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# The Volatility Structure Implied by Options on the SPI Futures Contract

*by*
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***Abstract:***

*The Asay (1982) option pricing model prices options on futures contracts where the premia are margined. The model assumes that the volatility of the underlying futures contract is constant over the life of the option. However it is an empirical observation in many markets that options on the same underlying futures contract with the same maturity, but at different strikes, trade at different implied volatilities. Since the 1987 crash, it has been documented that in many markets the volatility implied by out-of-the-money put options is higher than that implied by out-of-the-money call options. This phenomenon has become known as the 'volatility skew'. This paper examines the volatility structure for options on the SPI futures contract over the period June 1993 to June 1994, and provides theoretical explanations consistent with its shape.*

***Keywords:***

*ASAY MODEL; VOLATILITY SMILE; VOLATILITY SKEW.*

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## 1. Introduction

The Sydney Futures Exchange (SFE) is one of the few futures exchanges to trade options on futures where the options are subject to futures style margining.[1] An initial margin[2] is deposited and the option contract is marked to market at the end of each day, where the loss on a long option position is limited to the size of the initial premium. The margining applied to options traded on the SFE implies that option pricing models, developed for the situation where option premia are paid up front, are inappropriate.

The standard option pricing model used to price options on futures contracts is the Black (1976) model for pricing options on commodity futures. Asay (1982) and Lieu (1990) have modified the Black (1976) model,[3] to account for the daily margining of the option contract. Using the Asay model the call premium, $C$, for a European option on the underlying futures, $F$, satisfies:

$$C = FN(d_1) - XN(d_2), \tag{1}$$

where:

$$d_1 = \frac{\ln(F/X) + \frac{1}{2}\sigma^2 t}{\sigma\sqrt{t}},$$

$$d_2 = d_1 - \sigma\sqrt{t},$$

and
$F$ = futures price;
$X$ = exercise price;
$C$ = call price;
$t$ = time to maturity; and
$\sigma$ = instantaneous volatility.

The put premium, $P$, is given by:

$$P = XN(-d_2) - FN(-d_1) \tag{2}$$

The model given by equations 1 and 2 is similar to Black's (1976) model for pricing options on commodity futures, the difference being the absence of the interest rate term in the above equations. Therefore the price of an option where the premium is margined, relative to one where the premium is paid up front, will be higher. When the option premium is paid up front the buyer is committing funds and the writer receives those funds, while for options which are margined the option premium no longer flows from the buyer to the writer.

It can be shown that under certain conditions it is optimal to exercise a put option early when the premium is charged up front. The Black and Scholes (1973) model and the Black (1976) model which are developed for European options are

1. Another exchange which also margins its futures options is the LIFFE.
2. The SFE introduced the SPAN margining system in 1994. This system accounts for the overall risk of a position (containing futures and options on the SPI) as both the futures price moves and the volatility changes.
3. This modified model will be referred to as the Asay model throughout the paper.

not immediately applicable to pricing American options because these models do not price the early exercise flexibility of American put options (or American call options where the underlying asset pays a dividend).[4] However, Lieu (1990) shows that under futures-style margining it is never optimal to exercise a call option or a put option early, and therefore the model given by equations 1 and 2 above applies to the American style options on the Share Price Index (SPI) futures contract traded on the SFE.

The assumptions underpinning the Asay (1982) model are the same as for the Black (1976) and the Black and Scholes (1973) models. The underlying futures price is assumed to be lognormally distributed, markets are assumed to be frictionless with trading taking place continuously, and the short term interest rate is assumed to be known with certainty. The process that drives changes in the futures price is assumed to have two components: an expected drift rate and an uncertain or stochastic component scaled by the volatility parameter, which is assumed constant over the life of the option.

In practice, the volatility parameter is the only unobservable parameter in the model. Because the option price, the futures price, time to maturity, interest rate and strike price are all observable (or measurable), we can substitute these parameters into the equations, and solve for the only unknown parameter, volatility.[5] This volatility derived from the known parameters is called the implied volatility and is obtained by backing the volatility out of equations 1 and 2. Using this procedure to solve for an implied volatility assumes that market participants are using the Asay model to price options. If the model were correctly specified and all its assumptions valid, then the implied volatility for all options (observed at the same time) with the same maturity but different strikes, should be equal. Indeed, under the assumption that the market for stock index futures options is efficient then empirical observation of implied volatility varying across strike prices, contrasts the option valuation with the Black (1976) or the Asay (1982) formulae.

In many markets prior to the 1987 stock market crash, there appeared to be a symmetry around the zero moneyness, where out-of-the-money and in-the-money options traded at higher implied volatilities than the implied volatilities for at-the-money options. This dependence of implied volatility on the strike, for a given maturity became known as the smile effect, although the exact structure of volatility varied across markets and even within a particular market from day to day. However, since the 1987 stock market crash the smile has changed shape in many markets, particularly for traded options on stock indexes, where the function has gone from a smile shape to more of a ‘sneer’. The idea of the volatility ‘smile’ had its genesis in the early papers documenting the systematic pricing biases of the Black and Scholes (1973) option pricing model. Black (1975) suggests that the non-stationary behaviour of volatility would lead the Black-Scholes model to overprice or underprice options. Other authors have confirmed the existence of systematic biases in the model.[6]

4. It may be optimal to exercise an American call option just prior to a dividend payment. Merton (1973) shows that this will not occur in theory but it could occur in practice due to factors outside the option pricing model.
5. This requires a numerical search procedure because the equations are not immediately solvable for volatility.
6. See, for example, Macbeth and Merville (1979), Whaley (1982), Emanuel and Macbeth (1982), Rubinstein (1985), Brown and Taylor (1997).

Following Heynen, Kemna and Vorst (1994), explaining the implied volatility structure may lead to the conclusion that option prices are better described by an alternative underlying asset price process. Taylor and Xu (1993) study the smile effect of implied volatilities and show that the existence of stochastic volatility is a sufficient reason for smiles to exist. They show that an approximation to the theoretical implied volatility is a quadratic function of $\ln(F/X)$ where $F$ is the forward price and $X$ is the strike price, and that this approximate function has a minimum when $X = F$. This theoretical result requires that asset price and volatility differentials are uncorrelated and that volatility risk is not priced. Using currency option data obtained from the Philadelphia Stock Exchange, over the period from 1984 to 1992, and regressing a function of theoretical and observed implied volatilities on moneyness, they find little evidence of asymmetry in implied volatilities. However, the empirical smile pattern is about twice the size predicted by the theory.

**Figure 1**

**Implied Volatility Smiles for German Mark/USD Call Options (adapted from Xu & Taylor (1993))**

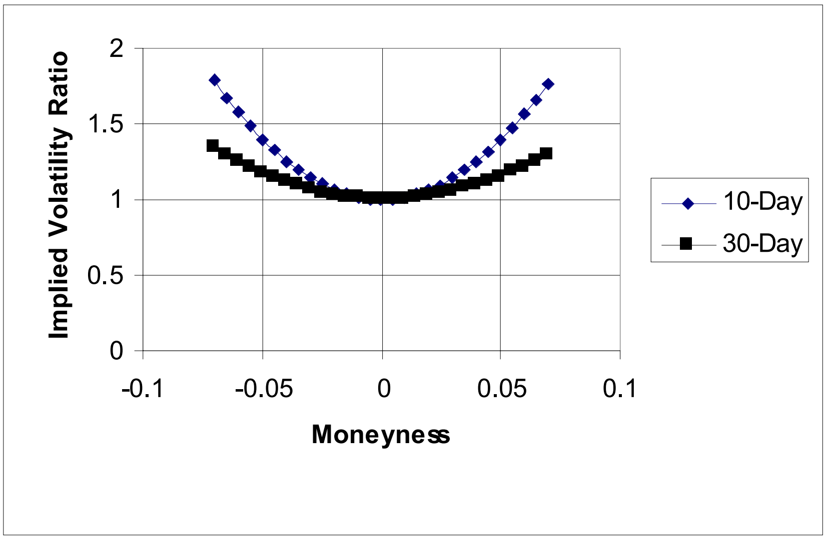



Figure 1 reproduces the nature of the volatility smile for foreign exchange options as presented by Taylor and Xu (1993). On the vertical axis the ratio is the implied volatility at the relevant strike divided by the implied volatility when the strike price is exactly equal to the forward price of the currency.[7] Thus, a ratio of 1.5 for a 5% out-of-the-money option implies that the out-of-the-money option has an implied volatility that is 1.5 times the implied volatility of an at-the-money option. Shastri and Wethyavivorn (1987) find similar results for foreign currency options traded in 1983 and 1984, while Sheik (1991) has argued that a similar pattern occurred for S&P 500 options during 1983 to 1985.

7. Because it may not be possible to observe an option trading exactly at-the-money Xu and Taylor (1994) give a method to estimate the at-the-money implied volatility.

In contrast to the above theoretical and empirical results showing a symmetric pattern for implied volatility against strike price, Dumas, Fleming and Whaley (1998) illustrate that the volatility structure for S&P 500 options has changed since the stock market crash of 1987, and the symmetric 'smile' pattern has changed to more of a 'sneer'. Call (put) option implied volatilities are observed to decrease monotonically as the call (put) goes deeper out-of-the-money (in-the-money).

The volatility 'sneer' implies that out-of-the-money put options trade at higher implied volatilities than out-of-the-money call options. This is often referred to in the markets as the 'volatility skew', and can arise when the market places a relatively greater probability on a downward price movement than an upward movement, resulting in a negatively skewed implied terminal asset distribution (Bates 1997).

This paper examines empirically the volatility structure implied by SPI options on the SFE. Section 2 describes the data set used to conduct the analysis, while section 3 provides illustrations of the volatility structure. Section 4 provides a discussion of the results and conclusions are contained in section 5.

## 2. Data

The sample consists of thirteen months of transaction data for the SPI futures contract and call and put options on the contract, over the period June 1993 through 30 June 1994. In the data set there are 219,272 transactions in the SPI futures contract and 9,613 option contracts, of which 5,311 are call option transactions. In order to calculate an implied volatility, the futures price and the option price must be observed at the same time, so the data set is used to construct a set of contemporaneous futures and options transactions pairs.[8] This results in a data set consisting of 4,517 matched pairs, of which 2,488 involve call options and 2,029 involve put options. Trading in the far-dated contracts is not frequent, yielding few matched futures and option pairs from the time matching process, so only the near-dated contract is considered. The average time between the futures trade and the option trade in the matched pair data set is 28s. On some days in the data set there are no matched call and/or put option trades. The average number of matched call (put) option trades per trading day is 9.4 (7.7), with the maximum number of matched call (put) trades for any one trading day in the data set equal to 45 (38).

Option records that violate American boundary conditions are excluded. When an option violates these conditions there is good reason to suggest that a trade could not be made at this price, and furthermore implied volatility cannot be calculated for prices that violate arbitrage bounds. Implied volatilities are then calculated for each futures and option pair,[9] so that the volatility structure can be examined.

8. Option prices are matched with a futures price which preceded the option trade by one minute or less. The data was obtained via a live feed from the SFE and constitutes what is known as 'pit' data, where the data is collected via the recording of all prices in the pit, with an associated time of the trade. Thus the time recording on both the options trades and the futures trades can be assumed accurate, although some details may be lost in busy trade periods. This is a limitation of the data set.
9. Note that the matched pairs for each day will have the same option maturity as only the near-dated contract is considered.

## 3. The Volatility Structure

Brown and Taylor (1997) investigate the pricing errors associated with using the Asay model given in equations 1 and 2 to price options on the SPI futures contract. They find that the model tends to overprice call options and underprice put options, when a single volatility[10] input is used in the model. For call options, out-of-the-money options are overpriced and in-the-money options are underpriced while at-the-money options are not significantly mispriced. The opposite result is found for put options. Generally, empirical research on standard option pricing models finds that market option prices are not exactly consistent with prices predicted by the models.

However, both traders and the SFE tend to use the Asay model as a framework for quoting prices and setting margins. Traders quote an option's price in terms of the constant volatility that will make the option's price consistent with the Asay model; denote by $\sigma_i$ this constant volatility that is backed out of the model to make market prices and Asay model prices consistent. Traders are thus pricing using an interpretation of the Asay model that allows $\sigma_i$ to vary according to the option's exercise price and volatility. The Asay model then becomes a translator between the traded prices and the implied volatilities, so that the implied volatility, $\sigma_i$, effectively becomes a price substitute.

While the assumption of constant volatility has been relaxed in the jump diffusion model (Merton 1976), stochastic volatility models (Hull & White 1987) and in time varying volatility estimation techniques (Brailsford & Oliver 1994), there have also been recent developments in lattice methods to build a binomial tree which takes into account the volatility smile (Derman & Kani 1994; Barle & Cakici 1995). Dupire (1994) shows how the Black-Scholes model can be extended to account for observed volatility smiles. Bates (1997) derives a skewness premium metric to identify the moneyness biases present in option prices. He then uses this metric to test which of the underlying distributional hypotheses are consistent with the observed skewness premium.

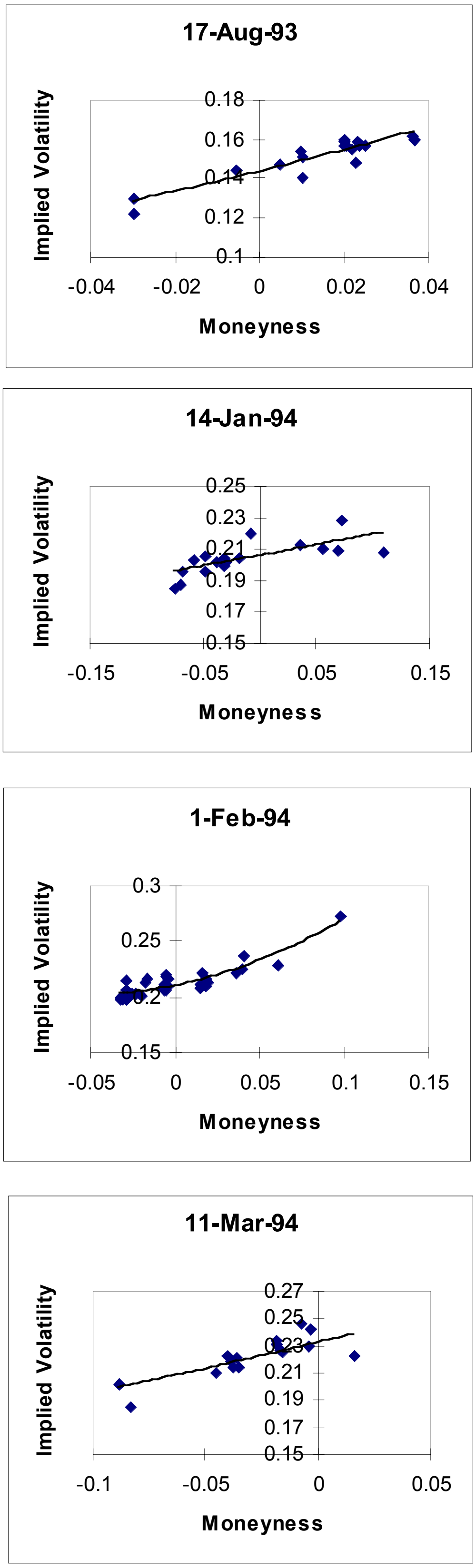
Notwithstanding the fact that other models have been developed to take account of the empirical observation of implied volatility varying across exercise prices, as stated previously, the Asay model is the framework used for pricing options on the SPI futures contract by both traders and the SFE. The volatility input to the model is the only variable that can be adapted to take account of any inadequacies in the model; for example a trader requiring a higher premium for holding one side of an option position because of liquidity risk will price the option at a higher volatility. Implied volatilities then become a price reflecting the willingness of market participants to take on and lay off risks that are not adequately priced by the model. It is therefore of interest to explore the volatility structure for the SPI futures option contract and search for explanations for the shape.

10. The volatility implied by the option trading closest to the money from the previous day's trades is used as the input to the model.

## Figure 2

## Graphs of Implied Volatility Against Degree of Moneyness for Call Options

Moneyness is defined as $F/K - 1$. Out of the money call options trade at lower implied volatility than in the money call options.



The inconsistency between traded option prices on the SPI futures contract and those predicted by the Asay model is illustrated in the volatility structure for call options in figure 2, for particular days from the data set.[11] A polynomial of best fit[12] has been superimposed on the implied volatility plots. Dumas, Fleming and Whaley (1998) conclude that parsimony in the specification of the volatility function appears warranted, when they find that the volatility function that is most robust empirically, has only linear and quadratic terms in the asset price.

Data used to create the graphs is given in table 1.

**Table 1**

| Date | Number of matched trades | Days to maturity |
|---|---|---|
| 17.8.93 | 19 | 44 |
| 14.1.94 | 18 | 76 |
| 1.2.94 | 45 | 58 |
| 11.3.94 | 19 | 20 |

The call option implied volatilities illustrated in figure 2 conform to the general shape hypothesized by Dumas, Fleming and Whaley (1998) for S&P 500 options since the 1987 crash. In-the-money call options are generally trading at higher implied volatilities than out-of-the-money call options.

In order to investigate the volatility structure further, a three dimensional graph of implied volatility against moneyness and maturity of the option is plotted in figure 3. This is achieved by grouping the data over the whole period of the analysis in intervals for moneyness and maturity and then taking the average implied volatility over the period for each interval.[13] For example, for the 2,488 matched call option trades, each trade is placed in a maturity grouping and a moneyness grouping. Within each interval the average implied volatility is then calculated. The results of this ordering are given for call options in table 2. An implicit assumption in producing an average implied volatility over the period is that trends in implied volatility will affect the different strike and different maturity options' implied volatilities equally. To the extent that this assumption is not satisfied, the long term average picture for implied volatility may imply a different volatility structure to that observed on a daily basis. Figure 3 shows that in-the-money call options on average trade at higher implied volatilities than out-of-the money call options.

11. The dates chosen represent the variety of shapes present in the data set.
12. For all figures where a polynomial of best fit has been superimposed, the polynomial is a quadratic. However the convexity must be constrained so that the second derivative of volatility with respect to the strike price is positive. For the graphs reproduced in figure 2, the polynomial of best fit is of order 2 when the convexity is of the correct sign, otherwise it is linear. The same construction has been used for figure 4.
13. Note that the points plotted at –0.05 on the x-axis actually belong to the moneyness interval where moneyness < –0.05, and points plotted at +0.05 belong to moneyness > 0.05. The same point applies to Figures 4, 6 and 7.

**Figure 3**

**Implied Volatilities for Call Options on the SPI Futures Contract over the Period 1 June 1993 to 30 June 1994**

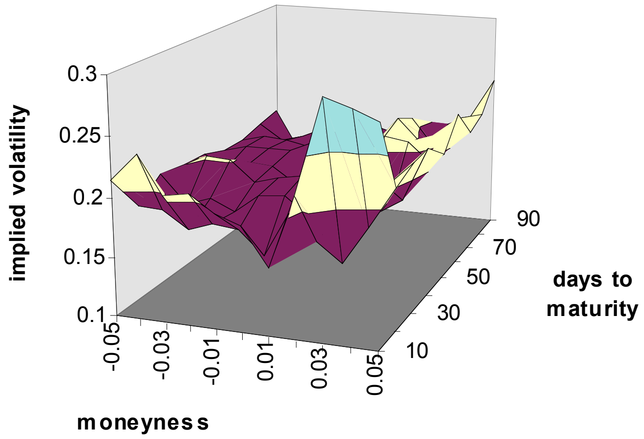



**Table 2**

**Implied Volatility Averages for Call Options**

| | | Moneyness | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | –0.05 | –0.04 | –0.03 | –0.02 | –0.01 | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 |
| Days to | 10 | 0.215 | 0.239 | 0.206 | 0.210 | 0.196 | 0.190 | 0.158 | 0.217 | 0.297 | 0.290 | 0.281 |
| Maturity | 20 | 0.181 | 0.179 | 0.165 | 0.173 | 0.170 | 0.150 | 0.188 | 0.168 | 0.152 | 0.184 | 0.219 |
| | 30 | 0.196 | 0.172 | 0.181 | 0.169 | 0.186 | 0.188 | 0.173 | 0.172 | 0.182 | 0.206 | 0.228 |
| | 40 | 0.193 | 0.203 | 0.202 | 0.183 | 0.189 | 0.194 | 0.178 | 0.173 | 0.167 | 0.182 | 0.228 |
| | 50 | 0.192 | 0.181 | 0.188 | 0.187 | 0.171 | 0.172 | 0.176 | 0.166 | 0.168 | 0.196 | 0.211 |
| | 60 | 0.184 | 0.189 | 0.190 | 0.190 | 0.199 | 0.196 | 0.188 | 0.212 | 0.207 | 0.190 | 0.237 |
| | 70 | 0.184 | 0.190 | 0.187 | 0.183 | 0.197 | 0.174 | 0.194 | 0.218 | 0.196 | 0.209 | 0.211 |
| | 80 | 0.190 | 0.175 | 0.181 | 0.191 | 0.171 | 0.185 | 0.190 | 0.208 | 0.183 | 0.212 | 0.218 |
| | 90 | 0.193 | 0.156 | 0.163 | 0.173 | 0.193 | 0.183 | 0.177 | 0.190 | 0.194 | 0.204 | 0.241 |

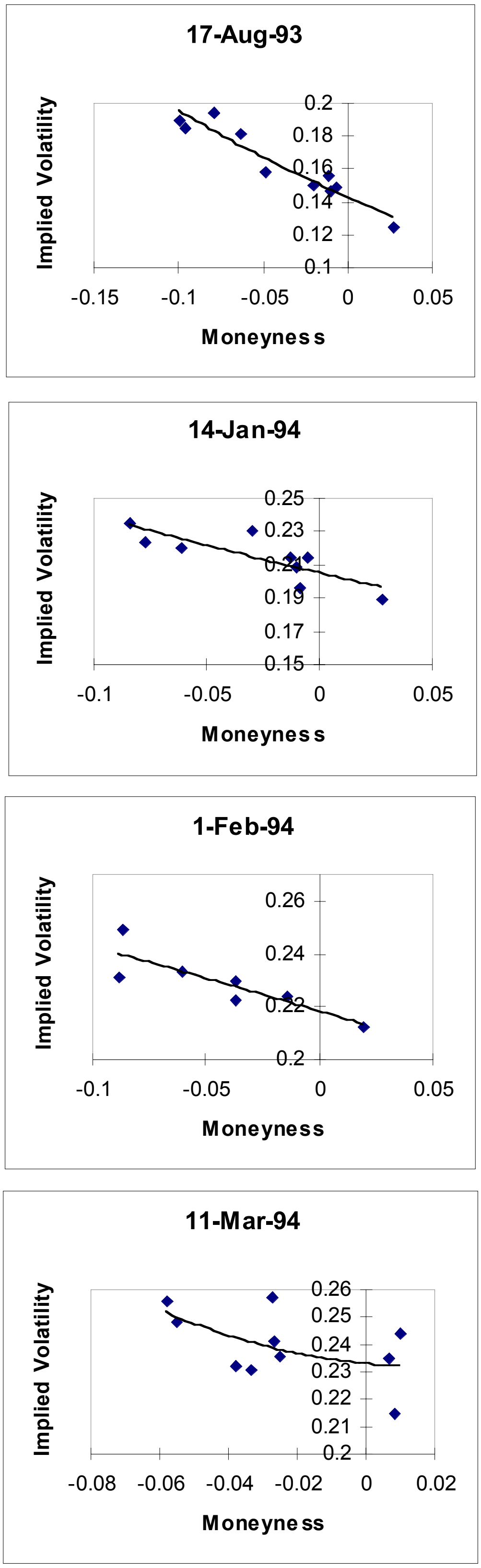
Generally the volatility implied by out-of-the-money put options is higher than that implied by out-of-the-money call options, as is illustrated by comparing figures 2 and 4. The three dimensional graph for put option implied volatilities is presented in figure 5.[14] Out-of-the-money implied volatilities for put options are on average higher than at-the-money implied volatilities, except for the longer dated options.[15]

14. The graph is constructed in the same manner as for figure 3 and table 2.
15. Dumas, Fleming and Whaley (1998) adjust the moneyness variable by the square root of time, because the slope of the sneer steepens as the option's life grows shorter. This adjustment is not done for the options illustrated in figures 3 and 5 and partially explains the steepness of the volatility surface for the very short dated out-of-the-money options.

**Figure 4**

**Graphs of Implied Volatility against Degree of Moneyness for Put Options**

Moneyness is defined as $K/F - 1$. Out of the money put options trade at higher implied volatility than in the money put options.



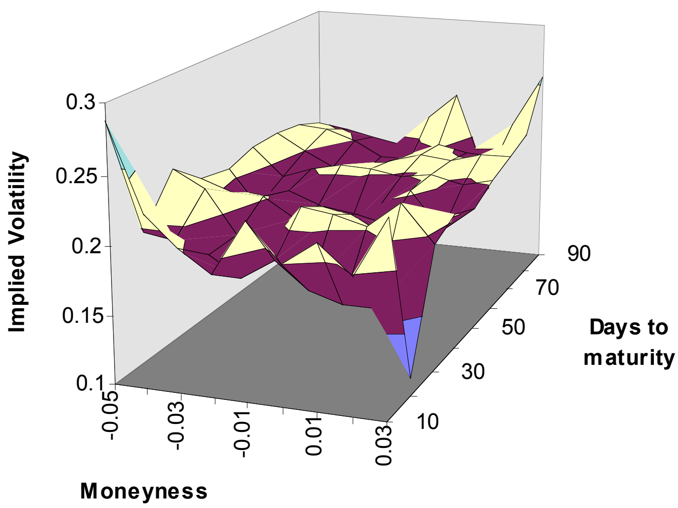
Data used to create the graphs is given in table 3.

**Table 3**

| Date | Number of Matched Trades | Days to Maturity |
|---|---|---|
| 17.8.93 | 12 | 44 |
| 14.1.94 | 9 | 76 |
| 1.2.94 | 7 | 58 |
| 11.3.94 | 10 | 20 |

**Figure 5**

**Implied Volatilities for Put Options on the SPI Futures Contract over the Period 1 June 1993 to 30 June 1994**



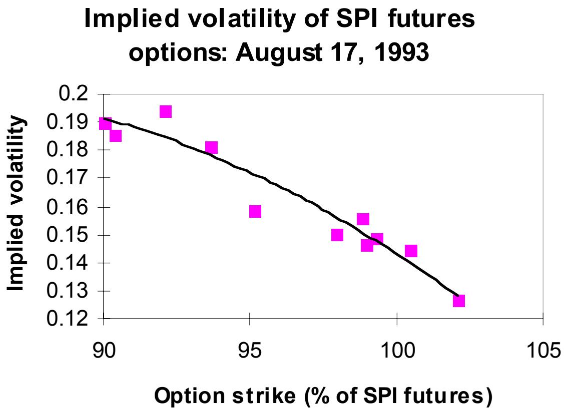

In-the-money call options have a tendency to trade at higher implied volatilities than out-of-the-money options while the reverse is true for put options. This implies that if the horizontal axis were converted to option strike as a percentage of the futures price, then the smile would be skewed upwards to the right for both call options and put options. To further illustrate the relationship between implied volatilities, figure 6 shows a plot of implied volatility against strike price as a percentage of the SPI futures level, for prices observed on 17 August 1993.[16] Implied volatilities for strikes above (below) the current SPI futures level were calculated using out-of-the-money call (put) options. Figure 6 illustrates the volatility skew, where implied volatilities for out-of-the-money put options are generally higher than the implied volatilities for out-of-the-money call options.[17]

16. Figure 8 illustrates the typical pattern in SPI implied volatilities for the data sample.
17. The SPI futures contract multiplier was downsized from $100 times the futures level to $25 times the futures level on 11 October 1993. On 17 August 1993, out-of-the-money put options trading at an implied volatility of 18.5% and a price of 4 index points (equivalent to $400) would have had a price of 0.51 index points or $51 if they had been trading at the out-of-the-money call option implied volatility

**Figure 6**

**Implied Volatilities for Out-of-the-Money Put Options and Out-of-the-Money Call Options**

This graph is constructed with out-of-the-money put options (option strike < 100) and out-of-the-money call options (option strike > 100).




Thus, the volatility structure for SPI options over the sample period studied indicates that implied volatility for put (call) options decreases monotonically as the put (call) option goes further in (out) of the money. This result has also been documented by Dumas, Fleming and Whaley (1998) for S&P 500 options studied over the period from June 1988 to December 1993.

## 4. Discussion

A possible explanation for the volatility structure might lie in the risks associated with option positions that are not adequately priced by the standard models. Following the analysis of Black and Scholes (1973) and Black (1976), Asay (1982) and Lieu (1990) construct a riskless hedge portfolio consisting of a short call option position and a long position in (delta units of) the underlying futures contract. A continuously adjusted delta hedged position in the futures contract will hedge the option position, so that this overall position will earn the risk free rate of interest. This is the key insight of the Black-Scholes analysis, and implies that the option will be priced relative to the underlying asset so that there are no arbitrage opportunities in the market.

The risk of an option position on the SPI futures contract can be captured by the hedge parameters; delta, gamma, vega and theta. Vega measures the change in the option price with respect to a change in the implied volatility. While gamma measures how frequently the option position will have to be adjusted to remain delta hedged, it also captures the risk of changes in option prices as a result of changing actual volatility. The volatility, the one unknown input to the option

of 12.6%. This example illustrates the result that using an at-the-money option volatility to set margins may underestimate (overestimate) the change in option price for out-of-the-money put (call) options.

pricing formula, is also the most important variable affecting the price of the option.

Development of the Asay (1982) model relies on the same risk neutral arguments as used in Black and Scholes (1973) and Black (1976). The formation of the riskless hedge portfolio requires volatility to be constant, or at most to be a deterministic function of the underlying asset and time. Volatility risk is therefore *not* priced by the Asay model; that is the risk of volatility changing and the additional costs imposed on option traders to hedge volatility risk is not built into the Asay framework for pricing options on the SPI futures contract. As stated previously, the implied volatility $\sigma_i$ can be viewed as a price. One explanation for the shape of the volatility structure is that it will reflect the willingness of sellers in the option market to lay off volatility risk and for buyers to take on volatility risk.

Murphy (1994) argues that because these risks can be hedged with shorter dated options of the same strike, a particular demand is created for near-the-money options because gamma and vega risks are at their greatest for at-the-money options. The hedges have to be frequently rebalanced creating a demand for near-the-money options and causing their implied volatilities to be lower than in- and out-of-the-money options. This argument may not be as applicable to the SPI futures options market as trading in contracts other than the nearest dated contract is relatively infrequent. In terms of the matched option pairs, 2,104 pairs were out-of-the-money, while 1,929 were at-the-money and 414 were in-the-money.[18] These statistics do not imply a particular demand for at-the-money options.[19]

Options on the SPI futures contract are used by institutions for hedging purposes.[20] To protect against a fall in the value of a share portfolio a fund manager could sell SPI futures contracts. Alternatively there are two commonly adopted option strategies to protect a share portfolio's value. The first strategy involves writing call options on the SPI futures contract. When a long position in equity is held simultaneously this strategy is known as a 'covered call'. The option writer receives premium income, mitigating downside losses in the event of a downturn in value for the equity portfolio, while locking in upside profits (at a lower level than an unhedged position). In adopting this strategy, depending on the level of protection required, out-of-the-money calls are generally written as the probability of exercise is lower (as is the premium income).[21] It is clear from figures 2 and 3, and from table 2, that the implied volatilities for out-of-the-money calls are lower than the at-the-money volatility. Therefore the demand by fund managers for written call positions to implement the covered call strategy will be largely met on the buy side of the transaction by the market makers, who will push the price down, causing the implied volatility to be lower.

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18. For these statistics, at-the-money options are defined as those where the strike price is within 2% of the futures price, out-of-the-money (in-the-money) options are those where the strike price is more than 2% outside (inside) the money. However 72% of matched call option trades occur with $F - K < 0$ and 79% of matched put option trades occur with $K - F < 0$. That is, a large percentage of trades are out-of-the-money for both call options and put options.
19. Although these are not all the option trades, almost 50% of the option trades were matched with a futures trade to within 1 min as the futures contract is much more liquid.
20. Locals constituted around 21% as a percentage of pit traded volume in futures and options on the SPI contract in 1995 (Futures Forum 1996). Around 80% of trade (by volume) is by institutional traders.
21. Discussion with traders from the SFE also suggests that out-of-the-money call options are written and in-the-money call options are simultaneously purchased. This is known as a 'collar' strategy.

The second strategy adopted for protecting the value of an equity portfolio is the protective put strategy, where a put option on the SPI futures contract is purchased against a long position in equity. In this case an absolute lower bound on the equity portfolio value is achieved; in return some of the upside potential is given away. Adoption by institutions of this strategy and the consequent demand for out-of-the-money put options, may drive the implied volatility of out-of-the-money puts up, as market makers require a higher premium to write the put options. Thus, demand in the market for option positions that will provide a hedge to an existing equity exposure may be influencing the implied volatility structure in the market for SPI options.

Daigler, Sullivan and Wiley (1998) examine options on T-bond futures contracts in the US and find that implied volatility for out-of-the-money put options is higher than for out-of-the-money call options. They analyse option volume by type of trader and find that option strategies, namely the protective put strategy used in the market, can explain the volatility skew pattern.

There is little incentive to write in-the-money options unless a substantial movement in the underlying is expected. There are only 414 matched in-the-money option pairs, of which 273 were call option pairs. Call options also traded deeper in-the-money than put options over the sample period.[22] A simple explanation for the fact that in-the-money call options trade at high implied volatilities is provided by the put-call parity relationship.[23] If a put at a given strike is in-the-money then a call at the same strike will be out-of-the-money. Put-call parity then guarantees that the out-of-the-money put option and the in-the-money call option at the same strike price must trade at similar implied volatilities, or arbitrage opportunities will arise. For example, if the call option prices are too high, traders will sell calls, buy puts and go long the underlying futures contract.[24] Therefore because *out-of-the-money* puts trade at higher implied volatilities than at-the-money puts, then the put-call parity relationship implies that *in-the-money* calls must trade at higher implied volatilities than at-the-money call options. This argument is supported in figures 2, 3 and table 2 for call options. Again using the put-call parity relationship, because *out-of-the-money* call options trade at low implied volatility, *in-the-money* put options will trade at a similar implied volatility, as illustrated in figures 4 and 5. Deep in-the-money put options are not traded over the sample period.

The volatility structure is consistent with the market view that the market falls more quickly than it rises.[25] Option writers are concerned with the direction and nature of price movements. Call option writers prefer prices that creep upwards and gap downwards, while put option writers like the reverse. Option traders aware of a changing volatility may be able to take advantage of the knowledge. For example, if there are indications that the skew may be flattening, one strategy could involve selling at the higher volatility and reversing the position at the lower volatility.

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22. Calls traded up to 17% in-the-money wheras puts traded up to 8% in-the-money.
23. The put-call parity relationship for margined options is given by $C = P + F - X$. This relationship holds independent of any pricing model and must be satisfied by puts and calls with the same strike price, maturity date and underlying futures price, otherwise arbitrage opportunities arise in the market.
24. This strategy is called a conversion.
25. 'Up by the stairs and down by the elevator' is the trader's perspective.

## 5. Conclusion

This paper examines the implied volatility structure for call and put options trading on the SPI futures contract on the SFE, and offers a possible explanation for its shape. Rather than focusing on the pricing biases of the Asay model, implied volatilities are viewed as prices reflective of the willingness of market participants to take on and lay off the risks involved in trading volatility, and other risks not priced by the model. If the supply and demand by institutional traders for out-of-the-money options affect the implied volatility of the options, as this paper has argued, then the put-call parity relationship implies a level for implied volatility for in-the-money options. Thus the volatility skew arises from the hedging needs of institutional traders and the requirement that the market be arbitrage free.

In order to accurately measure the demand for SPI options by institutional investors to implement a protective put strategy or a covered call strategy, it would be necessary to have the origin of the trade designated. Thus, a possible avenue for future research, is to explore directly the significance of supply and demand in determining option prices. An important implication of this supply and demand effect will be in determining how to set margins that adequately account for the riskiness of the positions. The importance of volume on option pricing may indicate that existing models do not account for all the factors important in pricing options. The explanation presented in this paper is one that accords with the implied volatility structure for SPI options over the period studied, and is one that has been used in other markets to explain the shape of the implied volatility structure.

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## References

Asay, M. R. 1982, ‘A note on the design of commodity option contracts’, *Journal of Futures Markets*, 52, pp. 1–7.

Barle, S. & Cakici, N. 1995, Growing a smiling tree, *Risk*, vol. 8, no. 10, pp. 76–81.

Black, F. & Scholes, M. 1973, ‘The pricing of options and corporate liabilities’, *Journal of Political Economy*, 81, pp. 637–59.

Black, F. 1975, ‘Fact and fantasy in the use of options’, *Financial Analysts Journal*, 31, pp. 36–41,

Black, Fisher, 1976, ‘The pricing of commodity contracts’, *Journal of Financial Economics*, 3, pp. 167–79.

Brailsford, T.J. & Oliver, B.R. 1994, Time-varying volatility estimates in option pricing: can superior estimates be obtained?, Paper presented in University of Melbourne Seminar Series, August 1994.

Brown, C.A. & Taylor, S.D. 1997, ‘A test of the Asay Model for pricing options on the SPI futures contract’, *Pacific-Basin Finance Journal*, 5, pp. 579–94.

Daigler, R., Sullivan, M. & Wiley, M. 1998, The effect of net option demand on the implied volatility ‘smile’, Paper presented to The Financial Management Meeting, Chicago, October.

Derman, E. & Kani, I. 1994, ‘Riding on a smile’, *Risk*, vol. 7, no. 2, pp. 32-39.

Dupire, B. 1994, ‘Pricing with a smile’, *Risk*, vol. 7, no. 1, pp. 18–20.

Dumas, B., Fleming, J. & Whaley, R. 1998, 'Implied volatility functions: empirical tests', *Journal of Finance*, vol. 53, no. 6, pp. 2059–2106.

Emanuel, D.C. & Macbeth, J.D. 1982, 'Further results on the constant elasticity of variance call option pricing models', *Journal of Financial and Quantitative Analysis*, vol. 17, pp. 533–54.

*Futures Forum*, 1996, vol. 1, no. 1, Sydney Futures Exchange Limited, 18.

Heynen, R.A., Kemna, G.Z. & Vorst, T. 1994, 'Analysis of the term structure of implied volatilities', *Journal of Financial and Quantitative Analysis*, 29, pp. 31–56.

Hull, J. 1997, *Options, Futures, and Other Derivative Securities,* Prentice Hall, 3rd edition.

Hull, J. & White, A. 1987, 'The pricing of options on assets with stochastic volatilities', *Journal of Finance*, 42, pp. 281–300.

Lieu, D. 1990, 'Option pricing with futures-style margining', *Journal of Futures Markets*, 10, pp. 327–38.

Macbeth, James D. & Merville, Larry J. 1979, 'An empirical examination of the Black-Scholes call option pricing model', *Journal of Finance*, 34, pp. 1173–1186.

Merton, R. 1973, 'The theory of rational option pricing', *Bell Journal of Economics and Management Science*, vol. 4, no. 1, pp. 141–83.

Merton, R.C. 1976, 'Option pricing when underlying stock returns are discontinuous', *Journal of Financial Economics*, 3, pp. 125–44.

Murphy, G. 1994, 'When options price theory meets the volatility smile', *Euromoney*, pp. 66–74.

Rubinstein, M. 1985, 'Non-parametric test of alternative option pricing models using all reported trades and quotes on the 30 most Active CBOE option classes from August 23, 1976 through August 31, 1978', *Journal of Finance*, 40, pp. 455–80.

Shastri, A.M. & Wethyavivorn, K. 1987, 'The valuation of currency options for alternate stochastic processes', *Journal of Financial Research*, 10, pp. 283–93.

Sheikh, A.M. 1991, 'Transaction data tests of S&P 100 call option pricing', *Journal of Financial and Quantitative Analysis*, 26, pp. 459–75.

Taylor, S.J. & Xu, X. 1993, 'The magnitude of implied volatility smiles: theory and empirical evidence for exchange rates', *Review of Futures Markets*, 13, pp. 355–80.

Whaley, Robert, E. 1982, 'Valuation of American call options on dividend paying stocks: empirical tests', *Journal of Financial Economics*, 10, pp. 29–58.

Xu, X. & Taylor, S.J. 1994, 'The term structure of volatility implied by foreign exchange options', *Journal of Financial and Quantitative Analysis*, vol. 29, no. 1, pp. 57–74.