = strike price

T = time to expiry

r = risk free rate

σ = volatility of the stock price

The function $N(x)$ is the cumulative probability function for the standardised normal variable.

b) WARRANTS

For the Warrants the closing price on first day of trading or the issue price is used. The ISD is calculated using the Black-Scholes formula. The Derivagem® Excel add in formulae were used for the calculations from Hull (2000).

The formulae for pricing options with the Black Scholes are as follows:

For a call option $c = S_0 N(d_1) - Ke^{-rT} N(d_2)$

For a put option $p = Ke^{-rT} N(-d_2) - S_0 N(-d_1)$

Where $d_1 = \frac{\ln(S_0 /) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}}$

$$d_2 = \frac{\ln(S_0 / K) + (r - \sigma^2 / 2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

c = current call option price

p = current put option price

S_0 = current stock price

K = strike price

T = time to expiry

r = risk free rate

σ = volatility of the stock price

The function $N(x)$ is the cumulative probability function for the standardised normal variable.

c) THE BINOMIAL MODEL

The Binomial Tree method (also from Derivagem® in Hull(2000)) was also used as a comparison since this is often thought to be a better approximation for American style options. A hypothesis test was conducted to establish any significant difference between the results. The null hypothesis that they are the same could not be rejected. The results are the same to three decimal points.

4.7.2 Realised Standard Deviations

The Realised Standard Deviation (RSD) is calculated using the daily closing prices of the relevant underlying equities from Sharenet where the options have reached the full term and expired. The calculations as used by Apostolellis and Maxwell (2002) are used to calculate the RSD:

$$RSD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X})^2}$$

Where using log normal returns:

$$X_i = \ln\left(\frac{S_i + D}{S_{i-1}}\right)$$

S_i = share price on day i

D = any dividends paid during the life of the option.

4.7.3 Historical standard deviation

The Historical Standard Deviation (HSD) is determined from historical market data. In the case of the warrants the daily closing values for a period that matches the period of the warrant is used, as suggested by Hull (2005). The calculation of the historical standard deviation for the warrants and futures options is based on matching the time to maturity applicable to the option and using the same period to look back and calculate the historical volatility.

The following formula, again as used in the research by Apostolellis and Maxwell (2002) is used to calculate the historical volatility/standard deviation:

$$HSD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_i - \overline{\overline{X}})^2}$$

n = the number of trading days that match the period to maturity of the option/warrant

Where using log normal returns:

$$X_i = \ln\left(\frac{S_i + D}{S_{i-1}}\right)$$

S_i = share price on day i

D = any dividends paid during the life of the option.

4.7.4 Premiums

In order to compare the premiums of the warrants and the Single Stock Future Options a match is required between the warrants and the options with the same underlying and both being traded in the same time period. It is possible that both may not have exactly the same time to maturation. Chan and Pinder (2000) conducted similar research between warrants and options in Australia and they adopted the following methodology.

Chan and Pinder (2000) tested for differences between the pricing between corresponding warrants and options in Australian markets for a period of Jan 1997 to June 1998. They matched the options and warrants on the basis of matching the underlying security, the exercise price and the maturity dates. Option and warrant trades were matched to the nearest minute and only trades that took place within 15 minutes of each other were considered. The data set required for this level of research would need to be detailed transactional trade data. This is not practical in the South African market due to the lack of liquidity and thin trade and a lack of detailed transactional data. The data is based on matching the underlying equity and the maturity date as closely as possible. The maturity dates will not always be the same since the futures all mature on the third Thursday of each quarter, whereas the warrants are issued at any time and have a time to maturity of 6 months.

Furthermore, in order to extract the base volatility for the SSFO markets the inter bank transactions are identified as described in the sample selection above in section 4.3. These volatilities are used as the base data for the comparison with the matched warrants. The differences in the volatility between the Realised and Implied for both instruments are compared to determine if there are any pricing premiums. The premiums are calculated by using the following formulae:

$$P_{war} = ISD_{war} - RSD$$

$$P_{SSFO} = ISD_{SSFO} - RSD$$

Where:

P_{war} = Premium for warrant

ISD_{war} = Implied volatility for the warrant

P_{SSFO} = Premium for SSFO inter bank

ISD_{SSFO} = Implied volatility for the SSFO inter bank

RSD = Realised volatility for the corresponding warrant or SSFO over the same time period.

4.7.5 Intrinsic Value Groupings

The calculation as used by Figlewski (1993) is followed in this research. The "moneyness" of an option is the degree to which an option is "in" or "out" of the money and is defined by the difference between the spot value of the underlying and the strike value of the option. For call options there will be a positive difference between the spot and the strike when the option is "in the money" (ITM), and a negative difference when the option is "out the money"(OTM). The reverse is true for put options.

"Moneyness" = $S_o - K$

Where:

S_0 = current stock price

K = strike price

4.8 STATISTICAL ANALYSIS.

All the statistical analysis is conducted using the Number Crunching Statistical Software (NCSS).

4.8.1 Hypothesis 1.

a) PAIRED T-TEST STATISTIC

The same methodology as adopted by Apostolellis (2000) is applied. A paired sample T-test is performed on the data to establish whether the difference between the (ISD-HSD) and the (HSD-RSD) is significant.

Ho: Implied Standard Deviation (ISD) for volatility of options traded on the JSE Single Stock Future Options are not better predictors of Realised Standard Deviations (RSD) than Historical Standard Deviation (HSD) of the underlying equities.

The null hypothesis is as follows: There is no difference between the (ISD-HSD) and the (HSD-RSD).

The impact of time to maturity and moneyness is also evaluated using the paired T-test statistic for each maturity sample group (i) to ensure that the internal validity of the T-test results are validated.

b) NON PARAMETRIC TESTS

The number of observations in the samples are substantial so the issue of non-normality can be ignored; however as confirmation the non-parametric statistics that would be used in the case of non-normal sample distributions were also checked to confirm the T-tests and to ensure reliability of the results. The appropriate non-parametric statistic in this case for paired samples is the Wilcoxin rank sum statistic. Yu and Chen (2002) used the same test statistic in their analysis of paired data.

c) REGRESSION ANALYSIS

Latane and Rendleman (1979), Chiras and Manaster (1979), Canini and Figlewski (1993) and more specifically in South African market Apostolellis and Maxwell (2002) used regression analysis to establish the informational content of the ISD and HSD on RSD.

The ISD and HSD are regressed against the RSD of the underlying shares to determine which predictor is superior. The R squared values from the regression analysis give an indication of how much of the variance in the RSD is described by the independent variables. In this case it provides an indication of the informational content of the independent variable (the ISD and HSD) on the dependent variable the RSD. This is a confirmatory methodology to the Paired T-test and again confirms reliability of the T-tests.

In the development of a regression model that can enable forecasting of the realised volatility a multiple regression is performed taking into account a number of the independent variables that are considered to influence the calculation of the realised volatility. This research evaluates the same set of independent variables that Ramaswamy and Sundaresan (1985) used. These are as follows:

Time to Maturity

Volatility (historical)

Moneyness

Risk free rate

These independent variables will be checked for significance as a contributor toward the model. The degree to which each variable individually influences the R squared value will provide insight as to how much variance in the RSD is described by the variables.

The correlation matrix is be to evaluated to establish if there is any multicollinearlity between the variables.

4.8.2 Hypothesis 2

a) PAIRED T-TEST STATISTIC

The same methodology as described above is used but in this case for the warrants. A Paired Sample T-test is performed on the data to establish whether the difference between the (ISD - HSD) and the (HSD –RSD) is significant.

Ho: Implied Standard Deviation (ISD) for volatility of warrants traded on the JSE are not better predictors of Realised Standard Deviations (RSD) than Historical Standard Deviation (HSD) of the underlying shares.

The null hypothesis is as follows:

There is no difference between the (ISD –HSD) and the (HSD-RSD).

b) NON-PARAMETRIC TESTS

The samples are again substantial, omitting the issue of non-normality. As confirmation, however, the non-parametric statistics used in the case of non-normal sample distributions were also checked for reliability purposes. The Wilcoxin rank sum test statistic is used for the paired data analysis.

c) REGRESSION ANALYSIS

The same methodology as described in section c above is used for the Warrants.

4.8.3 Hypothesis 3

a) TWO SAMPLE T-TEST STATISTIC

The sample used in the analysis of Hypothesis 3 is not paired data. In this case the samples are two individual samples, one being the warrants call option premiums and the other being the SSFO inter-bank call premiums. Therefore a two sample T-test statistic is the appropriate test statistic. The objective is to establish whether there is a significant difference in the premiums being charged between the warrants and the SSFO for the same underlying share and over the same period. The number of observations for each individual share are all less than 30 and the samples are non-normal so the results form the T-tests must be treated with caution.

Ho: The difference between the Implied Standard Deviation (ISD) and Realised Standard Deviation (RSD) on the Single Stock Futures Options are not significantly larger than the corresponding difference in the warrants market for the same underlying asset, indicating that there is no evidence of overpricing of SSFO relative to the warrants.

b) NON-PARAMETRIC TESTS

Due to the limitation of the sample size for the individual shares selected, the two sample T-test will not result in reliable results with such small samples.

According to NCSS (2007) the Kruskal Wallis one way Analysis Of Variance (ANOVA) statistic should be used when in doubt with non-normal distributions, and has therefore been selected. Apostolellis (2000) used the same statistic for analysis where non-normality and small samples were present. This statistic compares the medians, so the results will be an indication of the premiums in terms of a median premium.

The Kruskal Wallis statistic considers the number of ties between the two samples. For this reason the warrants sample sizes were matched to the number of corresponding SSFO inter-bank observations by using a random selection of the entire sample. This reduced the number of ties making the results more reliable.

CHAPTER 5 : PRESENTATION OF RESULTS

5.1 HYPOTHESIS 1

5.1.1 Call Options

a) PAIRED T-TEST

The results for the T-tests for the SSFO calls are presented in the table below. The T-test rejects the null hypothesis at a 5% level of significance.

Table 7 Predictors of realised volatility for Single stock future call options

Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
ISD-RSD	2086	14.01 %	Paired T-test	Reject Ho	0.00
HSD-ISD	2086	0.9933 %			

b) NON-PARAMETRIC TESTS

The non-parametric Wilcoxin ranked sum test statistic is presented below and rejects the null hypothesis at 5% level of significance. This confirms the T-test decision.

Table 8 Non-Parametric Results Predictors of realised volatility for Single stock future call options

Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
ISD-RSD	2086	14.01 %	Wilcoxin	Reject Ho	0.00
HSD-ISD	2086	0.9933 %			

c) Regression Analysis

Table 9 Regression results SSFO Calls (Dependent variable RSD)

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	0.0618	0.0092	6.727	0.0000	Yes	1.0000
Historical	0.4766	0.0187	25.554	0.0000	Yes	1.0000
irate	0.7635	0.1009	7.567	0.0000	Yes	1.0000
moneyness	0.0000	0.0000	-0.523	0.6012	No	0.0819
ttm	0.0000	0.0000	0.925	0.3548	No	0.1524

Table 10 Regression R Squared summary SSFO Calls (Dependent variable RSD)

Independent Variable	Total R2 for This I.V. And Those Above	R2 Increase When This I.V. Added To Those Above	R2 Decrease When This I.V. Is Removed	R2 When This I.V. Is Fit Alone	Partial R2 Adjusted For All Other I.V.'s
Historical	0.3178	0.3178	0.2076	0.3178	0.2382
irate	0.3359	0.0182	0.0182	0.1207	0.0267
moneyness	0.3360	0.0001	0.0001	0.0050	0.0001
ttm	0.3363	0.0003	0.0003	0.0077	0.0004

Table 11 Regression of ISD for SSFO Calls (Dependent variable RSD)

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	0.1089	0.0054	20.029	0.0000	Yes	1.0000
Historical	0.4872	0.0193	25.215	0.0000	Yes	1.0000
Implied	0.0592	0.0113	5.230	0.0000	Yes	0.9995

Table 12 Regression of ISD R Squared summary SSFO Calls (Dependent variable RSD)

Independent Variable	Total R2 for This I.V. And Those Above	R2 Increase When This I.V. Added To Those Above	R2 Decrease When This I.V. Is Removed	R2 When This I.V. Is Fit Alone	Partial R2 Adjusted For All Other I.V.'s
Historical	0.3178	0.3178	0.2049	0.3178	0.2332
Implied	0.3266	0.0088	0.0088	0.1217	0.0129

5.1.2 Put options

a) PAIRED T-TEST

Table 13 Predictors of realised volatility for Single stock future put options

Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
ISD-RSD	1529	8.929 %	Paired T-test	Reject Ho	0.00
HSD-ISD	1529	0.6811 %			

b) NON PARAMETRIC TESTS

The non-parametric Wilcoxin ranked sum test statistic is presented below and rejects the null hypothesis at 5% level of significance. This is confirmatory of the T-test decision.

Table 14 Non-Parametric Results Predictors of realised volatility for Single stock future put options

Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
ISD-RSD	1529	8.929 %	Wilcoxin	Reject Ho	0.00
HSD-ISD	1529	0.6811 %			

c) REGRESSION ANALYSIS

Table 15 Regression results SSFO puts (Dependent variable RSD)

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	0.0277	0.0122	2.273	0.0231	Yes	0.6230
Ttm	0.0000	0.0000	0.800	0.4239	No	0.1259
i-rate	0.9648	0.1391	6.938	0.0000	Yes	1.0000
Historical	0.5662	0.0252	22.430	0.0000	Yes	1.0000
moneyness	0.0000	0.0001	-0.265	0.7908	No	0.0581

Table 16 Regression R Squared summary SSFO puts (Dependent variable RSD)

Independent Variable	Total R2 for This I.V. And Those Above	R2 Increase When This I.V. Added To Those Above	R2 Decrease When This I.V. Is Removed	R2 When This I.V. Is Fit Alone	Partial R2 Adjusted For All Other I.V.'s
Ttm	0.0049	0.0049	0.0003	0.0049	0.0004
i-rate	0.1941	0.1892	0.0191	0.1888	0.0306
Historical	0.3962	0.2022	0.1993	0.3770	0.2482
moneyness	0.3963	0.0000	0.0000	0.0037	0.0000

Table 17 Regression of ISD for SSFO Puts (Dependent variable RSD)

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	0.0806	0.0071	11.415	0.0000	Yes	1.0000
Historical	0.5801	0.0235	24.711	0.0000	Yes	1.0000
Implied	0.1002	0.0132	7.583	0.0000	Yes	1.0000

Table 18 Regression of ISD R Squared summary SSFO Puts Dependent variable RSD)

Independent Variable	Total R2 for This I.V. And Those Above	R2 Increase When This I.V. Added To Those Above	R2 Decrease When This I.V. Is Removed	R2 When This I.V. Is Fit Alone	Partial R2 Adjusted For All Other I.V.'s
Historical	0.3770	0.3770	0.2402	0.3770	0.2858
Implied	0.3996	0.0226	0.0226	0.1594	0.0363

5.1.3 Time to Maturity

The tables below outline the results for the analysis of the impact of Time To Maturity (TTM) on the volatility.

Table 19 Impact of time to maturity for ISD-RSD and HSD-RSD for SSFO calls.

Maturity group	Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
I=1	ISD-RSD	98	15.09 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	98	-3.015 %			
I=2	ISD-RSD	295	13.29 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	295	0.9102 %			
I=3	ISD-RSD	680	14.37 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	680	1.295 %			
I=4	ISD-RSD	690	13.362 %	Paired T-test	Reject Ho	0.00
	HSD-ISD	690	1.305 %			

Figure 2 SSFO Calls Volatility premium by maturity groups

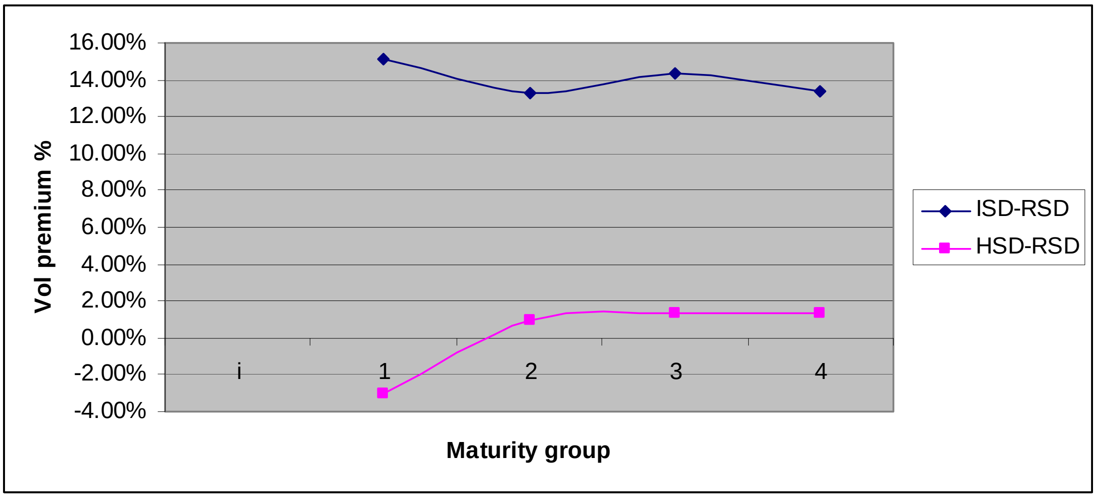


Figure 3 SSFO Puts Volatility premium by maturity groups

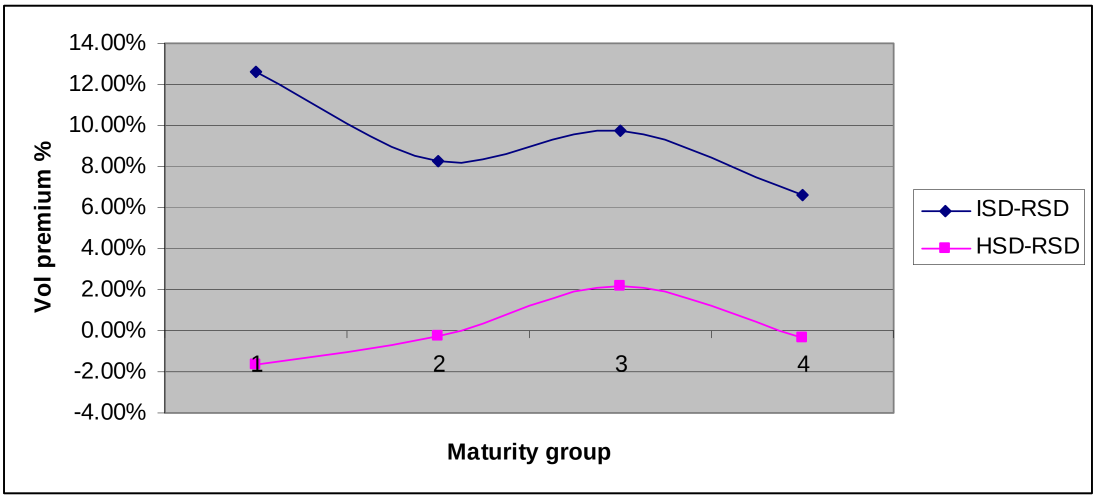


Table 20 Impact of time to maturity for ISD-RSD and HSD-RSD for SSFO puts

Maturity group	Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
I=1	ISD-RSD	98	12.610 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	98	-0.1610 %			
I=2	ISD-RSD	218	8.244%	Paired T-test	Reject Ho	0.00
	HSD-RSD	218	-0.280 %			
I=3	ISD-RSD	493	9.720 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	493	2.141 %			
I=4	ISD-RSD	511	6.638%	Paired T-test	Reject Ho	0.00
	HSD-ISD	511	-0.314 %			

5.1.4 Moneyness

a) CALL OPTIONS

Table 21 Impact of intrinsic value for ISD-RSD and HSD-RSD for SSFO calls

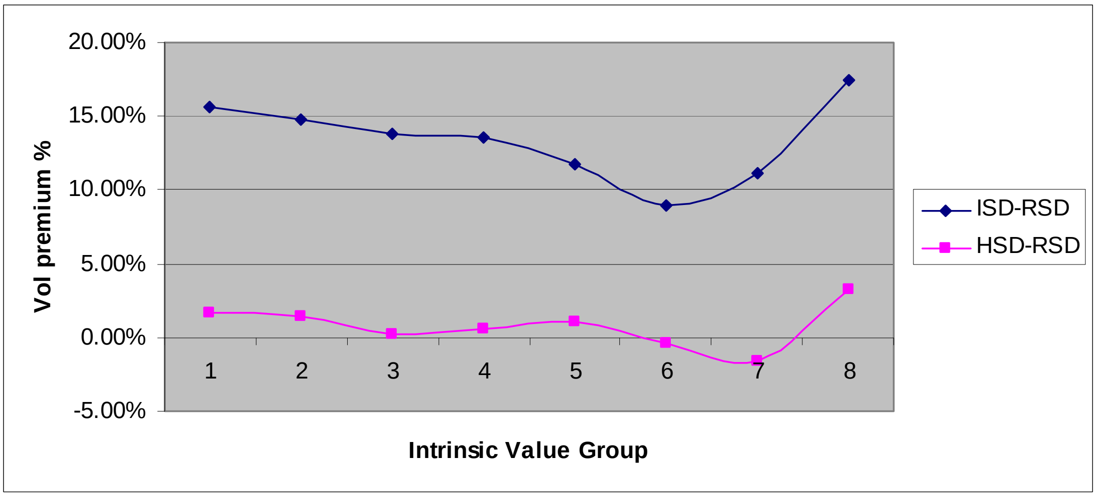
Intrinsic group	Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
J=1* OTM	ISD-RSD	160	15.645 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	160	1.697%			
J=2** OTM	ISD-RSD	224	14.730.%	Paired T-test	Reject Ho	0.00
	HSD-RSD	224	1.393%			
J=3 OTM	ISD-RSD	134	13.795%	Paired T-test	Reject Ho	0.00
	HSD-RSD	134	0.220 %			
J=4 OTM	ISD-RSD	537	13.594%	Paired T-test	Reject Ho	0.00
	HSD-ISD	537	0.618 %			
J=5 ITM	ISD-RSD	156	6.578 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	156	-0.1691 %			
J=6 ITM	ISD-RSD	75	8.934%	Paired T-test	Reject Ho	0.00
	HSD-RSD	75	-0.437 %			
Ij=7** ITM	ISD-RSD	33	11.086%	Paired T-test	Reject Ho	0.00
	HSD-RSD	33	-0.1610%			
I=8* ITM	ISD-RSD	18	17.480%	Paired T-test	Reject Ho	0.00
	HSD-ISD	18	3.226%			

*Power value = 0.4

** Power value 0.7

The power values suggest that the probability of a Type I error is high; this means that there is a possibility that the null hypothesis could be rejected when it is, in fact, true. These two results should therefore be treated with caution. The non-parametric results reject the hypothesis for these values for the difference in the medians.

Figure 4 SSFO Calls Volatility premium by Intrinsic value groups



b) PUT OPTIONS

Table 22 Impact of moneyness for ISD-RSD and HSD-RSD for SSFO Puts

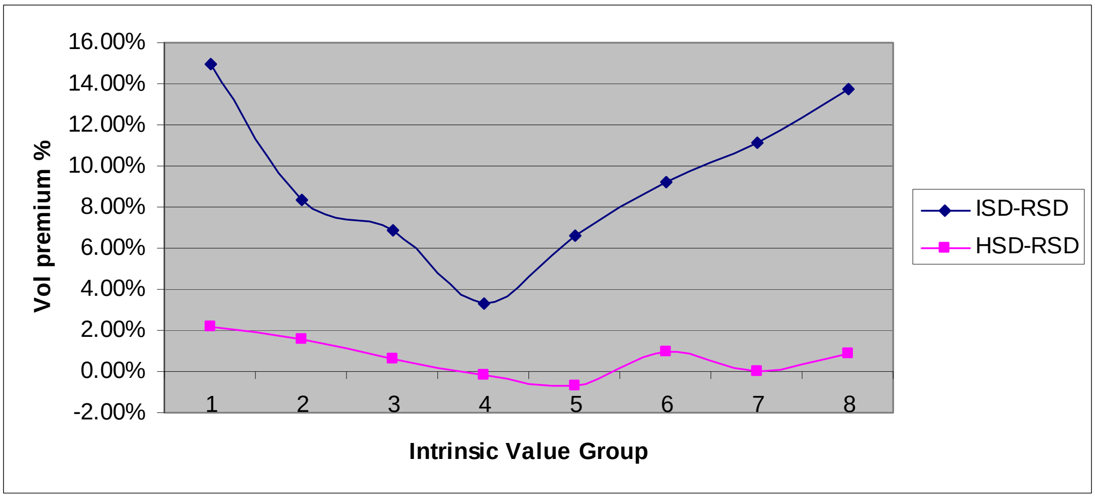
Intrinsic group	Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
J=1* ITM	ISD-RSD	30	14.966 %	Paired T-test	Reject Ho	0.9989
	HSD-RSD	30	2.152%			
J=2** ITM	ISD-RSD	63	8.320%	Paired T-test	Reject Ho	0.999
	HSD-RSD	63	1.563%			
J=3 ITM	ISD-RSD	134	6.903%	Paired T-test	Reject Ho	0.00
	HSD-RSD	134	0.622 %			
J=4 ITM	ISD-RSD	289	3.328%	Paired T-test	Reject Ho	0.00
	HSD-ISD	289	-0.215 %			
J=5 OTM	ISD-RSD	276	6.578 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	276	-0.1691 %			
J=6 OTM	ISD-RSD	177	9.195%	Paired T-test	Reject Ho	0.00
	HSD-RSD	177	0.950 %			
J=7 OTM	ISD-RSD	129	11.167 %	Paired T-test	Reject Ho	0.00
	HSD-RSD	129	-0.020%			
J=8 OTM	ISD-RSD	85	13.778%	Paired T-test	Reject Ho	0.00
	HSD-ISD	85	0.864 %			

*Power value = 0.6

** Power value 0.33

As with the results above the power values suggest that the probability of a type I error is high; this means that there is a possibility that the null hypothesis could be rejected when in fact it is true. These two results should therefore need to be treated with caution. The non parametric results reject the hypothesis for these values for the difference in the medians.

Figure 5 SSFO Puts Volatility premium by Intrinsic value groups



5.2 <u>HYPOTHESIS 2</u>

5.2.1 Call Options

a) PAIRED T-TEST

Table 23 Predictors of realised volatility for Warrant call options

Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
ISD-RSD	5176	27.63 %	Paired T-test	Reject Ho	0.00
HSD-ISD	5176	6.19 %			

b) Regression Analysis

Table 24 Regression results Warrants Calls (Dependent variable RSD)

Regression Independent Variable	Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	0.9031	0.0179	50.360	0.0000	Yes	1.0000
historical	0.2318	0.0080	28.915	0.0000	Yes	1.0000
i_rate	-7.7932	0.1937	-40.224	0.0000	Yes	1.0000
moneyness	0.0295	0.0092	3.199	0.0014	Yes	0.8922
ttm	0.0000	0.0000	-1.343	0.1792	No	0.2692

Table 25 Regression R Squared summary Warrants Calls (Dependent variable RSD)

Independent Variable	Total R2 for This I.V. And Those Above	R2 Increase When This I.V. Added To Those Above	R2 Decrease When This I.V. Is Removed	R2 When This I.V. Is Fit Alone	Partial R2 Adjusted For All Other I.V.'s
historical	0.1049	0.1049	0.1104	0.1049	0.1396
i_rate	0.3172	0.2123	0.2137	0.2074	0.2389
moneyness	0.3190	0.0018	0.0014	0.0001	0.0020
ttm	0.3192	0.0002	0.0002	0.0027	0.0003

Table 26 Regression of ISD for Warrants Calls(Dependent variable RSD)

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	0.1863	0.0040	47.118	0.0000	Yes	1.0000
historical	0.2209	0.0091	24.150	0.0000	Yes	1.0000
implied	0.0264	0.0043	6.139	0.0000	Yes	1.0000

Table 27 Regression of ISD R Squared summary Warrants Calls

(Dependent variable RSD)

Independent Variable	Total R2 for This I.V. And Those Above	R2 Increase When This I.V. Added To Those Above	R2 Decrease When This I.V. Is Removed	R2 When This I.V. Is Fit Alone	Partial R2 Adjusted For All Other I.V.'s
historical	0.1049	0.1049	0.1005	0.1049	0.1016
implied	0.1113	0.0065	0.0065	0.0109	0.0073

5.2.2 Put Options

a) PAIRED T-TEST

Table 28 Predictors of realised volatility for Warrant European put options

Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
ISD-RSD	1814	27.63 %	Paired T-test	Reject Ho	0.00
HSD-ISD	1814	5.87 %			

b) REGRESSION ANALYSIS

Table 29 Regression results Warrants Puts (Dependent variable RSD)

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	0.8737	0.0280	31.247	0.0000	Yes	1.0000
historical	0.3128	0.0152	20.558	0.0000	Yes	1.0000
irate	-7.9048	0.2951	-26.787	0.0000	Yes	1.0000
moneyness	0.0605	0.0129	4.688	0.0000	Yes	0.9968
ttm	0.0000	0.0000	0.118	0.9058	No	0.0516

Table 30 Regression R Squared summary Warrants Puts (Dependent variable RSD

Independent Variable	Total R2 for This I.V. And Those Above	R2 Increase When This I.V. Added To Those Above	R2 Decrease When This I.V. Is Removed	R2 When This I.V. Is Fit Alone	Partial R2 Adjusted For All Other I.V.'s
historical	0.1910	0.1910	0.1348	0.1910	0.1895
irate	0.4167	0.2256	0.2288	0.2780	0.2842
moneyness	0.4238	0.0072	0.0070	0.0001	0.0120
ttm	0.4238	0.0000	0.0000	0.0096	0.0000

Table 31 Regression of ISD for Warrants Puts (Dependent variable RSD)

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	0.1252	0.0079	15.940	0.0000	Yes	1.0000
historical	0.3491	0.0180	19.372	0.0000	Yes	1.0000
Implied	0.0598	0.0110	5.447	0.0000	Yes	0.9998

Table 32 Regression of ISD R Squared summary Warrants Puts (Dependent variable RSD)

Independent Variable	Total R2 for This I.V. And Those Above	R2 Increase When This I.V. Added To Those Above	R2 Decrease When This I.V. Is Removed	R2 When This I.V. Is Fit Alone	Partial R2 Adjusted For All Other I.V.'s
historical	0.1910	0.1910	0.1651	0.1910	0.1718
Implied	0.2041	0.0131	0.0131	0.0390	0.0161

5.3 HYPOTHESIS 3

5.3.1 Total Interbank and warrants sample Call Option Premiums

Table 33 Pricing premiums between American call warrants and SSFO interbank calls.

Measure	Sample size	Mean difference	Test used	Decision 5%	Probability level
SSFO ISD-RSD	148	13.13 %	Two Sample T-test	Reject Ho	0.00
Warrant ISD-RSD	5175	27.65 %			

5.3.2 Matched Premiums

The table below outlines the results for the ANOVA tests to establish the difference in premiums for the matched underlying shares between the SSFO inter-bank call options and the corresponding warrant call options.

Table 34 Pricing premiums between American call warrants and SSFO interbank calls for matched underlying shares.

Share group	Measure	Sample size	Median	Test used	Decision 5%	Probability level
AMS	SSFO ISD-RSD	4	23.96 %	Kruskall-Wallis one way ANOVA	Accept Ho	0.248213
	Warrant ISD-RSD	4	34.54 %			
ANG	SSFO ISD-RSD	22	10.81 %	Kruskall-Wallis one way ANOVA	Reject Ho	0.000011
	Warrant ISD-RSD	22	33.62 %			
BIL	SSFO ISD-RSD	16	13.91 %	Kruskall-Wallis one way ANOVA	Reject Ho	0.009308
	Warrant ISD-RSD	16	20.66 %			
GFI	SSFO ISD-RSD	14	14.92%	Kruskall-Wallis one way ANOVA	Reject Ho	0.043208
	Warrant ISD-RSD	14	27.24%			
HAR	SSFO ISD-RSD	14	17.88%	Kruskall-Wallis one way ANOVA	Reject Ho	0.000029
	Warrant ISD-RSD	14	43.48%			
IMP	SSFO ISD-RSD	14	16.91%	Kruskall-Wallis one way ANOVA	Reject Ho	0.024538
	Warrant ISD-RSD	14	23.60%			
MTN	SSFO ISD-RSD	24	12.62 %	Kruskall-Wallis one way ANOVA	Reject Ho	0.000190
	Warrant ISD-RSD	24	23.66 %			
RCH	SSFO ISD-RSD	12	12.67%	Kruskall-Wallis one way ANOVA	Reject Ho	0.001496
	Warrant ISD-RSD	12	20.25%			
SOL	SSFO ISD-RSD	12	14.20 %	Kruskall-Wallis one way ANOVA	Reject Ho	0.000999
	Warrant ISD-RSD	12	24.60 %			
TKG	SSFO ISD-RSD	12	12.44 %	Kruskall-Wallis one way ANOVA	Reject Ho	0.005072
	Warrant ISD-RSD	12	21.06 %			

CHAPTER 6 : INTERPRETATION OF THE RESULTS

6.1 HYPOTHESIS 1.

The T-test rejects the null hypothesis for both the SSFO call options and the SSFO put options. This indicates that there is a significant difference between the means. It implies a significant difference between the Implied and Historical volatility.

The paired T-test results for the call and put options indicate that there is a significant difference between the means. The mean for the ISD for the call options is 14 % and for the HSD it is 0.99 %. The difference between the HSD and ISD versus the RSD is 13.1 %. The mean for the ISD for the put options is less at 8.9 % and for the HSD it is also less at 0.68 %. The difference between the HSD and ISD versus the RSD is 13.1 % and 8.2% for the calls and puts respectively. The HSD does not take into account any transactional costs, levies and brokerage. This is typically a maximum of 2-3 basis points, and on large institutional transactions such as the inter-bank transactions is negligible.

The margin of the difference of between the RSD and the ISD possibly provides insight into the markets' perceptions. According to Poon & Granger (2003) the option implied volatility is the markets' perception of the future volatility. Investors may have a different approach; the premium they are paying could be the premium they are willing to pay for hedging, which is what many of the large institutions are using the SSFO for. In the case where an investor has a view of the potential upside this may be the premium they are willing to pay.

The results are consistent with that of Apostolellis and Maxwell (2002), Day & Lewis (1992), Lamoureux & Lastrapes (1993) and Canina & Figlewski (1993). The result is not consistent with that of Poon & Granger(2003), their overall review of 34 studies that evaluates many different implied and historical models. They indicate that historical has only been better than implied in 24% of the studies conducted.

However Poon & Granger (2003) do identify one characteristic that may be relevant, and this is the market size impact. They find that the studies on small markets, specifically German, Australian, Canadian and Swedish markets all showed that implied forecasts were not superior, either biased or erratic. For the Swedish markets historical was better than implied. The South African market can be classed in the same context as these markets and hence our results are consistent if one takes market size into consideration. Apostolellis (2000) conducted research on the South African warrants markets and his findings that HSD is better than ISD concurs with the small market observation of Poon & Granger (2003) and with the results from this research.

The results for options on futures specifically are not consistent with other results. Amin and Ng (1997), Edey and Elliot (1992) and Fung and Hsieth (1991) as indicated in Poon & Granger’s (2003) studies, find the forecasting power of implied is significant for interest rate futures. For commodities, Day and Lewis (1992). Claessens (1995), Marten and Zein (2002) and Szakmary (2002) find that implied is superior as reported in the findings of the Poon & Granger (2003) study. This research specifically considers single stock future options, and the dynamics of the markets, liquidity and market size could have an impact.

The time to maturity was identified by Bekkers (1981), Ball and Touros (1986), Figlewski (1993) and Yu and Chen (2002) as being a key factor influencing the pricing of options. The results indicate across all maturity groups selected that there is a marked difference between the HSD and RSD and the ISD and RSD at a 5% significance level. This confirms the result of the overall T-test for the larger sample which spans across many maturity groups. An evaluation of the individual groups indicates that once again ISD is less accurate in predicting RSD.

The means across the maturity groups that HSD is better as a predictor than ISD. There does appear to be a trend in the difference between the means for each maturity group: as the time to maturity increases, the error between ISD and HSD becomes less. This is consistent with the results from Canina and Figlewski (1993). Both Figures 2 and 3 in Chapter 4 show that the HSD underestimates the RSD when the option is close to maturity. A possible reason for this is the forecast horizon methodology used. The period used to look back on the option's historical volatility is the same as the period looking forward to maturity, so for options that are close to maturity the data is limited and the small changes can have a large impact. For the other maturity groups the data appears to be rather insensitive to volatility.

The premium paid for an option is closely tied to how far "in" or "out" of the money the option is. The premium is normally higher for "in" the money options since there is an immediate benefit to be derived. The influence of moneyness was also evaluated across various intrinsic value groups. At a 5% level of significance the difference between HSD and ISD versus the RSD is significant using the paired T-test. An evaluation of the means for each pair indicates that HSD is a better predictor than ISD across all intrinsic value groups.

The graphical representation indicates a trend in the data which is consistent with the theory indicating that the premiums are higher when the options are "deep in the money".

The data for these 'deep in the money' groups has small sample observations and the power values suggest that there is potential for a Type I error. The non-parametric statistics confirm the decision to reject the null hypothesis for a difference in the medians. These results only confirm the result for the overall T-test within each group. They were not analysed for a significant difference between the premiums for the different intrinsic groups. The regression analysis will highlight this influence.

The trend also shows that “deep out of the money” premiums are higher. Ederington and Guan (2005) also found that the implied models were not accurate in forecasting “deep out of the money” calls. What’s more they find the informational content of implied volatility across strikes is highest “near the money” and those that have moderately high strikes. (Out the money calls and in the money puts). They find that implied forecasts that are far away from “at the money” are poor and biased. This is consistent with the trends in this research.

However the results are not consistent with the findings of Hull (2000). Hull (2000) finds that equity options tend to have a skew rather than a smile. The trend for the SSFO is more of a smile than a skew. Furthermore the volatility skew typically indicates that “deep in the money” calls should be more expensive than “deep out the money” calls.

Another reason for the poor volatility forecasts for deep “in” or “out” of the money options may be liquidity. According to Poon & Granger (2003), Bekkers (1981) and Figlewski and Canina (1997) these options are generally illiquid due to large bid ask spreads and non-synchronous data could result in poor forecasts.

The regression analysis indicates that interest rates and the historical volatility are significant contributors to the informational content of the realised volatility for both the call and put options. The moneyness and time to maturity elements cannot be rejected at a 5% level of significance. In other words the null hypothesis that the slope is equal to zero cannot be rejected. The regression coefficients for these independent variables are zero.

For the call options the contribution of the Historical volatility to the R squared is 0.32 and the interest rate is 0.12 if used exclusively. The combined model is dominated by the contribution from the historical with a total R squared of 0.336, and the interest rate only adding less than 0.02 to the overall value.

For the put options the contribution of the Historical volatility to the R squared is 0.38 and the interest rate is 0.19 if used exclusively. The combined model is dominated by the contribution from the historical with a total R squared of 0.4.

The regression using implied volatility and historical volatility as independent variables to predict the realised volatility produced results that correspond with that of Apostolellis and Maxwell (2002) for both puts and calls. The results of the T-tests reject the null hypothesis that the slopes are equal to zero for both independent variables, indicating that ISD and RSD do contain information about the RSD.

For the call options the R squared reports show that HSD contains more information and is a better predictor of RSD than ISD. Implied alone has only an R squared of 0.12 whereas the Historical has a value of 0.32, indicating that HSD is far superior when used in isolation. This confirms the results for the T-tests. The combination of the two produces an overall R squared of 0.3266, indicating that in combined model the contribution of implied is extremely marginal only adding 0.0088 to the overall R squared. Apostolellis and Maxwell (2002) found that the combined model was in fact worse for the warrants. This result implies that a simple evaluation of historical volatility will provide a more accurate forecast than using complex modelling techniques.

The results for the put options are the same. The R squared for the Implied alone is 0.16; while the Historical has a value of 0.38. Again HSD is far superior when used alone. The T-tests results are again confirmed. The combined model produces an overall R squared of 0.3996, and again the contribution of implied is marginal at 0.0226.

6.2 HYPOTHESIS 2 WARRANTS.

The sample in this research is much larger than the sample in the previous study by Apostolellis and Maxwell (2002). In 2002 the market was relatively immature, there were not many transactions. Furthermore, the liquidity of the market was problematic.

In this research there are 5176 observations for the American calls from the 10 major underlying stocks and 1814 observations for the European puts. The sample is taken 9 years from inception of the warrants markets covering the year's trade from June 2006 to June 2007, and as such is considered to be representative of a stable and mature market.

A paired T-test is conducted to establish if there is a significant difference between the means of the ISD and RSD, the HSD and RSD for call and put options separately.

The results from the paired T-test indicate that the null hypothesis is rejected at a 5% level of significance for both the European put style options and the American call options. This research produces the same result that Apostolellis found in 2000 for the American calls listed on the JSE. HSD is also found to be a better predictor than ISD for the current warrants market. The mean for the ISD for the call options is 27.6% and for the HSD it is 6.19 %. The mean for the ISD for the put options the same at 27.6% and for the HSD it is slightly less at 5.87 %.

The regression analysis for the warrants differs from Apostolellis and Maxwell's (2002) research. This research takes into account the time to maturity, the strike and the interest rate effects as contributing variables to the warrants pricing.

A multiple regression analysis was conducted using the RSD as the dependent variable and using the ISD, HSD, interest rates, time to maturity and moneyness, all as independent variables.

The results for the call warrants reject the null hypothesis for all variables except the time to maturity, indicating that historical volatility, the risk free rate and the moneyness contain information about the realised volatility. The R squared summary shows the individual contributions of all significant independent variables. What is interesting to note is that the interest rate has the largest contribution on an individual basis with an R squared of 0.21. Historical volatility and moneyness are less significant with values of 0.001 and 0.11. The combined model of the three produces an overall R squared of 0.319.

The results for the European put warrants are the same with historical volatility, the risk free rate and the moneyness being rejected at a 5% level of significance. Time to maturity could not be rejected. The R squared analysis again indicates that the risk free rate is the most dominant contributor at 0.28 if used alone, and if using historical volatility exclusively, one would only have an R squared of 0.19. The moneyness is not highly correlated with an R squared of 0.0001. The combined model produces an R squared of 0.4238.

The risk free rate has a negative regression coefficient and is the most dominant contributor. This is consistent with the trend in the interest rate over the period assessed. The JIBAR had moved from 7.688% to 10.646 % during the period June 2006 to the end of June 2007. The historical analysis cannot account for the future volatility in the risk free rate. The realised volatility will, however, account for the increasing risk free rate. Therefore in periods where the risk free rate is volatile, this variable becomes a significant contributor to forecasting future volatility when using historical data. This result is consistent with the findings of Ramaswamy and Sundaresan (1985), who establish that small changes in the interest rate, ±200 basis points can lead to errors in volatility in a range of -5% to +7%. Yu and Chen (2002) also establish that risk free rates have a bias on the pricing of warrants.

The evaluation of the sensitivity of the option with respect to changes in the interest rate is known as the Greek term *rho* according to Hull (2000). An evaluation of *rho* would indicate the absolute range of sensitivity to interest rates as done by Ramaswamy and Sundaresan (1985).

The predictive capabilities of the implied volatility are investigated using the same methodology as Apostolellis and Maxwell (2002). They found that ISD was not a good predictor of RSD and that the combination of HSD and ISD worsened the result, indicating that HSD already contained information about ISD.

For the call warrants both implied and realised volatility are rejected at a 5% level of significance. The R squared for historical alone is 0.11 and for implied a meagre 0.01. The combination of the two produces an R squared of 0.11, indicating that Implied adds minimal additional information. The puts show similar results. Historical alone has an R squared of 0.19 and implied 0.039. The combination does improve the result to 0.204.

For warrants the simple historical model combined with interest rates produces the most accurate forecasting tool.

These results concur with previous research by Apostolellis and Maxwell (2002),Day & Lewis (1992), Lamoureux & Lastrapes (1993) and Canina & Figlewski (1993).

6.3 HYPOTHESIS 3 PREMIUMS

The implied volatility calculated from the data is based on transactional data which includes a price paid for the options. The premium paid in retrospect is the difference between the implied and the realised volatility, less any transactional costs and duties.

A two sample T-test is conducted to compare the premiums paid for between the warrants and the SSFO. The test rejects the null hypothesis that the means are equal at a 5% level of significance. Therefore there is a significant difference between the mean premiums paid between the two instruments.

The mean premium for the warrants is 27.6% as compared to 13.1% for the SSFO. The warrants market could be considered to be “retail” and the SSFO market “wholesale”. The mark-up between the two is rather substantial. The warrants market has been targeted and marketed aggressively to the general investor by the banks which are the market makers. This research concurs with the findings of Apostolellis (2000), Chan and Pinder (2000).

The inter-bank SSFO are trades that are between banks. The results indicate the premium that these same market makers are willing to pay for the same instruments amongst themselves. The two sample T-test, comparing the mean difference between the HSD and the RSD for both the warrants and SSFO inter-bank trades, produces insufficient evidence to reject the null hypothesis that the differences are equal.

6.3.1 Individual shares.

The Kruskal-Wallis one-way Analysis Of Variance (ANOVA) test was used to compare the premiums for the warrants and the SSFO inter-bank trades with matched underlying shares and over the same period of June 2006 to June 2007. The time to maturity was not matched due to the small sample size and due to the fact that the multiple regression analysis conducted in the first two hypotheses indicated that the contribution of time to maturity to RSD was very small, and ISD which is used here as the calculation for the premium accounts for time to maturity.

The two sample T-test results for the individual share analysis produced inconclusive results due to non-normality and a small number of observations. The Kruskal-Wallis ANOVA was selected as a test statistic. The results from the one way ANOVA for all the matched share codes reject the null hypothesis that the medians are equal. The only exception, where the null hypothesis could not be rejected, is for the AMS sharecode. The reason for this is that there are only 4 observations and this cannot produce a statistically sound result. For the other 9 shares there is a significant difference between the median premiums for the SSFO and the warrants.

The median premiums for all the call warrants for the matched shares are significantly higher than that of the corresponding SSFO call options. Chan and Pinder (2000) also find that warrants are systematically overpriced relative to options when they are matched on the basis of the underlying.

CHAPTER 7 : CONCLUSION

7.1 INTRODUCTION

The pricing of options is an ongoing science. According to Poon & Granger (2003) there is no conclusive single solution for forecasting volatility. There are a number of factors that influence the forecasting process and often make the solution unique to a particular type of investment, the market dynamics, size and liquidity. There is no "'one size fits all"' model.

This research attempts to identify which methodology provides better forecasting when pricing SSFO and warrants with the Black or Black Scholes Implied volatility model, as opposed to the simple historical volatility model. Furthermore the research attempts to indicate a significant premium between the two derivative instruments available to the investor on the South African derivatives markets.

This research was conducted on warrants as traded on the JSE and SSFO as listed by South African Futures Exchange (SAFEX).

7.2 SUMMARY OF THE MAIN FINDINGS

7.2.1 Single Stock Future Options Volatility

Historical Volatility is a better predictor of Realised Volatility than Implied Volatility when using the Black model for the pricing of single stock future options as written on SAFEX. A simple historical model produces the most accurate forecast.

7.2.2 Warrants Volatility

Historical Volatility is a better predictor of Realised Volatility than Implied Volatility when using the Black Scholes model for the pricing of warrants as written on the JSE. The complicated models requiring more input produce a poorer forecast of future volatility. A combination of Historical Volatility and the risk free rate produced the most accurate forecast.

7.2.3 Premiums

The market makers that dictate the pricing and premiums for the warrants (typically banks) are charging the investor significantly higher premiums than the premium demanded in the single stock future options markets. It is a well known fact that the costs associated with listing a warrant are higher than that of a SSFO; however these costs certainly cannot account for the large differences as observed in the research.

The warrants market is directed at the “man in the street” investor as a highly geared investment instrument. The single stock future options market appears to be more “wholesale” and the majority of the trades are large institutional trades for hedging purposes. The savvy institutions have better access to information and leverage in terms of negotiation when it comes to negotiating the premiums to be paid for a particular option. The “man in the street” investor has less access to information and is hamstrung by the fact that only authorised institutions such as banks may short warrant options, so has no leverage in terms of negotiation.

The banks are often trading the difference between the volatility between the warrants and the single stock future options. They have the ability to charge a large premium to the investor for the warrants and subsequently hedge that warrant on the other side with an inter-bank trade in the single stock future option markets. Regardless of their obligation to honour the warrant when exercised in favour of the investor, they have no risk or in cases still achieve a margin.

7.3 RECOMMENDATIONS

Trading strategies play an important role in the SSFO markets. It is recommended that the transactions be evaluated as such and not simply on the individual volatility arising from the transaction. An evaluation of the volatility for different trading strategies will potentially highlight the premium that certain investor groups are willing to pay.

7.4 SUGGESTIONS FOR FURTHER RESEARCH

Investigate the impact of liquidity on the markets as done by Koorts and Smith (2002), Bartram and Fehle (2007), Chiu, Lee, and Lin (2005), Fedderke and Joao (2001).

Consider alternative methodology for the calculation of the implied volatility using stochastic models such as that used by Huang and Chen (2002), and alternative methods for calculating historical volatility such as the ARCH and GARCH methods.

The sample for the premium calculations should be increased by considering the entire warrants market from inception.

Compare the SSFO premiums with another first world country market.

An evaluation of *rho* to determine the absolute range of sensitivity to interest rates and quantify the values.

The size of the transactions may have an influence on the premiums paid. A study on the number of contracts and the value of the transactions should be considered.

CHAPTER 8 LIST OF REFERENCES

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