VALUING CALL OPTIONS ON SINGLE STOCK FUTURES: DOES THE PUT-CALL PARITY RELATIONSHIP HOLD IN THE SOUTH AFRICAN DERIVATIVES MARKET?

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Abstract

Research has shown that violations of put-call parity do occur and that these violations present an investor with opportunities to profit from arbitrage deals. Mispricing may lead to significant superior returns and maximisation of shareholders' wealth if found and acted upon in a timely manner.

This study attempts to determine whether this mispricing of financial derivatives is present in the South African derivatives market. This will be achieved through the valuation of options on single stock futures using the put-call parity relationship. The theoretical fair values obtained, is compared to the actual market values over a period of three years, that is, from 2009 to 2011.

The results show that arbitrage opportunities do present themselves for the chosen shares. Further research may involve more shares over a longer period to determine whether any pattern may exist which may form the basis of an arbitrage trading strategy.

Keywords: Put-Call Forward Parity, Arbitrage Trading, Mispricing, Violations

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Introduction

Single Stock Futures (SSF's) contracts were introduced into the South African derivatives market in 1999; initially this only included derivatives on four of the Johannesburg Stock Exchange's (JSE) listed companies. The demand for these derivative instruments has grown substantially since their inception. South Africa currently boasts a large market for SSF's with about 800 000 contracts being traded daily. The growth in these instruments has provided unique opportunities to hedge equity risk, speculate, and earn arbitrage profits and to increase liquidity in the market.

A SSF is a futures contract in which an individual equity, listed on the Johannesburg Stock Exchange (JSE), is the underlying asset. SSFs are therefore derivatives instruments whose value is determined by movements in the underlying equity. An investor will enter a long futures position, hereafter called "long", if it is believed the share price is set to increase and will enter a short position, hereafter called "short", if it is believed the share price is set to decrease. The difference between the spot price and the futures price, at expiration, will determine the gain or loss of the position. An SSF contract can be reverse-traded at any time before expiration, with the return determined by the difference between the initial value of the contract and the current spot price of the SSF contract.

SSF contracts were first introduced in South Africa in 1999 and have grown in popularity ever since. This increase in demand is attributed to the wide range of investors that SSFs appeal to. Low margin requirements give many investors access to high-priced shares that some may not previously have had access to due to cash constraints. The leverage that futures contracts provide also attracts aggressive investors who are looking for high returns.

Apart from the SSF's, options on SSF's may also be traded on the JSE. An investor may choose to long or short a call or a put on a SSF. Longing a call option on an SSF means the investor may protect against an increase in the price of the underlying. If the option is out-of-the-money on expiry date, the investor may walk away from the agreement and only lose the option premium.

The put-call theorem describes the relationships between put and call option prices. This theorem works on the principle that the payoff or difference between a long call and a short put (together describing a leveraged underlying) is equal to a long underlying and the present value of the exercise price (also called a bond). This is a no-arbitrage relationship. Thus, for mispricing and arbitrage opportunities to exist there must exist violations of this theorem. These violations mean that the market prices of puts and calls are either more or less than their theoretical or model prices. This mispricing allows for arbitrage opportunities and unique profit opportunities to increase investment returns.

The results of this research will be of particular interest to individual and institutional investors. This is due to the fact that, if mispricing does exist in the South African market, it will create unique arbitrage opportunities for investors as mentioned above. This involves selling the overpriced instrument and buying the under-priced equivalent. This strategy results in a return that is above the risk-free rate of return. Investors will be able to adopt this strategy by simultaneously buying and selling the underlying asset and the synthetic underlying asset in order to profit from the differential in the price. This strategy will alter investors' trading decisions as it offers a unique opportunity to earn a riskless profit without the use of own capital. Synthetic underlying asset refers to an asset which is created synthetically with derivative instruments.

The growing interest in SSFs is evidence of the need for research in this field. Research done by De Beer (2008: 133) found that trading in SSFs increases the spot market trading volumes and reduces the level of spot market volatility. This was achieved through the use of t-tests and GARCH[1] models to test the volumes and volatility respectively. SSFs have a significant impact on the markets and therefore information about the pricing and trading of SSFs will prove to be very valuable to many investors.

Objective of the study

The aim of this study is to value option contracts on SSF's, using the put-call forward parity theorem, and to determine whether the theorem holds in the South African derivatives market or whether mispricing exists in the market. Mispricing of options, generally, are not considered in this research. Only calls relative to puts through the put-call parity relationship. The objective then is to determine whether setting up synthetic calls (whether shorting or longing) will deliver arbitrage profits.

This study does not address the possible effect of derivatives trading on general volatility in the market. Historic volatilities available on the JSE database is used for pricing and is assumed to be relatively constant and unaffected by trading/arbitrage activities for the sake of this research. This study also does not address the implied versus historic volatility issue.

Transaction fees were also ignored for the sake of this research. Only once the arbitrage profit moves out of these bounds will arbitrage trading be profitable.

[1] GARCH or Generalised autoregressive conditional heteroskedasticity model

Scope of the research

SSF's contracts on two different shares were selected and were evaluated over a period of four years to determine whether mispricing is prevalent. Only call options on the SSF for the same underlying were examined for mispricing in this research. The mispricing was done by calculating the call option prices with the Black model and then comparing the calculated call option prices with the data obtained from the JSE through the application of the put-call parity formula. The calculated call price is therefore compared to the synthetic call (long underlying, long actual put and short bond).

The put mispricing is not covered in this research.

Methodology

In order to conduct this research, option contract prices were obtained from the Derivatives Division of the JSE (previously called the South African Futures Exchange (SAFEX)). The study period spanned four years: 2009 to 2012. This was due to the availability of data from the Johannesburg Stock Exchange's Electronic Derivatives Market statistics (EDMStats) downloadable files. This time period also represents fairly recent data; this ensured that the results were relevant at the time the study was conducted. Daily put and call closing prices as well as the closing prices of the underlying futures contract were used. The put and call prices were on options with the same expiration dates as well as the same exercise prices. The exercise price was the price of the underlying SSF. Only American-style option prices were determined. American options can be exercised at any time before expiration date. The options used for valuation were options that had already expired.

The option contract data were acquired for two different underlying shares. One of the chosen shares was a company of which the shares were considered liquid, that is, high trading volumes were observed in the market. The other share was of a company that was considered relatively illiquid. The shares were picked based on their trading volumes. This allowed for a comparison of the relationship between put and call prices and the effect trading volume may have on prices and any mispricing, should it exist.

The liquid underlying share of choice was BHP Billiton (BILQ) and the relatively illiquid underlying share of choice was Sasol (S0LQ). This decision was based on traded volume of option contracts data downloaded from EDMStats. Once this data had been collected the futures contracts were valued using the following formula obtained from the JSE website (JSE 2012b):

Equation (1): The basic equation to price SSF contracts is the cost-of-carry pricing model:

- SSF price = Share price (spot) + Interest - Dividends
- Long position bid-offer equations (Standard Bank, 2006b: 21)

$$SSF_{Bid} = S_{Bid} * (1 - c) * (1 + i)^{(t1/365)} - div * (1 + i)^{(t2/365)}$$

$$SSF_{Offer} = S_{Offer} * (1 - c) * (1 + i)^{(t1/365)} - div * (1 + i)^{(t2/365)}$$

Where:
SSF_{Bid} = SSF bid price
SSF_{Offer} = SSF offer price
S_{Bid} = bid price of underlying
S_{Offer} = offer price of underlying
r = risk-free interest rate
div = underlying asset's projected/expected dividend
t1 = number of days to expiry of particular SSF
t2 = number of days between the dividend date and SSF expiry date
c = commission

The call options and put options were then valued using the Black model.

Equation (2):

$$c = e^{-rT}\left[f_0(T)N(d_1) - XN(d_2)\right]$$
$$p = e^{-rT}\left\{ X\left[1 - N(d_2)\right] - f_0 T\left[1 - N(d_1)\right]\right\}$$

Where:

$$d_1 = \frac{\ln(S_0 / X) + \left[r + (\sigma^2/2)T\right]}{\sigma\sqrt{T}}$$
$$d_2 = d_1 - \sigma\sqrt{T}$$

Where:

c_0 = the call price on valuation date 0
p_0 = put price on valuation date 0
X = the strike price
F_0 = futures price on day 0
N = probability
e = Naperian constant, 2.71828
r = the risk-free interest rate
σ = volatility

The valuation of the options was done with Microsoft Excel. Once all the relevant values had been calculated, the put-call forward parity equation (Equation 3 below) was used to determine whether any mispricing existed.
Equation (3):

$$c_0 + \frac{(X - F(0,T))}{(1+R)^T} = p_0$$

Where:
c_0 = call option price at time 0
p_0 = put option price at time 0
X = the exercise price of the option (futures price)
R = the risk-free interest rate
T = time to expiration
$F_{(0, T)}$ = futures price at time 0 spanning period T

The risk-free rate that was used in this study was the Johannesburg Interbank Agreed Rate (Jibar). The 3-month, 6-month, 9-month as well as the 12-month Jibar rates were used. The rates were acquired from the daily traded data, which was obtained from the EDMStats section of the JSE website. A year day count convention of 365 was used which is in accordance with the market practice in South Africa.

The fair values obtained from equation 3 were then compared to the actual values in the market to determine whether mispricing was prevalent and whether this presented an investor with arbitrage trading opportunities. A difference would indicate mispricing.

A study such as this is important as traders and researchers always search for opportunities to formulate new trading strategies that may present opportunity to realise returns above the risk-free rate.

Brief literature overview

In order for arbitrage opportunities to exist, there needs to be violations of the put-call parity principle which opens up an arbitrage window. These arbitrage opportunities can lead to significant profit opportunities if acted upon in a timely manner. Research has been done over recent years on violations of put-call parity and its effect on the market.

It is important to point out that a special relationship exists between call options and put options. A call options gives the right to the holder (buyer) to buy an underlying (in this case a SSF) at a predetermined date at a predetermined price (called the strike). One would normally buy a call if it is the intention to buy the underlying in the future at today's price. Buying the call means that we expect the price of the SSF to increase in the future. The put is basically the opposite of the call as buying a put means that we expect prices to fall. The payoff profiles of calls and puts are therefore opposite to each other.

Original work done by Stoll (1969) quite some time ago found that the payoff of a long call and long bond is equivalent to a position of a long put option and long stock position. Stoll (1969) found that the main reason for divergences from put-call parity was the introduction of transaction costs into the theorem. He found that transaction costs can cause a divergence of between one or two percent on either side of the parity line (on the fiduciary call side or protective put side).

Cremers and Weinbaum (2010) found that a deviation from put-call parity contains information about future returns. They determined that the degree to which deviations can be predicted is larger when the option liquidity is high and the stock volumes are low. Their research suggested that violations of put-call parity can simply be due to market imperfections, data-related issues and short selling constraints. The research used volatility spreads to measure the deviations from put-call parity and found that relatively expensive call options outperform relatively expensive put options.

Research conducted by Goh and Allen (1984) to test for parity, involved creating long- and short-hedged positions based on the put-call parity theorem. They did this by writing a call option and combining it with a long call position for the long hedge and writing a put and combining it with a long put position for the short hedge. The results determined that the more in-the-money a call is, the more likely it is to be overvalued relative to the put and the more likely the long hedge will be profitable. This is therefore an example of a violation of the put-call parity principle.

Each JSE SSF contract is standardised in terms of its size, expiration date and tick movement. Each contract is based on 100 shares of the underlying equity. The contract will specify the particular underlying share, the price of the contract and the expiration date (Standard Bank, 2006a: 68). SSF investors have three options at expiration. The contract can be physically settled, meaning that the commitment will be carried out in that the actual number of shares will be traded between the two counterparties. Next the contract can be settled in cash, meaning cash will change hands at expiration and no physical delivery will take place. The last option available to investors is that the contract can be rolled over to the next expiration date. All SSFs expire on the third Thursday of March, June, September and December.

Table 1. Contract specifications of single-stock futures

Code	**The three-letter stock code followed by a Q (e.g. SOLQ)**
Underlying	In this case shares
Contract size	100 times the futures price
Contract months	March, June, September, December
Quotations	Price per underlying share to two decimals
Minimum price movement	R1 per contract (R0, 01 of the share price)
Initial margin	Approximately 10% of contract value
Settlement method	Physically and cash settled
Clearinghouse fees	R0, 30 per futures contract R0, 15 per option contract
Commissions	15-40 basis points to enter or exit a position
Brokerage	Fixed amount plus VAT per trade
Dividends	Reflected in the price of the futures contract
Corporate Events	SSF contracts will adjust to reflect changes in the underlying shares
Options on SSF contracts	Each option is on one futures contract
Strike Price intervals	R5, 00 in the futures price

(Source: JSE (2012c); Nedbank (2012:9))

SSFs have two main users: hedgers and speculators. Hedgers seek to reduce risk by protecting an existing share portfolio against possible adverse price movements or locking in future anticipated purchases of shares. Speculators use SSFs in the hope of making a profit in the short-term movements in the underlying share price by closing out the position before expiry date.

Generally, futures allow the investor an opportunity to use gearing. In the South African market an initial investment of about 10% of the underlying value will give the investor the full exposure to price movements (Harris, S. 2005: 75). Harris (2005) indicates that this has proved very popular for retail investors, as futures trading require a low initial capital outlay. The use of gearing allows for increased returns, as well as increased losses. This strategy is very popular as it gives the investor a lot of exposure to price movements with a small commitment of capital.

SSFs provide a simple and cost-effective way of gaining exposure to the specific underlying stock. Due to the use of leverage, investors obtain geared exposure to the underlying shares without actually having to own the share. Investors obtain exposure at a fraction of the total value of the transaction. The use of leverage also enables investors to gain exposure to high-value shares otherwise not possible. By initiating a leveraged position in an SSF contract it will mean that cash is free to invest in other parts of the market (De Beer, 2008:27). The transactions costs for SSFs are lower than the costs of trading in the underlying securities. There are also no uncertified securities taxes (UST) or STRATE (Share Transaction Totally Electronic – the electronic settlement of share transactions and recording of ownership) costs (Nedbank, 2012:3).

Pair trading also gives rise to another reason for trading in SSFs. SSF contracts allow an investor to pursue a long-short strategy when it is believed that one share (long) will out-perform another short (short). This strategy is usually applied for shares in the same sector or industry where the shares are affected by the same fundamental factors. The overall gain or loss will depend on the relative performance of the two shares (JSE, 2012b). It also means that forecasts of market movements will not have to be made, eliminating market-specific risks.

SSFs also allow investors to hedge against changes in index compositions, both when a share is added to an index and when a share is demoted from an index. Managers who follow index compositions normally rush to include the correct weights of shares involved in the index they are trying to replicate. This causes a distortion in the prices of the securities. SSFs allow the managers to gradually ease their way into the relevant stocks being added to the index. Similarly, when stocks are removed from an index, there is a rush to sell the security in question, which causes instability in less liquid shares. SSFs allow managers to move out of the security in an orderly fashion even when there are liquidity problems (JSE, 2012b).

SSFs can also be used to reduce the risk of an existing portfolio. By selling or shorting a SSF, the investor can protect the value of a portfolio, without having to sell any shares (Standard Bank, 2006b). Because SSF contracts do not give the holder any shareholder rights (voting rights and dividends) this feature is very attractive if there is a temporary decline in the market. The use of SSFs in a portfolio setting can also lead to significant tax savings. If the objective is to reduce equity exposure but selling the stock will create significant tax liability, the use of SSFs will help achieve this. The shares do not actually have to be sold therefore avoiding the tax liability (Mitchell, 2003:72).

SSFs offer high reward and also high risk. The main risk associated with SSFs is the fact that it is a leveraged investment. For a small outlay, a large exposure may be gained. Leverage can cause large losses over a short period of time. These losses can be larger than the initial margin requirement. Due to the fact that the average geared amount is ten percent of the initial value, it means that losses on the underlying share can be up to ten times larger on the SSF (Standard Bank, 2006b: 9).

By trading in SSFs the investor does not receive any shareholders rights. Therefore investor will not have any voting rights that could prove important when voting on corporate action events. Although the effect of dividends is taken into account in the pricing of the SSF, holders of SSFs do not receive any dividends. This will prove problematic if an investor is dependent on the cash flow that dividends provide.

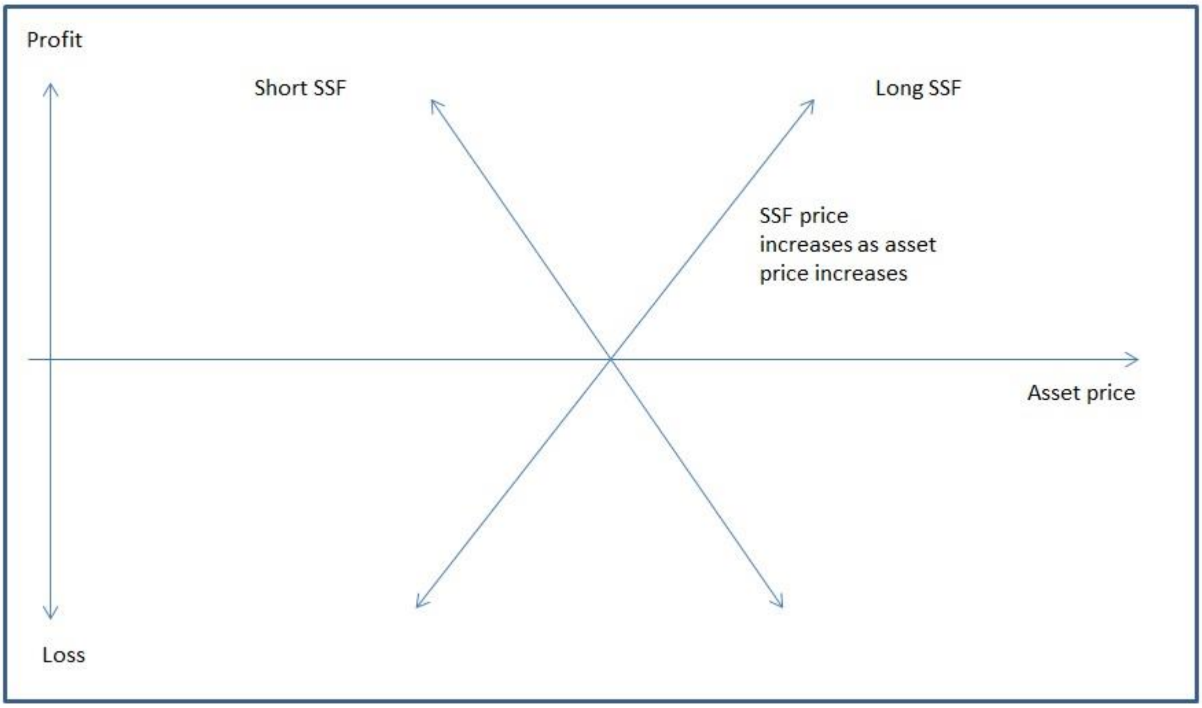
Due to the apparent risks involved with trading SSFs, it is important to monitor positions on a continuous basis. Stop-loss triggers can also be utilised in order to minimize losses. Essentially the trader will set a limit on the price at which the position will be automatically closed-out. If there are not enough traded contracts available in the market, the position might not be completely closed-out (Standard Bank, 2006b: 14). Thus the investor will still be exposed to some of the risk associated with price changes.

The risk profile of a SSF contract will be the same as the underlying share. If the price of the underlying share increases then the value of the SSF will increase. Figure 1 shows the relationship between the underlying share price and a long SSF position where the underlying share is Anglo American Plc. The risk profile when the investor shorts a SSF contract is the inverse of the long share position. The net effect when combining two such positions is 0 (ignoring transaction fees) and it termed the perfect hedge.

Pricing

The main variables that influence the prices of SSF contracts are the underlying share price, interest rates, dividends and commission. The spot price of the underlying share is the main determinant of the futures price and is used in the calculation of the interest and commission components. The interest is calculated on the value of the underlying share exposure for the remaining period of the contract. The holder of a SSF contract does not receive ordinary dividends, thus the bid and offer prices are adjusted accordingly to reflect this . Commission is charged as a percentage of the underlying value (Standard Bank, 2006b: 17-18).

Figure 1. Risk profile of a long and short SSF contract



Source: Standard Bank, 2006b: 12 (adjusted)

The basic equation used to price SSF contracts is the cost-of-carry model:

SSF price = Share price (spot) + Interest - Dividends

Long position bid-offer equations (Standard Bank, 2006b: 21).

$$SSF_{Bid} = S_{Bid} * (1 – c) * (1 + i)^{(t1/365)} – div * (1 + i)^{(t2/365)}$$
$$SSF_{Offer} = S_{Offer} * (1 – c) * (1 + i)^{(t1/365)} – div * (1 + i)^{(t2/365)}$$

Where:

SSF_{Bid}	=	SSF bid price
SSF_{Offer}	=	SSF offer price
S_{Bid}	=	bid price of underlying
S_{Offer}	=	offer price of underlying
r	=	risk-free interest rate
div	=	underlying asset's projected dividend
t1	=	number of days to expiry of particular SSF
t2	=	number of days between the dividend date and SSF expiry date
c	=	commission

If the share generates a very large dividend, the SSF will be priced at a discount to compensate the investor for not receiving the dividend. The estimation of dividends, when pricing SSFs, is done by looking at the share's dividend history to create an estimate of future dividends (Standard bank, 2006b: 18). If, at a later date the announced dividend is different to the estimated amount, there will be an adjustment to the fair value of the SSF.

Other issues such as supply and demand also affect the pricing of SSFs and cause the futures price to diverge from fair value (JSE, 2012b). Wasendorf and Thompson (2004: 44-45) also indicated that the choice of interest rates, the timing and uncertainty of dividends and the compounding method all complicate the pricing of SSFs.

Analysis

The first step in the valuation process was to value the future contracts over the study period. Table 2 below shows a short extract of the futures valuations. The same method was consistently applied for each month during the four year period.

Table 2. Calculation of the BHP Billiton futures contracts prices

Date traded	Contract code	Expiry date	Strike price	Spot price	Volatility (%)	JIBAR (%)	Day count	Carry cost	Futures price (FVF)
3/1/2012	BILQ	15/3/2012	N/a	248.75	37.25	5,60	72	2.747836	251.4978
3/1/2012	BILQ	21/6/2012	N/a	248.75	37.25	5,86	168	6.709299	255.4593
4/1/2012	BILQ	15/3/2012	N/a	252.00	37.25	5,60	71	2.745074	254.7451
4/1/2012	BILQ	21/6/2012	N/a	252.00	37.25	5,86	167	6.756500	258.7565
30/1/2012	BILQ	15/3/2012	N/a	263.90	37.25	5,60	45	1.82195	265.7220
30/1/2012	BILQ	21/6/2012	N/a	263.75	37.25	5,86	141	5.973973	269.8740
31/1/2012	BILQ	15/3/2012	N/a	248.75	37.25	5,60	45	1.822961	265.8630
31/1/2012	BILQ	21/6/2012	N/a	248.75	37.25	5,86	141	5.977142	270.0171

The Jibar rate and the year day count used were extracted from the daily trading data acquired from the JSE. Firstly, the finance costs were calculated using the above equation. The futures prices were then calculated by adding the pro rata calculated finance costs to the spot prices.

After the future contract prices were calculated, the put and call option prices were calculated using the Black-Scholes Merton formula.

The next step involved determining the parity call prices using the put-call forward parity theorem. The prices obtained during the valuation of the futures and option contracts were used as inputs to determine the put-call parity prices. The valuation involved identifying put and call option contracts with the same exercise prices as well as the same time to expiration.

Call mispricing evidence

Throughout the period in question, it became clear that mispricing of the call options existed. The call options were found to be overvalued (92,48%) of the time. The overvaluation of the call options was significant for both the BHP Billiton options (91, 10%) and the Sasol options (95,24%). These findings seemed to indicate that the relative liquidity of the two option contracts was not so significant or it may be that Sasol was still so liquid that it made little difference to pricing.

Table 3. Extract of BHP Billiton call option valuations using put-call forward parity (strike price R178, 20)

Call date	Expiry call	Futures Price	Fract of year	Rate	Strike	Spot price	Call price	Parity call	Mis-pricing
2009.03.02	18.06.2009	178,89	0,2904	9,33%	178,82	155,75	16,2378	15,9793	0,2585
2009.03.03	18.06.2009	191,58	0,2877	9,33%	178,82	155,40	16,6175	16,3656	0,2519
2009.03.04	18.06.2009	200,25	0,2849	9,33%	178,82	165,01	21,1785	20,9304	0,2481
2009.03.05	18.06.2009		0,2822	9,33%	178,82	166,40	21,7682	21,5226	0,2456
2009.03.06	18.06.2009		0,2795	9,33%	178,82	174,50	26,4568	26,2476	0,2093
2009.03.13	18.06.2009		0,2603	9,33%	178,82	168,49	33,1720	34,7588	-1,5868
2009.03.16	18.06.2009		0,2521	9,33%	178,82	179,00	28,9592	30,8549	-1,8958
2009.03.17	18.06.2009		0,2493	9,33%	178,82	184,05	27,1350	27,8023	-0,6674
2009.03.18	18.06.2009		0,2466	10,22%	178,82	155,75	26,2793	13,7957	12,4836
2009.03.23	18.06.2009		0,2329	10,22%	178,82	177,90	45,4216	41,6673	3,7543
2009.03.24	18.06.2009		0,2301	10,22%	178,82	197,33	37,9009	32,4141	5,4868

A number of different scenarios were evaluated in order to determine whether the mispricing found in the valuation was evident during different stages of the option contracts term. This was done for both Sasol contracts as well as the BHP Billiton contracts. Specific option contracts were isolated and evaluated. Options that were in-the-money and out-of-the money were evaluated as well as option contracts that were very close to expiration. Table 3 illustrates a BHP Billiton call option that was traded during March 2009 and expired on June 18, 2009. As can be seen the call options were out-of-the-money as the spot price was below the strike price for the majority of the month.

It can be seen that the call was overvalued (shown as a positive value in the last column of Table 3) for most of the month. However, as the spot price approached the strike price, the degree of mispricing decreased and for a couple of days the contract was undervalued (shown as a negative value in Table 3). Figure 2 graphically illustrates the mispricing for the above mentioned call option for different expiry dates. Figures 3 and 4 illustrates the same for calls expiring 15 December 2010 with a strike of R180 and calls with a strike of R280 expiring 15 June 2011.

Figure 2. BHP Billiton Call option with a strike price of R178,82 expiring 18 March 2009

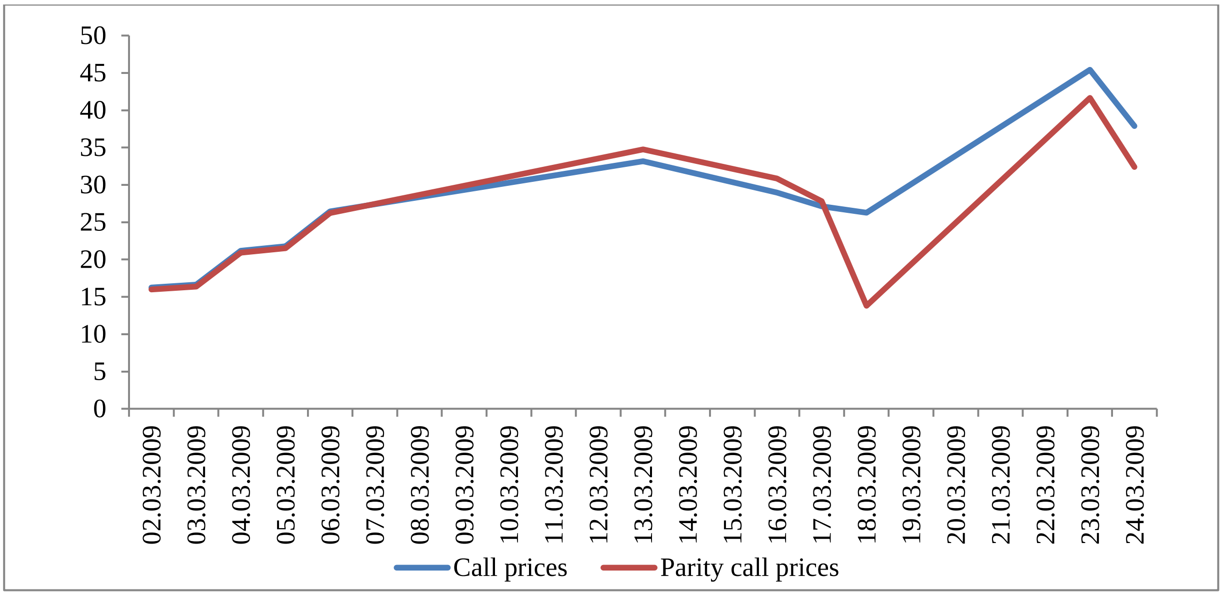


Figure 3. BHP Billiton Call option with a strike price of R180 expiring 15 December 2010

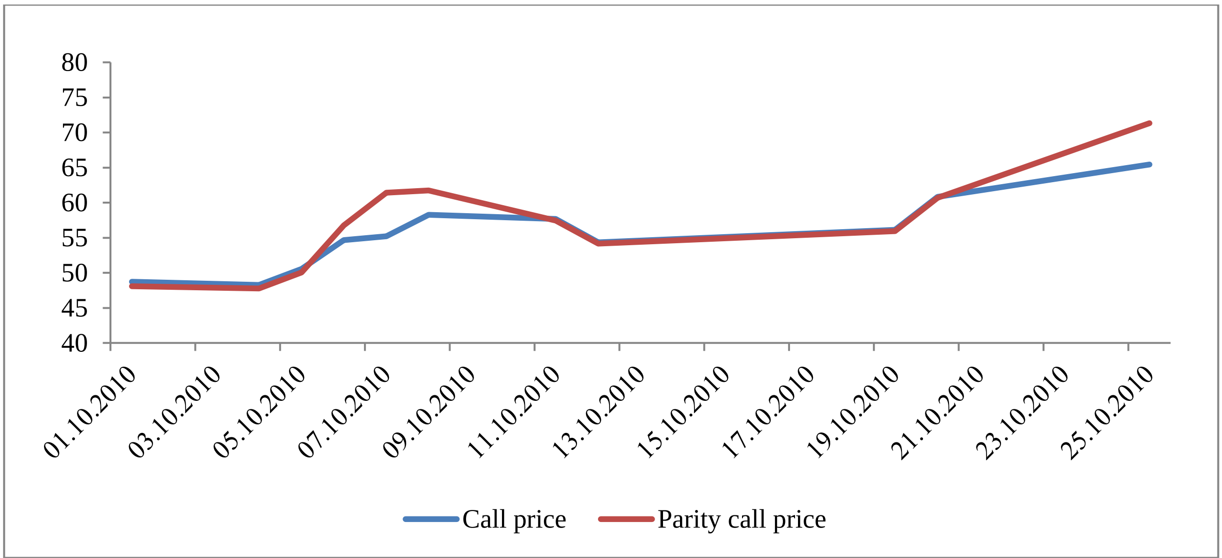


Figure 4. BHP Billiton Call option with a strike price of R280 expiring 15 June 2011

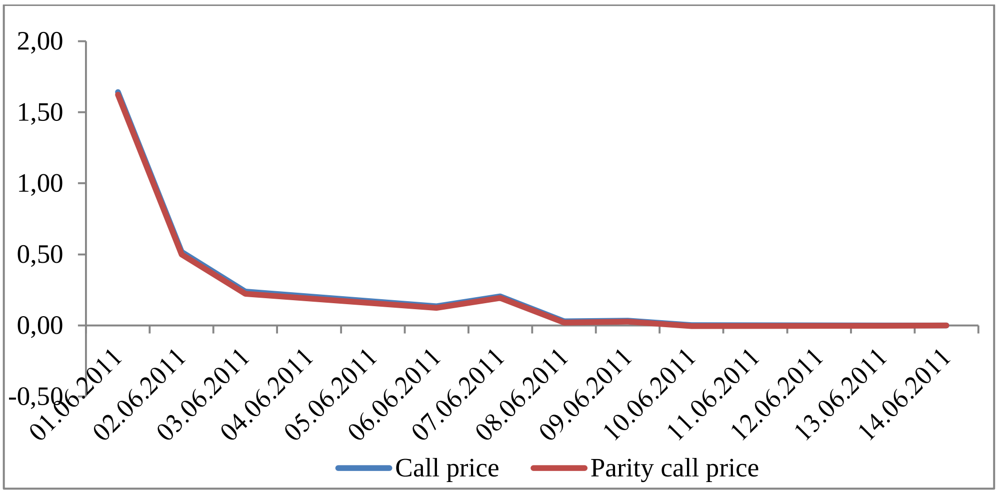


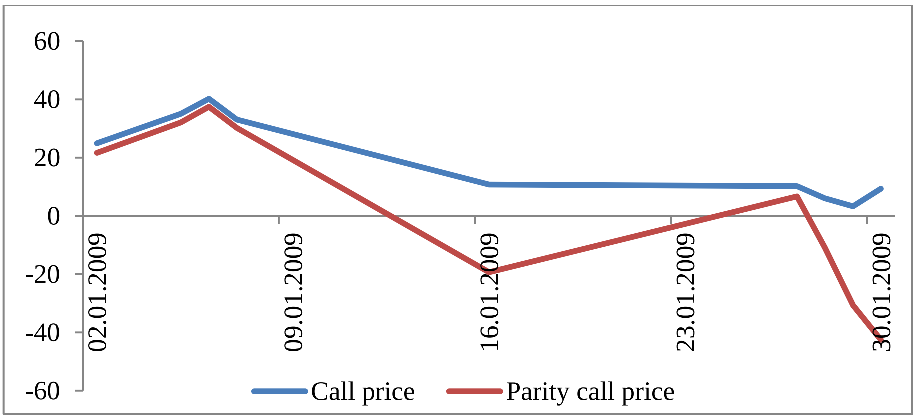
Table 4 illustrates the mispricing present for a Sasol call option that was also out-of-the money during the month of January 2009. This specific option contract was due to expire on March 19, 2009.

Table 4. Extract of Sasol call option valuation using put-call forward parity (Strike price R332, 20)

Date	Expiration	Futures price	Fract of year	Jibar	Strike price	Spot price	Call price	Parity call price	Mis-pricing
02.01.2009	19.03.2009	299,14	0,2110	12,10%	332,20	292,10	24,9264	21,6534	3,2730
05.01.2009	19.03.2009	370,58	0,2027	12,10%	332,20	315,00	35,0430	32,1420	2,9009
06.01.2009	19.03.2009	355,62	0,2000	12,10%	332,20	325,00	40,1787	37,4416	2,7371
07.01.2009	19.03.2009	335,39	0,1973	12,10%	332,20	312,50	33,1317	30,2039	2,9279
16.01.2009	19.03.2009		0,1726	12,10%	332,20	290,00	10,8438	-19,2578	30,1016
27.01.2009	19.03.2009		0,1425	12,10%	332,20	290,00	10,2503	6,7329	3,5174
28.01.2009	19.03.2009		0,1397	12,10%	332,20	278,00	6,0214	-10,8725	16,8939
29.01.2009	19.03.2009		0,1370	12,10%	332,20	275,60	3,3647	-30,6057	33,9704
30.01.2009	19.03.2009		0,1342	12,10%	332,20	272,01	9,3358	-42,4393	51,7751

As illustrated the call option was overvalued during the month of January. Figure 5.2 illustrates this information graphically. The call option was further out-of-the-money compared with the BHP Billiton option in Figure 5.1. This provides an indication that the further away the option contract was from being in-the-money the larger the relative mispricing present.

Figure 4. Sasol Call option with a strike price of R332,20 expiring 19 March 2009



Call option contracts were also evaluated that were in-the-money. Call options are said to be in-the-money when the underlying spot price is above the strike price and therefore will be exercised at the discretion of the investor, in the case of American options. Table 5 illustrates a Sasol call option that was in-the-money during August of 2010.

Table 5. Extract of Sasol call option valuation using put-call forward parity (Strike price R270)

Call date	Expiry future	Futures price	Fract of year	Jibar	Strike	Spot Price	Call price	Parity call	Mis-pricing
02.08.2010	16/09/2010	300,08	0,1205479	6,81%	270,00	297,50	31,6013	29,1775	2,4238
03.08.2010	16/09/2010	292,46	0,1178082	6,81%	270,00	290,00	25,1562	22,8452	2,3110
04.08.2010	16/09/2010	295,43	0,1150685	6,81%	270,00	293,00	27,5119	25,2318	2,2801
05.08.2010	16/09/2010	297,39	0,1123288	6,81%	270,00	295,00	29,0949	27,2212	1,8737
06.08.2010	16/09/2010	296,84	0,109589	6,81%	270,00	294,50	28,5482	26,3622	2,1861
11.08.2010	16/09/2010	292,47	0,0958904	6,81%	270,00	288,00	22,4919	22,9772	-0,4853
12.08.2010	16/09/2010	290,03	0,0931507	6,81%	270,00	285,65	20,4830	21,0165	-0,5334
13.08.2010	16/09/2010	287,61	0,090411	6,81%	270,00	289,50	23,4506	21,6784	1,7722
16.08.2010	16/09/2010	291,43	0,0821918	6,81%	270,00	290,25	23,6796	22,0640	1,6156
17.08.2010	16/09/2010	292,02	0,0794521	6,81%	270,00	290,50	23,7592	22,1960	1,5632
18.08.2010	16/09/2010	292,22	0,0767123	6,81%	270,00	288,15	21,6465	20,1489	1,4976
19.08.2010	16/09/2010	289,80	0,0739726	6,81%	270,00	284,45	18,5627	17,1365	1,4263
20.08.2010	16/09/2010	286,03	0,0712329	6,81%	270,00	281,50	16,1434	14,7836	1,3598
23.08.2010	16/09/2010	283,01	0,0630137	6,81%	270,00	288,10	20,9344	19,7039	1,2305
25.08.2010	16/09/2010	289,49	0,0575342	6,81%	270,00	277,05	12,5454	11,4634	1,0820
26.08.2010	16/09/2010	285,96	0,0547945	6,81%	270,00	278,02	13,0037	11,9697	1,0340
27.08.2010	16/09/2010	278,29	0,0520548	6,81%	270,00	277,00	12,0963	11,1174	0,9789
30.08.2010	16/09/2010	279,21	0,0438356	6,81%	270,00	280,00	13,5890	12,7557	0,8332
31.08.2010	16/09/2010	278,12	0,0438356	6,81%	270,00	280,85	14,2285	13,3928	0,8357

As shown above, the call prices were overvalued relative to the parity call prices obtained using the put-call forward parity theorem. As the spot price decreased towards the strike price, during the month, the degree of mispricing also decreased. The above information is illustrated graphically in Figure 5 below.

Figure 5. Sasol Call option with a strike price of R270 expiring 16 September 2010

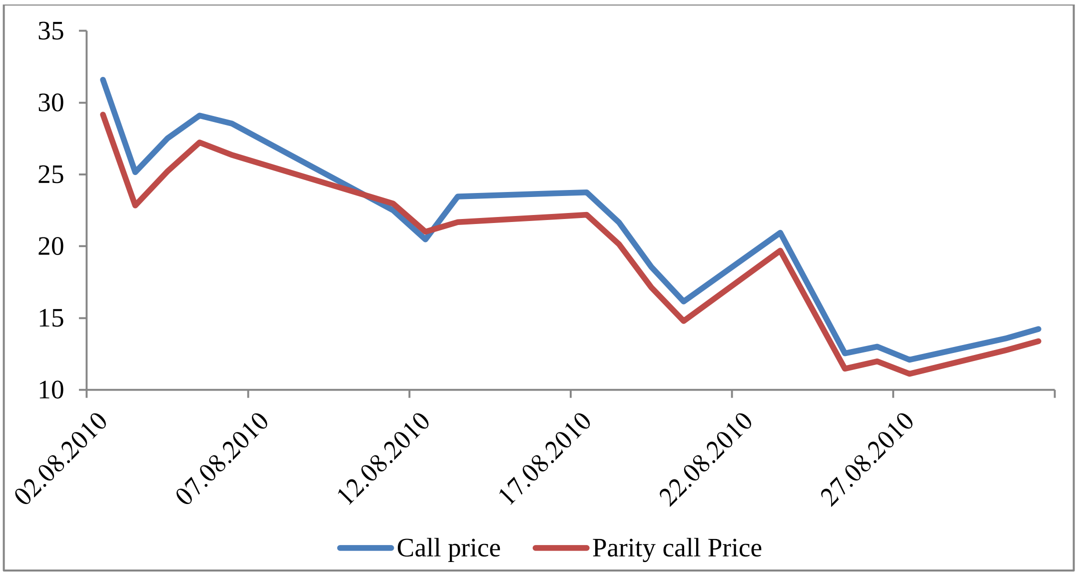
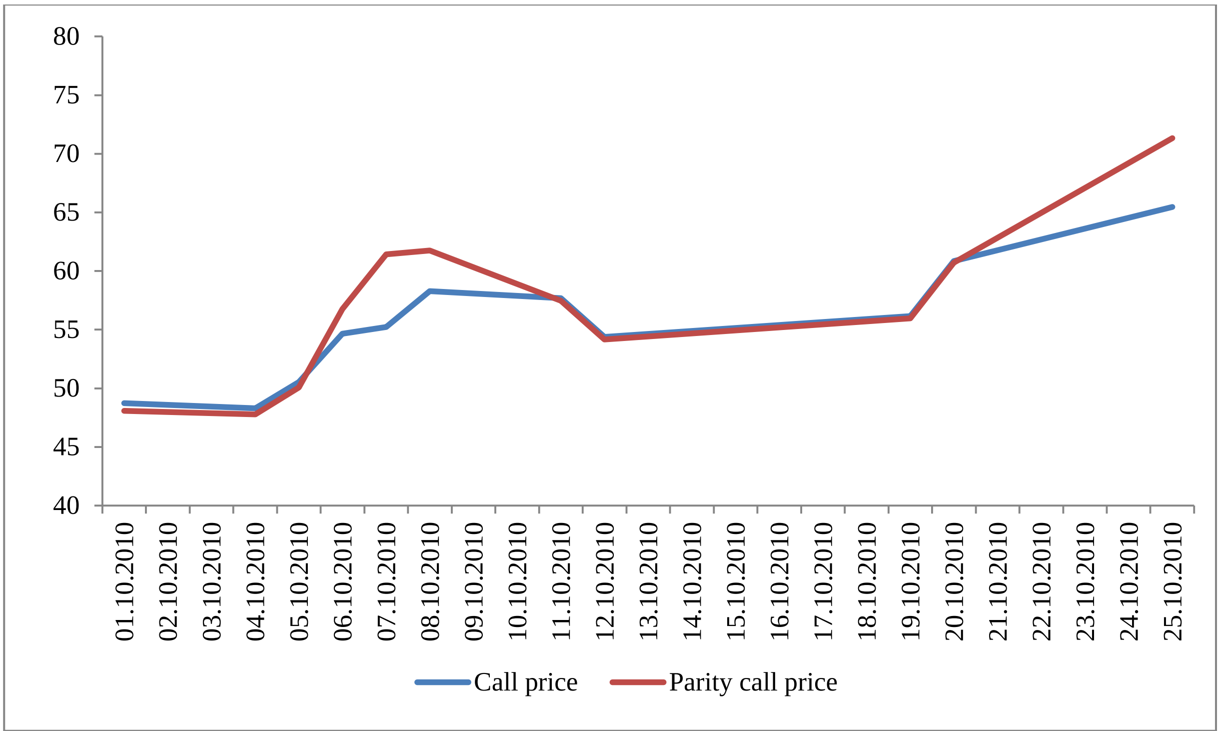


Figure 6 graphically shows the degree of mispricing as the parity call price is below the actual call price. The same overvaluation for a BHP Billiton call option that is in-the-money is shown in Table 6. The call option was traded during October 2010 and had a strike price of R180.

Table 6. Extract of BHP Billiton call option valuation using put-call forward parity (Strike price R180)

Call date	Expiry call	Futures Price	Fract of year	Jibar	Strike price	Spot price	Call price	Parity call	Mis-pricing
01.10.2010	15.12.2010	228,66	0,2027397	6,33%	180,00	225,90	48,7233	48,0811	0,6422
04.10.2010	16.12.2010	242,27	0,1945205	6,33%	180,00	225,61	48,3023	47,7858	0,5165
05.10.2010	17.12.2010	247,85	0,1917808	6,33%	180,00	228,00	50,5481	50,0595	0,4886
06.10.2010	18.12.2010	249,56	0,1890411	6,33%	180,00	232,26	54,6577	56,7699	-2,1122
07.10.2010	19.12.2010		0,1863014	6,33%	180,00	232,90	55,2435	61,4315	-6,1880
08.10.2010	20.12.2010		0,1835616	6,33%	180,00	236,10	58,2990	61,7528	-3,4538
11.10.2010	21.12.2010		0,1753425	6,33%	180,00	235,60	57,6938	57,4568	0,2370
12.10.2010	22.12.2010		0,1726027	6,33%	180,00	232,28	54,3757	54,1653	0,2104
19.10.2010	23.12.2010		0,1534247	6,33%	180,00	234,35	56,1549	55,9656	0,1892
20.10.2010	24.12.2010		0,1506849	6,33%	180,00	239,10	60,8412	60,7231	0,1181
25.10.2010	25.12.2010		0,1369863	6,33%	180,00	243,90	65,4650	71,3319	-5,8669

Figure 6. BHP Billiton Call option with a strike price of R180 expiring 15 December 2010

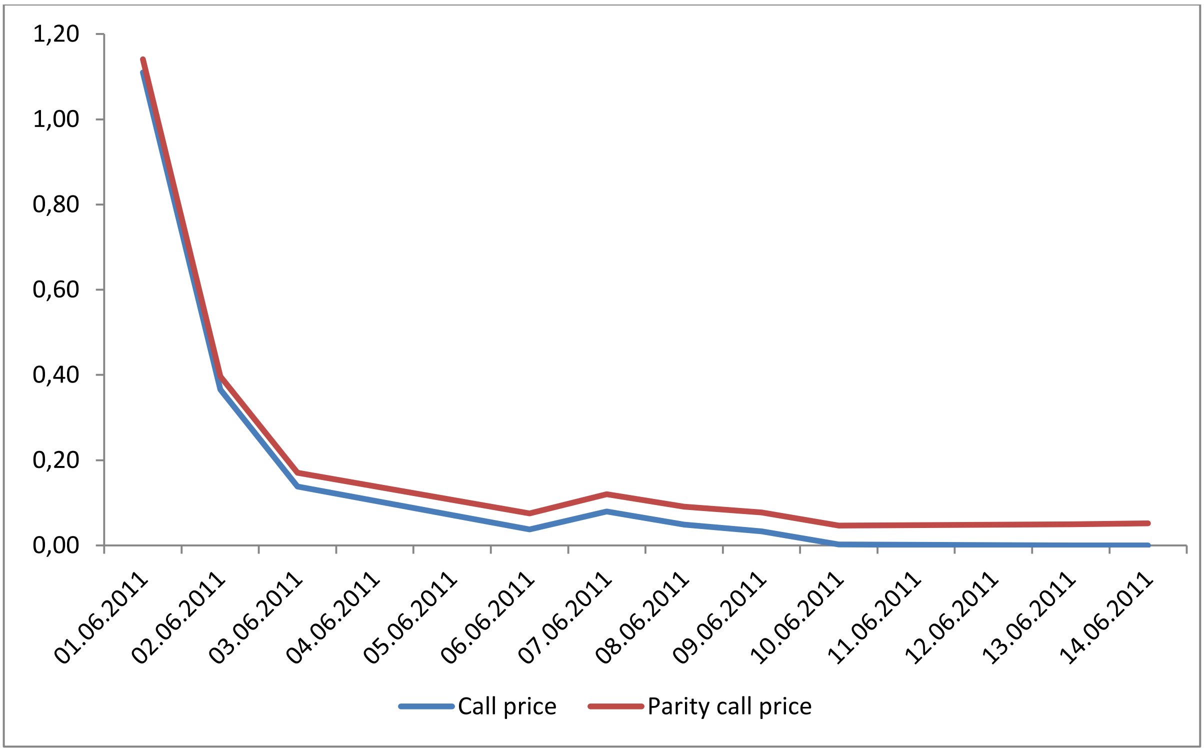


The last aspect looked at in identifying mispricing was option contracts that were traded during the months that they were due to expire. A call option of Sasol and a call option of BHP Billiton were evaluated to accomplish this. The Sasol contract evaluated was trading out-of-the money during the evaluation period and the BHP Billiton call option was trading in-the-money during the evaluation period. Table 7 illustrates the pricing of the Sasol contract during June 2011. The contract's expiration date was June 15 2011. Figure 7 graphically illustrates the results as depicted in Table 7.

Table 7. Extract of Sasol call and put option valuation using put-call forward parity (strike price R385)

Call date	Expiry call	Futures price	Fract of year	Jibar	Strike price	Spot price	Call price	Parity call	Mis-pricing
01.06.2011	15.06.2011	366,78	0,0383562	5,73%	385,00	360,60	1,11	1,1410	-0,0308
02.06.2011	15.06.2011	352,88	0,0356164	5,73%	385,00	352,50	0,37	0,3968	-0,0314
03.06.2011	15.06.2011	363,92	0,0328767	5,73%	385,00	347,03	0,14	0,1707	-0,0323
06.06.2011	15.06.2011	361,89	0,0246575	5,73%	385,00	346,00	0,04	0,0753	-0,0374
07.06.2011	15.06.2011	354,42	0,0219178	5,73%	385,00	352,40	0,08	0,1201	-0,0402
08.06.2011	15.06.2011	362,53	0,0191781	5,73%	385,00	352,50	0,05	0,0910	-0,0419
09.06.2011	15.06.2011		0,0164384	5,73%	385,00	353,50	0,03	0,0771	-0,0438
10.06.2011	15.06.2011		0,0136986	5,73%	385,00	346,98	0,00	0,0464	-0,0445
13.06.2011	15.06.2011		0,0054795	5,73%	385,00	346,00	0,00	0,0495	-0,0495
14.06.2011	15.06.2011		0,0027397	0,0573333	385,00	351,49	0,00	0,0520	-0,0520

Figure 7. Sasol Call option with a strike price of R385 expiring 15 June 2011



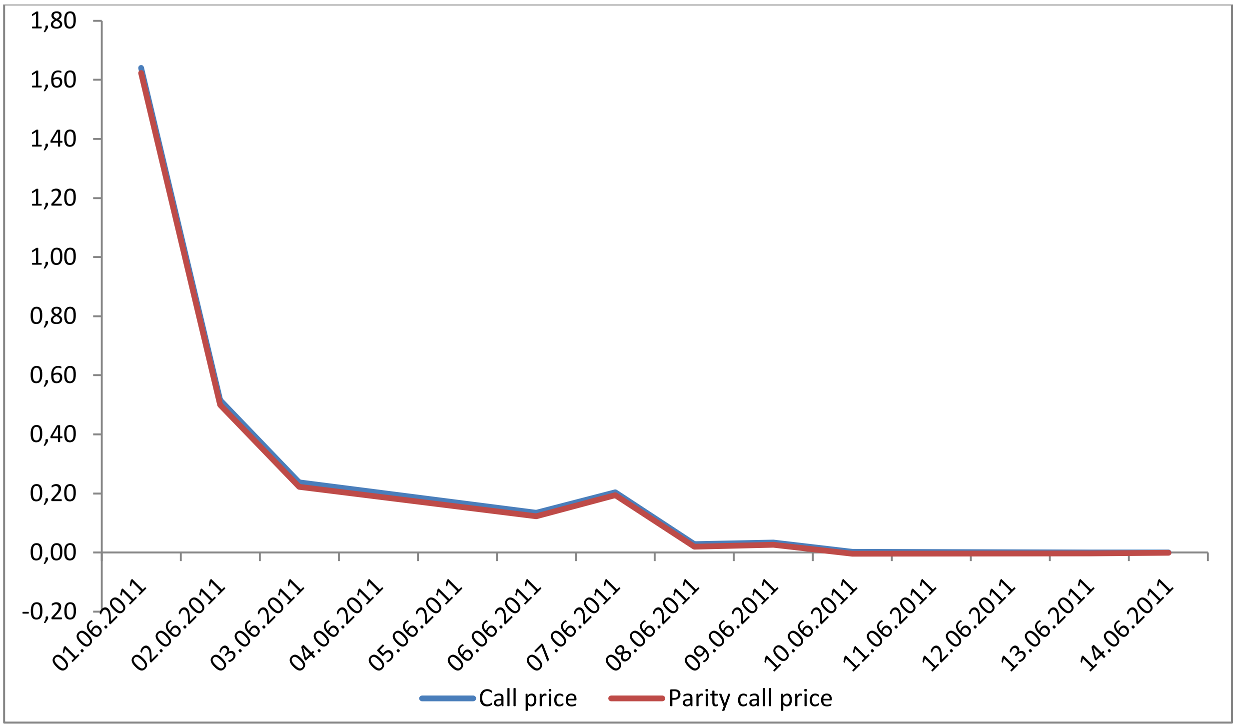
The results obtained from performing this analysis were the opposite of what had been determined before. As can be seen in Table 7, the call options valued using the put-call forward parity relationship were undervalued as opposed to the actual call prices. This finding was consistent throughout the study period and therefore it was determined that during the month the contract is due to expire, the actual call prices are lower relative to the parity prices. This makes sense due to the fact that call options offer little time value benefit close to expiry date as interest included in pricing, diminishes over time.

The same results for the BHP Billiton contracts were inconsistent with the results found with the Sasol contracts. Table 8 illustrates this. The call option was still found to be overvalued, even though the time to expiration of the two contracts was the same. Although mispricing was present, the relative amount of mispricing was very low, making arbitrage trading strategies very difficult to implement and as the contract neared expiration the relative degree of mispricing decreased. Figure 8 illustrates this graphically. This result was found consistently throughout the study period in question.

Table 8. Extract of BHP Billiton call option valuation using put-call forward parity (Strike price R280)

Call date	Expiry call	Futures price	Fract of year	Jibar	Strike price	Spot price	Call prices	Parity call	Mis-pricing
01.06.2011	15.06.2011	266,7291	0,0383562	5,73%	280,00	360,60	1,6411	1,6235	0,0176
02.06.2011	15.06.2011	259,2137	0,0356164	5,73%	280,00	352,50	0,5162	0,4999	0,0163
03.06.2011	15.06.2011	255,4674	0,0328767	5,73%	280,00	347,03	0,2370	0,2220	0,0150
06.06.2011	15.06.2011	256,5822	0,0246575	5,73%	280,00	346,00	0,1343	0,1231	0,0112
07.06.2011	15.06.2011	260,2176	0,0219178	5,73%	280,00	352,40	0,2039	0,1940	0,0099
08.06.2011	15.06.2011	254,2816	0,0191781	5,73%	280,00	352,50	0,0280	0,0193	0,0086
09.06.2011	15.06.2011	257,2355	0,0164384	5,73%	280,00	353,50	0,0336	0,0263	0,0074
10.06.2011	15.06.2011	252,0924	0,0136986	5,73%	280,00	346,98	0,0020	-0,0042	0,0061
13.06.2011	15.06.2011	252,5771	0,0054795	5,73%	280,00	346,00	0,0000	-0,0024	0,0024
14.06.2011	15.06.2011	257,5293	0,0027397	5,73%	280,00	351,49	0,0000	-0,0012	0,0012

Figure 8. BHP Billiton Call option with a strike price of R280 expiring 15 June 2011



The mispricing in the call options therefore presents investors an opportunity for arbitrage trading. Because the call options were found to be predominantly overvalued, investors would find advantage from arbitrage trading being short the call options and being long the synthetic call options. The put-call forward parity equation shows that a synthetic call option can be created by being long a put option and short a bond, with the face value of the bond being equal to the present value of the exercise price minus the futures price (Chance, 2003:230). An investor may execute the following transactions in order to take advantage of the situation where the call is overpriced:

- Short the actual overpriced call option and receive the option premium at the beginning of the trade.

Longing the following overall position on the same underlying (the synthetic call):

- Long the put option and receive the option premium at the beginning of the trade
- Short the bond and invest the cash from the transaction at the beginning of the trade
- Long the underlying futures contract at the beginning of the trade.

The above mentioned transactions will lead to a risk-free profit (depending on transaction fees) due to the relative mispricing of the call options in the South African market. In order for the arbitrage profits to be realised, the options need to have the same exercise prices as well as the same time to expiration. The existence of transaction costs will also reduce the

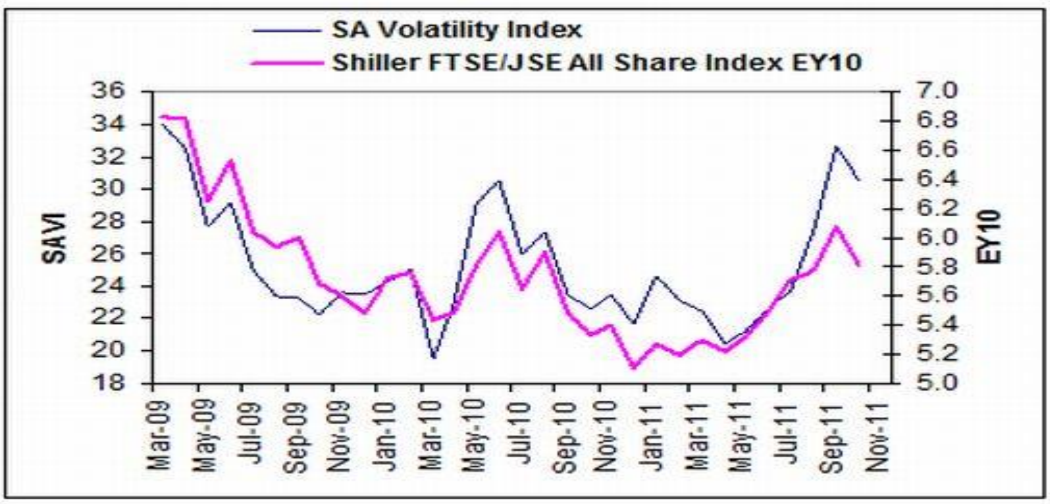
Mispricing in the South African market

The presence of mispricing in the South African market may occur due to a number of reasons and can vary depending on the time period under observation.

Violations of put-call parity can occur due to reasons such as short selling constraints, behavioural issues, market efficiency and data related issues.

The study period under observation was characterised by high levels of volatility. This can be seen in figure 9 below which covers the period after the 2008/2009 market crisis. As mentioned before, high levels of volatility may increase the probability of mispricing. The increased volatility also has an impact on the futures price's ability to accurately reflect the underlying stock prices. If the volatility levels in the market are high, then the futures price will less accurately reflect the underlying stock price, thus leading to mispricing. This has to do with the efficiency of the particular market. If mispricing is present, the mispricing will be amplified if volatility is high.

Figure 9. South African Volatility Index (2009-2011)



Source: JSE Database, 2012

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