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Effectiveness of the Black and Scholes Model in Pricing Nifty Call Options

Sheetal Gupta
Research Scholar, Department of Commerce
Delhi School of Economics, University of Delhi, Delhi, India

Abstract:
Derivatives today constitute the most important segment of the Indian securities market. Fischer Black and Myron Scholes (1973) made a major contribution in the subject matter of derivatives when they developed the theoretical model for the pricing of European options. The model influenced the academicians and practitioners in a great way to price European options. This study uses S&P CNX NIFTY call and put options for analysis for the sample period starting from January 1, 2003 through December 24, 2008. The objectives of the present study are to check whether implied volatility is a better predictor of volatility of future stock returns than historical volatility or not, to check whether there exists any correlation between historical volatility and implied volatility, to examine whether Black and Scholes model is misspecified or not by investigating the existence of volatility smile in case of S&P CNX Nifty options traded at NSE and to examine the predictive accuracy of the Black-Scholes model in pricing the Nifty index option contracts. The results show that implied volatility is more efficient predictor of option prices than historical volatility and there is a significant and positive correlation between historical volatility and implied volatility in case of the near month call and put option contracts. The implied volatility graphs for different samples depict the shape of a 'Smile' which indicates that out-of-the money options and in-the-money options are having high volatility values while near-the-money options are having low volatility values, The BS model provides pricing errors but pricing errors are less in the case of near-the-money call options, errors slowly increase as moneyness increases.

Keywords*: Black and Scholes model, historical volatility, implied volatility, implied volatility smile, predictive accuracy.*
JEL Classification No. – G14

1. Introduction

Derivatives today constitute the most important segment of the Indian securities market. Derivatives trading commended in June 2000, after SEBI approval, on the National Stock Exchange (NSE) and Bombay Stock Exchange (BSE) with the introduction of index futures contracts based on S&P NSE Nifty index and BSE-30 (Sensex) index. This was followed by the introduction of trading in options based on these two indices, options on individual securities and futures on individual securities. Trading in index options commenced in June 2001 while trading in options and futures on individual securities commenced in July 2001 and November 2001 respectively.

Fischer Black and Myron Scholes (1973) made a major contribution in the subject matter of derivatives when they developed the theoretical model for the pricing of European options. The model influenced the academicians and practitioners in a great way to price European options. The Black-Scholes (1973) model assumes constant volatility. However, the assumption of constant volatility is violated in financial markets. The Black-Scholes model while computing the prices of European options assumes that volatility of the underlying asset is the same across various exercise prices and/or time to maturity. Theoretically, since volatility is a property of the underlying asset it should be predicted by the pricing formula to be identical for all derivatives based on that same asset. However, in practice, implied volatility of the underlying asset vary across various exercise prices and/or time to maturity. That is, market does not price all options according to Black-Scholes model. There have been many studies which show that volatilities implied from the market price for options vary across different exercise prices and/or time to maturity. The picture obtained by plotting the implied volatility with different exercise prices (observed at the same time, with similar maturity and written on the same asset) is known as volatility smiles. The pattern of implied volatility across time to expiration is known as term structure of implied volatilities. The combination of volatility smiles and volatility term structures produces a volatility surface. Volatility surface defines volatility as a function of both the exercise price and time to maturity.

For the present study the underlying asset is S&P CNX NSE Nifty. In the Indian stock market, index options are of European style where as individual stock options are of American style. Since the present study is concerned only with index options, a European option is only relevant to us. Eight years have passed since the index option was introduced in the Indian stock market, yet there are very few studies on Indian Derivatives market especially options market. The present study attempts to contribute to the existing literature regarding index options' pricing in India.

2. Theoretical Framework
Dividend adjusted Black & Scholes model of Robert Merton has been used to derive the theoretical option price as follows:
Price of a Call option:
$c = Se^{-\delta t} N(d_1) - X e^{-r t} N(d_2)$……………………………………………….(1)
Price of a put option:
$p = X e^{-r t} N(-d_2) - Se^{-\delta t} N(-d_1)$……………………………………………….(2)
where,
$$d_1 = \frac{\ln(Se^{-\delta t}/X)+rt+ \sigma^2 t *0.5}{\sigma \sqrt{t}}$$

- $d_2 = d_1 - \sigma \sqrt{t}$
- c = price of a call option
- p = price of a put option
- $Se^{-\delta t}$ = adjusted price of the underlying asset
- X = Exercise price of the option
- t = time remaining until expiration, expressed as fraction of a year
- r = continuously compounded risk- free interest rate
- σ = annual volatility of price of the underlying asset
- ln = represents the natural logarithm of a number.
- N( ) = standard normal cumulative distribution function
- e = the exponential function

The most crucial component in measuring the fair price for an option contract in the BS model is the underling asset price volatility, as it is the only unobservable variable in the model. The price of an option is higher if the volatility of the underlying asset is high. Therefore, an appropriate procedure to calculate volatility has to be used. Volatility can be measured on the basis of the past prices of the index. This type of volatility is referred to as historical volatility. Historical volatility assumes that the volatility in the past is a good indicator of the volatility in the future and that the past can be used as a rough guide to the future. However, if a dramatic piece of news hits the market, historical volatility is not reliable. One widely used method of determining volatility value is to compute implied volatility value.
The volatility implied by the price of an option is quite naturally termed its *'implied volatility'*. This is the level of volatility in the BS formula that equates the market price of an option to its value given by the formula. Information implicit in option price is forward-looking and hence, provides a better measure of actual volatility. Past research studies have shown that implied volatility is much better estimate than historical volatility, as an input into the model since it looks more on the future.

3. Review of Literature
- **Black and Scholes (1972)** compared the theoretical value of option price (calculated from their Black and Scholes model) with the actual market prices and observed that "the model tends to overestimate the value of an option on a high variance security, market traders tend to underestimate the value, and similarly while the model tends to underestimate the value of an option on a low variance security, market traders tend to overestimate the value" (Black and Scholes (1972), pg 416-417). The measure of stock return variance used in their study was the sample variance of historic stock returns. However they said that the divergences between the theoretical and actual prices were not substantial enough to be counted for economic importance as the transaction cost of trading in options lessened the potential profit.
- **Latane and Rendleman (1976)** Their data set consisted of weekly closing option and stock prices of twenty four companies whose options traded on Chicago Board of Options Exchange for 38 weeks beginning October 5, 1973 and ending June 28, 1974. They used a weighted average implied standard deviation (WISD) in which the ISDs for all options on a given underlying stock were weighted by the partial derivative of the BS equation with respect to each implied standard deviation. The WISD was found to be a better predictor of future variability than standard deviation predictors based on historical data. Also they concluded that options were generally over-priced in terms of the Black and Scholes model during the sample period.
- **Chiras and Manaster (1978)** derived their results using the more general Merton model which adjusts the BS model for a specific dividend policy. They calculated the weighted implied standard deviation of the options on one stock for each observation date wherein the weights were assigned to different standard deviations according to the price elasticity of the option with respect to its implied standard deviation. They tested the hypothesis that the implied standard deviations are better predictors of standard deviations of future stock returns than standard deviations obtained from historic stock returns and found the results to be in favour of the hypothesis. Also, Chiras and Manaster developed a trading strategy using the WISDs to test the efficiency of the CBOE where a spread position was established for those options that deviated by 10% from the market price. They claimed that the results of their study conducted for the period June 1973 to April 1975 indicated market inefficiencies. However, they accepted that the inefficiency of the CBOE (Chicago Board of Options Exchange) could be explained by usage of non-simultaneous data, ex-post nature of their tests and exclusion of transaction costs from the data. (As compared to Chiras and Manaster, Schmalensee and Trippi followed an equal weighted average method where they used an arithmetic average of implied standard deviations as an estimator of the standard deviation. **(Schmalensee and Trippi (1978)**)

- **Macbeth and Merville (1979)** examined daily closing prices of options on six underlying securities from 31 December, 1975 to 31, December1976. They estimated the implied standard deviation. Macbeth and merville (1979) results were exactly opposite to those reported by Black and Scholes. They concluded that out-of-the-money call options were overpriced by Black-Scholes and in-the-money call options were underpriced by Black-Scholes. These effects became more pronounced as the time to maturity increased and the degree to which the option is in or out of the money increased. They assumed all along market efficiency, and attributed the deviations of the model price from the actual price to the weakness of the model, especially to its assumption of a constant variance of the stocks rate of return.
- **Rubinstein (1985)** studied options price data for the 30 most actively traded option classes on the CBOE between August 1976 and August 1978. Throughout the period, Rubinstein found that for out-of-the money options, short maturity options had significantly higher implied volatilities than long maturity options. He divided his data into two subgroups. The first subgroup included data from August 1976 to October 1977. In this period, Rubinstein reported a systematic mispricing pattern similar to that reported by Macbeth and Merville (1979), where the Black-Scholes model overpriced out-of-the-money options and underpriced in-the-money options. The second subgroup included data from October 1977 to August 1978. During this period, he reported a systematic mispricing pattern similar to that reported by Black (1975), where the Black-Scholes model underpriced out-of-the-money options and overpriced in-the-money options. He also found that implied volatility for at the money call options was higher with shorter times to expiration than for those with longer times to expiration in period 1. However, the results reversed in period 2. Rubinstein concluded that strike price biases for the Black-Scholes model were statistically significant and that the direction of bias tends to be the same for most options at any point of time. However, the bias direction changed from period to period.
- **Varma (2002)** studied the pricing efficiency of the Indian index options market for the sample period from June 2001 to February 2002. He calculated the implied volatility for each option on each day using the closing NIFTY futures and options prices through the Black model. Varma got a V-shaped smile rather than a U-shaped or 'sneer' shaped on plotting the defined implied volatilities against moneyness. Moreover the smiles were quite different for puts and calls, smiles being tilted towards left for calls and towards the right for puts and thus inconclusively indicative of violation of put-call parity. He also found some overpricing of deep-in-the-money calls and some inconclusive evidence of violation of put-call parity as to Nifty options traded on NSE.
- **Sonal Sharma (2004)** tested the Black and Scholes model to price index options and the efficiency of the Indian options market using S&P CNX NIFTY one-month call options for the period starting from January 1, 2002 through December 31, 2003.The results of this study showed that striking price biases took the form of a U-shaped or Saucer-shaped curve when various implied volatility values and option's moneyness were plotted on a graph. It indicates the model's incorrectness or the market's inefficiencies to price volatilities correctly or both. 13.8% of the option contracts had undefined implied volatility values, which indicates that options in India are highly mispriced. When the model prices were compared with the actual prices existing in the market, it was found that deep ITMs and OTMs were overpriced, whereas not-so-deep ITMs were over priced and not-so-deep OTMs were underpriced. Near-the-money index options were less volatile and were moderately mispriced. An ex-post test performed to know the model's hedging performances indicated significant positive returns for near-the-money options. The ex- ante test performed to test the market's efficiency further increased the returns, thus indicating Indian one-month option market's inefficiencies. Except for ITMs (both deep as well as not so deep) the hedging strategy provided abnormal profits. The positive returns, on an average, indicate market's inefficiencies
- **Misra**, **Misra and Kannan (2006)** investigated the existence of volatility surfaces in case of NSE Nifty options and found out other determinants of implied volatility using the data for the sample period starting from 1st January 2004 to 31st December 2004.

  They concluded the following: Deeply in the money and deeply out of the money options are having higher implied volatility than at the money options; implied volatility is the highest in case of out of the money call (in the money put) options and the lowest in case of at the money options; implied volatility is higher for far the month option contracts than for near the month option contracts but time to maturity does not influence the implied volatility in case of call options; deeply in the money and deeply out of the money options with shorter maturity are having higher implied volatility than those with longer maturity; for the same degree of moneyness and time to maturity, put options are having higher volatility than call options; high liquid options are having higher implied volatility than less liquid options. However, in case of call options, liquidity does not influence the implied volatility.
- **Kakati (2006)** assumed the Indian option market to be efficient and perfect at stated price and evaluated the performance of the Black-Scholes model using 200 options series written on underlying stocks of ten Indian companies and BSE index for the period July 2001 to March 2003. Both historical volatility and implied volatility were used. The study found that options were severely mispriced by the BS model indicating underpricing in many cases reflecting the fact that the early exercise feature of the American options is not being accounted for and appears to be overlooked by the BS model. Implied volatility entailed less pricing error than historical volatility for both index options and stock options. Also, moneyness bias, maturity bias and call vs.put bias occurred. Mispricing worsened with the increased moneyness and with the increased volatility of the underlying stocks. Further, short-term options were often underpriced and long-term options were mostly overpriced. On an average, mispricing was found to be more in the BSE index options than the stock options.

- **Mitra (2008)** addressed issues related to mispricing of options on account of negative cost of carry phenomenon observed in Nifty derivatives. He made an attempt to determine the efficacy of the Black formula in pricing Nifty options and comparing the accuracy of the same with that of the Black-Scholes formula by considering Nifty options traded during the period October 2005 to September 2006. From the comparison of errors (difference between actual and computed values measured), it was found that Black model produces less error than BS model, and therefore, use of Black model is more suitable than BS model for valuing Nifty options.

4. Research Objectives

- To check whether implied volatility is a better predictor of volatility of future stock returns than historical volatility or not.
  - To check whether there exists any correlation between historical volatility and implied volatility.
- To examine whether Black and Scholes model is misspecified or not by investigating the existence of volatility smile in case of S&P CNX Nifty options traded at NSE.
- To examine the predictive accuracy of the Black-Scholes model in pricing the Nifty index option contracts.

5. Research Hypotheses

- Implied volatility is not a better predictor of volatility of future stock returns than historical volatility.
  - There is no statistically significant correlation between historical volatility and implied volatility.
- Black and Scholes model is not misspecified as implied volatility smile does not exists in case of NSE Nifty options.
- The error in prediction of option prices for various exercise prices by the Black-Scholes model is not statistically significantly different from zero.

6. Data and their Sources

This study uses S&P CNX NIFTY call and put options for analysis. The sample period is very large and extends from January 1, 2003 through December 24, 2008.

The data collected includes:

(i) Daily transaction data for the near month S&P CNX Nifty Put and Call options consisting of:

- Trading date,
- Expiration date,
- Strike price/or exercise price,
- Closing price (premium),
- Number of contracts traded each day
- Daily closing values of S&P CNX Nifty.

(ii) Daily dividend yield on S&P CNX Nifty

(iii) 91-day T.Bill rates.

The above mentioned data has been collected for each trading day of the sample period from 1st Jan 2003 uptil 24th December 2008. However daily closing values of S&P CNX Nifty have been collected for the period from 1st June 2002 to 24th December 2008. The data for the study has been collected from www.nseindia.com, the website of National Stock Exchange of India Ltd. 91-day T.Bill rates have been collected from RBI website (www.rbi.org.in).

7. Research Methodology

Steps:

7.1. Formulation of Samples

The following steps have been followed for forming the samples for both call and put options:

1) For carrying out research for this study, data for the near month S&P CNX Nifty option trades (both calls and puts), daily dividend yield on S&P CNX Nifty, 91-day T.Bill rates and closing Nifty values were collected for each trading day of the sample period (1st January-2003 to 24th December 2008). The data for the near month option contracts consisted of 72890 observations for each call and put options.
2) For the above data, the following input parameters required for estimating theoretical option prices using Black and Scholes formula were computed:

a) **Time to expiry:** is the time left for the option contract to expire. Time to maturity is annualized by dividing the number of days left for the option to expire by the total number of calendar days (i.e. 365 days) in a year.

b) **Historical Volatility:** Daily volatility has been found out by calculating the standard deviation of the continuously compounded Nifty returns for immediately preceding six months. Hull (2004) suggested the following formula for calculating annual volatility based on daily volatility:

$$\text{Volatility per annum} = \text{Volatility per trading day} * \sqrt{No.\ of\ \ trading\ \ days\ \ per\ \ annum}$$

The number of trading days per year is assumed as 252.

It may be noted that the standard deviation is measured on returns of the trading days only since volatility on holidays is zero as no trading takes place on these days.

c) Risk free rate (RF): The 91-day T.Bills, floated by the Government of India from time to time through RBI, is used as a proxy for the risk free asset and the adjusted Yield to Maturity (YTM) implicit at the cut-off rate of 91 day T.Bills auctions is considered as the return of this asset.

d) Dividend yield: For the period when an option is introduced and till it matures, the dividend yields on Nifty are averaged. The average is then assumed to remain constant and known for a particular option during its life. Hence the variable "δ" should be set equal to the average dividend yield (continuously compounded and annualized) during the life of the option. The Nifty index prices are adjusted for this known and constant dividend yield δ as follows:

$S_A = S_t e^{-\delta t}$

Where S_A is the adjusted Nifty index level.

δ is the continuously compounded known and constant dividend yield on Nifty.

3) Following exclusion criteria were applied successively to the raw data to improve the quality of data actually used in carrying out this research.

a) Since it is well recognized that non-synchronous prices can cause errors in the test of the BS model, therefore, the option contracts, for a given exercise point and expiry dates, which registered only up to 50 numbers of trades on a single trading day have been excluded from the sample.

b) The options contracts where the time to maturity is 5 days or less than that have not been considered.

After applying the filter criteria, the sample consisted of 14846 observations for call options and 13855 observations for put options for the near month option contracts. Further for 2990 observations for call options and 1595 observations for put options (which stand at around 20.14% for call options and 11.51% for put options of the left observations), the option had no defined values of volatility because these options were traded below their intrinsic value. After eliminating these observations, the sample now consists of 11865 observations for call options and 12260 observations for put options for the near month option contracts, which is the actual data used for carrying out the research.

7.2. Calculation of theoretical premium prices

Theoretical prices, of both call options and put options, have been computed using both historical and implied volatility. We use equation (1) for the call options and equation (2) for the put options (as mentioned in the Theoretical Framework) to calculate their theoretical option prices.

7.2.1. Calculation of Implied Volatility and Theoretical Prices Using Implied Volatility

Implied volatility has been estimated using the following method-

Using option prices for all contracts within a given maturity series observed on a given day, we estimate a single implied standard deviation to minimize the total error sum of squares between the predicted and the market prices of options of various exercise prices. This has been calculated using *Microsoft Excel Solver function* by minimizing the following function by iteratively changing the implied standard deviation:

$$\min_{BSISD} \sum_{J=1}^{N} \left[C_{OBS,j} - C_{BS,j}\left(BSISD\right) \right]^2$$

where BISD stands for the Black-Scholes Implied Standard Deviation, N stands for the number of price quotations available on a given day for a given maturity series, C_{OBS} represents a market-observed call price, and C_{BS}(BSISD) specifies a theoretical Black-Scholes call price based on the parameter BSISD.

Initially predicted prices have been computed using historical volatility.

Using a prior-day, out-of-sample BSISD estimate, we calculate theoretical Black-Scholes option prices for all contracts in a current-day sample within the same maturity series.

7.3. Comparison of Theoretical Prices with the Actual Prices

The theoretical premium prices are compared with the actual market premium prices and then the pricing errors are calculated for each day of the sample for the Nifty contracts. The pricing errors are mean error, mean absolute error and mean squared error. The closer these values are to zero, the better is the forecast.

Mean Error (ME): It is computed by adding all error values and dividing total error by the number of observations.

$$ME = 1/N \sum_{J=1}^{N} (Y_J^{//} - Y_J)$$

Mean Absolute Error (MAE):

$$MAE = \frac{1}{N} \sum_{J=1}^{N} \left| \left(Y_J^{//} - Y_J \right) \right|$$

It is the average absolute error value. The neutralization of positive errors by negative errors can be avoided in this measure.

Mean Squared Error (MSE):
It is computed as the average of the squared error values. This is the most commonly used error indicator in statistical fitting procedures. As compared to the MAE value, this measure is very sensitive to large outlier as it places more penalties on large errors than MAE.

$$\text{MSE} = \frac{1}{N}\sum_{J=1}^{N}\left(Y_J^{//} - Y_J\right)^2$$

Where, $Y^{//}_J$ = the theoretical price of the option
Y_J = actual price for observation j
N = no. of observations
Two sample t-test has been applied to check whether these pricing errors (calculated when a) historical volatility and b) implied volatility is used as an input to the model) are significantly different from each other or not.
Karl Pearson's coefficient of correlation has been used to find out the correlation between historical volatility and implied volatility used in the calculation of theoretical prices in case of call and put option contracts. The correlation coefficient r (also called Pearson's product moment correlation after Karl Pearson) is calculated by

$$\boxed{r = \frac{\sum_{i=1}^{r}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2\sum_{i=1}^{n}(y_i-\bar{y})^2}}}$$

Where,
$\bar{x}$ = mean of series x
$\bar{y}$ = mean of series y
n = number of pairs of observations
The null hypothesis that the correlation is not statistically significantly different from zero has been tested using the t-test.

7.4. Investigating the existence of volatility smile in case of S&P CNX Nifty options and testing the predictive accuracy of the Black and Scholes model
For this, three different samples have been used to see the pattern of relationship between IVVs and moneyness. The data set for the sample period starting from January 1, 2003 till 31st December 2006, 1st January 2007 till December 24, 2008 and the entire sample period starting from January 1, 2003 till December 24, 2008 has been categorized on the basis of moneyness. Moneyness of an option determines the profitability of immediately exercising an option, leaving aside the premium charges. Moneyness (M) is defined as: $\frac{S_A}{X} - 1$ where S_A is the Nifty index value adjusted for the continuously compounded known and constant dividend yield on Nifty δ and X is the exercise price of the option. There are eight moneyness categories defined: deep out-of-the-money call options (M<-.15), not so deep out-of-the-money call options (-.15≤M<-0.10 and -.10≤M<-0.05), near-the-money call options (-0.05≤M<0 and 0≤M≤0.05), not so deep in-the-money call options (0.05<M≤0.10 and 0.10<M≤0.15) and deep in-the-money call options (0.15<M).
The basic procedure for backing out the model's implied-volatility series is as follows:

- Collect the information on the spot index, interest rates, exercise price, time to maturity, dividend yield on date t and the corresponding observed call price for each option.
- Substitute above values in the formula given by Black and Scholes and through iterations obtain the spot volatility value for each call option of date t.
- Obtain an average implied volatility value for the near month call option contracts based on their moneyness.

Microsoft Excel Goal Seek function has been used to estimate implied volatility for each of the option contracts.
The average IVVs have been plotted against moneyness to investigate the existence of volatility smile in case of S&P CNX Nifty options. Also the average pricing error (pricing error calculated as the difference between the theoretical option price, calculated using t-1 day's single implied volatility estimate as explained before, and the market price) has been computed for each of the above moneyness categories to examine the predictive accuracy of the Black and Scholes model. T-test has been applied to check whether these pricing errors are significantly different from zero or not.

8. Empirical Results

8.1. Historical Volatility or Implied Volatility as a better predictor of Standard Deviation of Future Stock Returns
Tables 1 shows pricing errors of the BS model obtained for call options and put options for the sample period starting from 1st January, 2003 to 24th December, 2008.

Call Options		
	Mean Absolute Error(MAE)	**Mean Squared Error(MSE)**
Using Historical Volatility	13.08	390.12
Using Implied Volatility	5.57	86.07
N	11865	11865
t statistic	49.45*	32.21*
Put Options		
	Mean Absolute Error(MAE)	**Mean Squared Error(MSE)**
Using Historical Volatility	17.20	688.04
Using Implied Volatility	7.80	188.43
N	12260	12260
t statistic	45.62*	26.76*

Table 1: Pricing errors for the Near Month Call and Put Options
** significant at 1% level*

It is evident from table 1 that when pricing errors are calculated using implied volatility, it entails less pricing error than historical volatility in case of both call and put options. The result is consistent with most of the studies (Latane and Rendleman (1976), Chiras and Manaster (1978), etc) that implied volatility is more efficient predictor of option prices than historical volatility. The t-test shows that the pricing errors, computed using historical volatility and implied volatility as an input to the BS model, are significantly different from each other.

Table 2 below states the results of the correlation between historical volatility and implied volatility for the near month call and put option contracts.

	Call Options	**Put Options**
Pearson Correlation Coefficient	.622(*)	.600(*)
Sig.(2-Tailed)	.000	.000
N	1104	1104

Table 2: Correlation Coefficient between Historical Volatility and Implied Volatility
**Correlation is significant at the 0.01 level (2-tailed)*

Table 2 shows that the coefficient of correlation is significant and positive in both the cases. Hence there is a significant and positive correlation between historical volatility and implied volatility in case of the near month call and put option contracts. Hence we can conclude that historical volatility is significantly related to the current volatility. However the correlation is not perfect.

8.2. Model Misspecification

This section tries to study the implied-volatility pattern in case of the near month call options across moneyness. For this, three different samples have been used as mentioned in detail in methodology i.e. January 1, 2003 till 31st December 2006, 1st January 2007 till December 24, 2008 and the entire sample period starting from January 1, 2003 till December 24, 2008. Figures 1, 2 and 3 represent the implied-volatility pattern for the three sample periods respectively.

8.2.1. Implied Volatility Smile Pattern

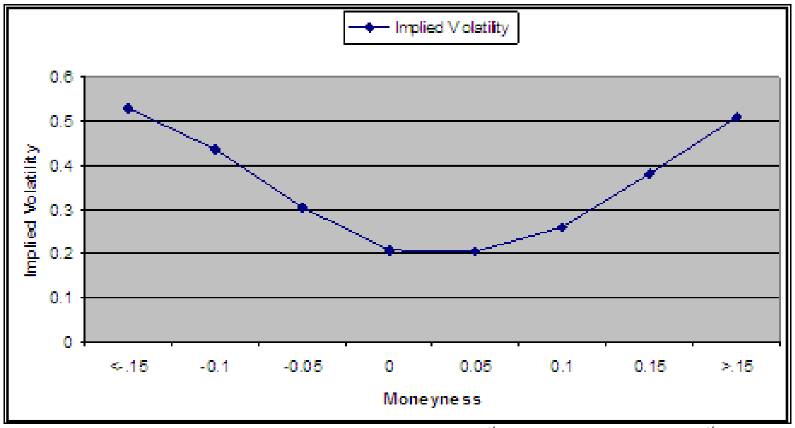

Figure 1: Implied Volatility Graph for sub sample from 1st January, 2003 to 31st December, 2006

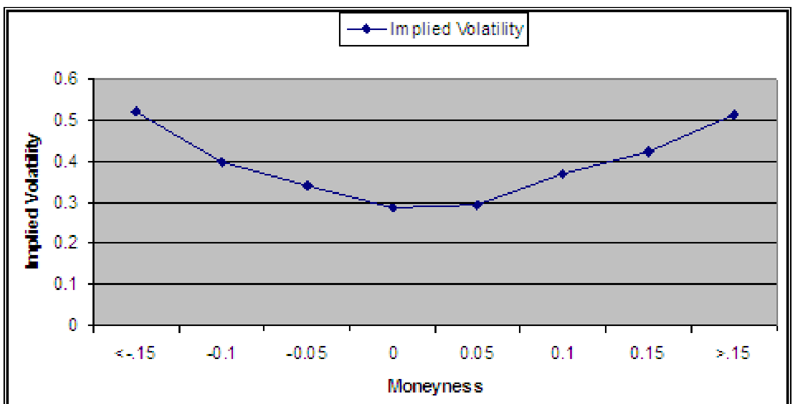

Figure 2: Implied Volatility Graph for sub sample from 1st January, 2007 to 24th December, 2008

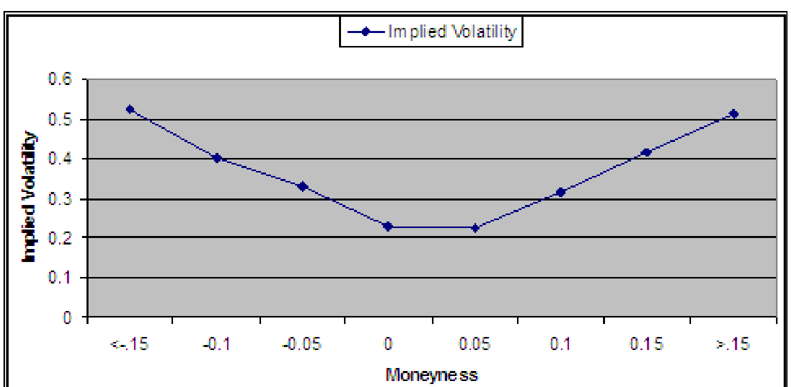

Figure 3: Implied Volatility Graph for the entire sample from 1st January, 2003 to 24th December, 2008

As can be seen from the figures, the implied volatility graphs depict the shape of a 'Smile' which indicates that out-of-the money options and in-the-money options are having high volatility values while near-the-money options are having low volatility values. The differences among the implied volatility values across exercise prices indicates that the BS model is not correct. These differences raise a question concerning the source of the BS model's deficiency. The assumptions underlying the model are often violated in real life. One possibility is that the constant volatility assumption is violated and thus IVVs change as time to maturity changes.

8.2.2. Pricing Errors

Pricing biases associated with the Black-Scholes model are well documented. For example, Early tests by Black (1975) found that the Black-Scholes model underprices deep out-of-the-money stock options and overprices deep in-the-money stock options. This section revisits the Black and Scholes model to find biases by taking data for Nifty index options for the period from 1st January, 2003 to 24th December, 2008.

Table 3 shows the pricing errors for the near month call options. Positive figures show overpricing and negative figures show under pricing by BS model.

	Moneyness							
	<-.15	**-.15≤M<-.10**	**-.10≤M<-.05**	**-.05≤M<0**	**0-0.05**	**.05<M≤.10**	**.10<M≤.15**	**>.15**
N	390	655	1355	4346	3744	918	247	111
PE	-4.95	-1.51	-0.92	-0.36	-0.11	-1.85	-5.13	-5.63
t stats	-4.42*	-5.47*	-3.88*	-3.0002*	-0.77	-4.08*	-5.08*	-3.64*

Table 3: Pricing Errors for the Near Month Call Options
**significant at 1% level*
where N stands for number of observations, PE stands for pricing error.

The results do not provide support for pricing accuracy of the BS model. Analysis of Table 3 shows that deep in-the-money and out-of-the-money options are highly underpriced by the BS model. Not so deep in-the-money call options and not so deep out-of-the-money call options too are underpriced. The minimum mispricing is for near-the-money call options. The smallest mean errors for the predicted prices are Rs. 0.11 (0-0.05) and Rs. 0.36 (-.05≤M<0) for near-the-money call options. The results show that near-the-money call options too are underpriced by the BS model. However, t test shows that the pricing error is not statistically significantly different from zero in case of option contracts where moneyness lies between 0 to 0.05. However, the pricing efficiency of the BS model is questionable in case of near-the-money options too as the model significantly under-prices those near the money options where moneyness is less than 0 but greater than or equal to -.05. This is in contrast with the international findings (for e.g., Black (1975)) on the predictive capability of the BS model that it is extremely accurate for pricing at-the-money options. In rest of the cases, there is significant under-pricing by the BS model and that the mispricing increases as the moneyness increases. In other words, mispricing worsens with the increased moneyness.

However an important point may be noted. We have assumed that the Indian Option market is efficient at stated price and that participants have the capability to price the options correctly. Thus, when the BS model price deviates from the market price determined by the option market participants, we conclude that the BS model is inappropriate for the Indian Option market. Our assumption that the Indian Option market is efficient may not be true. The things may be the other way round. Market inefficiency may be one of the sources of error.

9. Limitations of the Study

- The study is restricted to valuation of S&P CNX Nifty index options only. Sensex index options have not been studied.
- Only index options have been considered in the study. Stock options have not been included.
- The tests conducted are based on closing prices. When closing prices are used, a timing problem commonly referred to as a non-simultaneity problem, can exist. The problem becomes severe in a market where volume of trading is not that heavy. Use of intra-day prices would have improved the analysis; however substantial effort has been put in improving the quality of data and overcoming the limitations of the data collected.
- The study is restricted to Indian stock market and no comparison is made with the foreign options market.

10. Directions for Further Research

Options and futures are quite new instruments in India. They have shown varying growth rates since their inception. A lot of research related to financial futures and options has been done in developed countries. In India this is not so. Perhaps because it's a new field but there lies the opportunity to build on already existing and relevant knowledge to better analyse the peculiarities of Indian derivatives market and drawing a comparison with other emerging economies.

The predictive accuracy of the Black and Scholes model can be studied with the help of high frequency data to overcome the problem of non-simultaneity.

Similar research may be carried out on sensex index options as well as various stock options.

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