CHAPTER II
RESEARCH METHODOLOGY

2.1 INTRODUCTION

This chapter deals with the research methodology and research design. More precisely covers tests to be conducted for predictability and validity of assumptions. Data collection, editing, categorization and the rationalization of each step are explained. It also covers the analysis method. The methods of categorizing the data by moneyness, elimination of liquidity bias, price discreteness etc. are compared with the earlier published research papers in Journal of Finance etc.

2.2 RESEARCH DESIGN

2.2.1 TESTS FOR THE BLACK-SCHOLES MODEL

This empirical study is planned in such a way that it addresses the question of how well the best-known option pricing model - the Black-Scholes model works.

A long tradition in economics focuses on the first type of tests, arguing that "the proof is in the pudding." It is argued that any theory requires assumptions that might be judged "unrealistic," and that if we focus on the assumptions, we can end up with no foundations for deriving the generalizations that make theories useful. The only proper test of a theory lies in its predictive ability. The theory that consistently predicts best is the best theory, regardless of the assumptions required to generate the theory.

Tests based on assumptions are justified by the principle of "garbage in-garbage out." This approach argues that no theory derived from invalid
assumptions can be valid. Even if it appears to have predictive abilities, those can slip away quickly when changes in the environment make the invalid assumptions more pivotal.

Our analysis takes an agnostic position on this methodological debate, looking at both predictions and assumptions of the Black-Scholes model.

2.2.2 PREDICTIVE ABILITY

Before deciding the way of measuring the predictive ability of the model, many publications were studied and narrated below:

1. Ball, Clifford A., and Walter N. Torous, [12], in their paper "On Jumps in Common Stock Prices and Their Impact on Call Option Pricing," used percentage errors across various moneyness and expiration period to find the predictive ability of the model.


2.2.3 VALIDITY OF ASSUMPTIONS

The model is built on the following main assumptions.

1. Stock prices follow random walk.
2. Stock returns are log normally distributed.
3. Continuous time frame is assumed.
4. Continuous compounded risk free interest rate \( r \) and volatility \( \sigma \) of the log returns on the stock are constant throughout the life of the options.
5. No taxation and transaction cost and stocks are perfectly divisible.
6. Options are European and stocks pay no dividend.
7. There are no risk-less arbitrage opportunities.

The study is designed to cover testing the main assumptions one by one.

### 2.2.3.1 Stock prices follow random walk

The stock prices are not predictable and they follow random walk. The basics of this argument being efficient market theory. Most of the times, investment banks, stock brokers, financial advisors, and equity researchers use the technical analysis to predict the movement of the prices. Many famous techniques of Technical analysis such as Exponential Moving Averages (EMA), Moving Averages Convergences and Divergences (MACD), Rate of Change (ROC), and Relative Strength Index (RSI) are used to predict the future stock prices. Hence these techniques are used to test the random walk theory.

### 2.2.3.2 Stock returns are log-normally distributed

The meaning is that the returns of the stock prices should be lognormally distributed. Otherwise, the natural logarithms of the stock returns are to be normally distributed.

Normality can be tested, using a quick exploratory check and a formal test. Many times just the histograms and the box plot can show that the data are not normally distributed. As a rule, use of numerical summaries and graphical displays will be better judge of normality. This is done using mean based statistics like mean, median, mode, Pearson’s skewness coefficients and Kurtosis. In addition, it can be tested with more resistant order-based statistics.
such as median (Q2), upper, lower quartiles (Q3, & Q1), and Bowley’s Coefficient of Skewness. Finding the skewness and kurtosis will check the normality assumption. SAS package is used for the above analysis for calculation and drawing of charts like Histograms, Box-plot, normal percentile and normal quartiles.

2.2.3.3 Options are European and stocks pay no dividend.

European options mean they can be exercised only on the expiration day and not before. Actually the options offered by NSE can be exercised any time during the life of the options and hence, they are American in nature. Hence, to make the American type stock options suitable to be used in Black - Scholes model,

- The arbitrage opportunities are to be taken off from the sample.
- The options having dividend payment during the life of the options are removed from the sample.

If, the options satisfy the above two conditions, then, Black - Scholes model can be used for American type options, theoretically, as it will be never optimal to exercise it early. This is explained clearly by Hull, John C [71] in his book Options, Futures and Other Derivatives, 5e, in pages 175 to 177.

Accordingly, the research is so planned that it will collect all the dividend details like record dates, ex-dividend dates, and dates of the board meeting announcing the dividend for each stock have been collected (Appendix 1). From the above data, the stocks with cum-dividends are found and the options having of such stocks in their lives are found and taken away from the samples. This is a very very tedious process for which separate software has been developed using dotnet.
All options should follow the boundary condition of the model. That is the call option price should be greater than the lower boundary of So - X e^{-rt}. Any option which violates it will have a risk-free arbitrage opportunity. As the model assumes no that the options have no arbitrage opportunities they are found and taken off from the sample.

2.2.4 FINDING AN IMPROVEMENT IN THE MODEL

The research also attempts to improve the model's prediction power by improving some element in the model. Clues are to be obtained from the test of model's specifications such as residual analysis and weakness of the model like biases etc. The analysis is planned with the distribution of the residuals, and correlation of the residuals with the variables and parameters of the model. The new method, suggested, if any, will be compared with the BS original model. The percentages of the improvement is planned to be tested for its versatility.

2.3 The DATA

2.3.1 OPTION DATA

This research mainly depends on the secondary data from exchange-traded options in India. There are two stock exchanges viz. Bombay Stock Exchange (BSE) and National Stock Exchange (NSE) that are trading derivatives in India. The volume of cash market of BSE is about two third lower than the NSE volume. In derivative segment, the volume of trading in BSE is negligible and almost all the derivatives (99%) are traded only in NSE. This is shown by the data shown in table No.2.1 below.
<table>
<thead>
<tr>
<th>S. No.</th>
<th>DATE</th>
<th>DETAILS</th>
<th>TRADED AT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NSE</td>
</tr>
<tr>
<td>1</td>
<td>19-10-2006</td>
<td>Values (Crores)</td>
<td>32,056</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shares (lakhs)</td>
<td>5,959</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traded '000</td>
<td>478</td>
</tr>
<tr>
<td>2</td>
<td>20-11-2006</td>
<td>Values (Crores)</td>
<td>34,812</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shares (lakhs)</td>
<td>5,409</td>
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<tr>
<td></td>
<td></td>
<td>Traded '000</td>
<td>521</td>
</tr>
<tr>
<td>3</td>
<td>29-11-2006</td>
<td>Values (Crores)</td>
<td>37,178</td>
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<tr>
<td></td>
<td></td>
<td>Shares (lakhs)</td>
<td>7,760</td>
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<td></td>
<td></td>
<td>Traded '000</td>
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<td>30-11-2006</td>
<td>Values (Crores)</td>
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<td></td>
<td></td>
<td>Traded '000</td>
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<td>5</td>
<td>06-12-2006</td>
<td>Values (Crores)</td>
<td>32,054</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td>Traded '000</td>
<td>514</td>
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<tr>
<td>6</td>
<td>07-12-2006</td>
<td>Values (Crores)</td>
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<td></td>
<td></td>
<td>Shares (lakhs)</td>
<td>4,280</td>
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<tr>
<td></td>
<td></td>
<td>Traded '000</td>
<td>386</td>
</tr>
</tbody>
</table>

Source: Business standards dated 20-10-06, 21, & 30th November 06, & 1, 7 & 8th December, 06.
From the above table showing six days details of actual options traded both at NSE and BSE, it may be observed that the trade value at NSE is at an average of Rs.33,746 crores per day, while for the BSE is at Rs. 407 crores. It is only 1.20%. If we consider the notional number of shares committed the NSE has it is around 6500 lakhs on an average and the same at BSE is around 3 lakhs only, not even a decimal of percentage. Hence the sample is taken from trades of stock options at NSE alone. More precisely, the study is restricted to call options alone, as the Black - Scholes model is mainly developed for the call options. As per NSE data, when the research started during 2003, there were only about 52 stocks traded in F & O (derivative) segment. The stocks that are traded in F & O from 2002 till 2007 are given in Appendices 2 to 6. The Later more and more companies were included; 116 stock options were traded during 2005 (Appendix 5) and as on 2007, about 223 companies were included in this segment. The stock options related to these companies which exist from the beginning and till 31.10.2007 were considered (Appendix 6). From that at random 28 companies were selected. There are some company stocks eliminated from the list of derivatives. Some have changed their name during the period of study such as TISCO to Tata Steel, Hindustan Lever to Hindustan Unilever, Telco to Tata Motors, Gujarat Ambuja Cement Ltd. into Ambuja Cement Ltd. etc. The data covers almost all important industries like Cement, Steel, Automobiles, Banks, Pharmaceutical, FMCG, IT, Telecom, Oil, and Engineering. The selected stock options are given in the Table no. 2.2

The companies whose stock options were traded in most of the period of our study are taken. From the same, if the no. of trades is less than 1000 during the period of study they were eliminated. (As practiced in Journal publications). The resultant companies are listed in alphabetic order and randomly 28 companies were taken as sample. It is aimed that the final sample size at 1,00,000 at least.
<table>
<thead>
<tr>
<th>S.NO.</th>
<th>OPTIONS ON INDIVIDUAL SECURITIES</th>
<th>SYMBOL</th>
<th>LOT SIZE</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Ambuja Cements Ltd.</td>
<td>AMBUJACEM</td>
<td>2062</td>
</tr>
<tr>
<td>2</td>
<td>Andhra Bank</td>
<td>ANDHRABANK</td>
<td>2300</td>
</tr>
<tr>
<td>3</td>
<td>Associated Cement Co. Ltd.</td>
<td>ACC</td>
<td>375</td>
</tr>
<tr>
<td>4</td>
<td>Bajaj Auto Ltd.</td>
<td>BAJAJAUTO</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Bank Of Baroda</td>
<td>BANKBARODA</td>
<td>1400</td>
</tr>
<tr>
<td>6</td>
<td>Bank Of India</td>
<td>BANKINDIA</td>
<td>1900</td>
</tr>
<tr>
<td>7</td>
<td>Bharat Heavy Electricals Ltd.</td>
<td>BHEL</td>
<td>300</td>
</tr>
<tr>
<td>8</td>
<td>Bharat Petroleum Corporation Ltd.</td>
<td>BPCL</td>
<td>1100</td>
</tr>
<tr>
<td>9</td>
<td>Canara Bank</td>
<td>CANBK</td>
<td>1600</td>
</tr>
<tr>
<td>10</td>
<td>Cipla Ltd.</td>
<td>CIPLA</td>
<td>1250</td>
</tr>
<tr>
<td>11</td>
<td>Dr. Reddy’S Laboratories Ltd.</td>
<td>DRREDDY</td>
<td>400</td>
</tr>
<tr>
<td>12</td>
<td>Grasim Industries Ltd.</td>
<td>GRASIM</td>
<td>88</td>
</tr>
<tr>
<td>13</td>
<td>Hindustan Unilever Ltd</td>
<td>HINDUNILVR</td>
<td>1000</td>
</tr>
<tr>
<td>14</td>
<td>Icici Bank Ltd.</td>
<td>ICICIBANK</td>
<td>350</td>
</tr>
<tr>
<td>15</td>
<td>Infosys Technologies Ltd.</td>
<td>INFOSYSTCH</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>Itc Ltd.</td>
<td>ITC</td>
<td>2250</td>
</tr>
<tr>
<td>17</td>
<td>Mahanagar Telephone Nigam Ltd.</td>
<td>MTNL</td>
<td>1600</td>
</tr>
<tr>
<td>18</td>
<td>Mahindra &amp; Mahindra Ltd.</td>
<td>M&amp;M</td>
<td>312</td>
</tr>
<tr>
<td>19</td>
<td>Oil &amp; Natural Gas Corp. Ltd.</td>
<td>ONGC</td>
<td>225</td>
</tr>
<tr>
<td>20</td>
<td>Punjab National Bank</td>
<td>PNB</td>
<td>600</td>
</tr>
<tr>
<td>21</td>
<td>Ranbaxy Laboratories Ltd.</td>
<td>RANBAXY</td>
<td>800</td>
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<tr>
<td>22</td>
<td>Reliance Industries Ltd.</td>
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</tr>
<tr>
<td>23</td>
<td>Satyam Computer Services Ltd.</td>
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<td>600</td>
</tr>
<tr>
<td>24</td>
<td>Shipping Corporation Of India Ltd.</td>
<td>SCI</td>
<td>1600</td>
</tr>
<tr>
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<td>Syndicate Bank</td>
<td>SYNDIBANK</td>
<td>3800</td>
</tr>
<tr>
<td>26</td>
<td>Tata Steel Ltd.</td>
<td>TATASTEEL</td>
<td>764</td>
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<tr>
<td>27</td>
<td>Union Bank Of India</td>
<td>UNIONBANK</td>
<td>2100</td>
</tr>
<tr>
<td>28</td>
<td>Wipro Ltd.</td>
<td>WIPRO</td>
<td>600</td>
</tr>
</tbody>
</table>

Source: www.nseindia.com
2.3.2 SHARE PRICE DATA

As the volatility of returns of the stock prices are to be calculated, stock prices of the 28 companies were downloaded at least from 120 days prior to the first date of the option data. On a safer side, stock prices were downloaded from 1.6.2001 to 31.10.2007 from NSE website [69]. For the 28 companies almost about 48,000 price data were collected.

2.3.3 RISK-FREE RATE OF INTEREST – METHODOLOGY

In all the developed nations where options are traded in exchanges, risk-free rate of interest is calculated by the yield of the Treasury Bills which will mature as on the same date of expiration of the options. But in India, the Treasury Bills market is not matured and deep, the NSE itself uses the MIBOR and MIBID rates as the risk-free rate of interest. Hence, this study also takes the same, for calculating the Black - Scholes call options prices. There are 4 types of these data available, which are overnight, 14 days, 1 month and 3 months rates. The same were downloaded from NSE website [69] from 1.1.2002 till 31-10-2007 (Appendix 7).

2.3.3.1 Method of obtaining MIBID / MIBOR rates

The yardstick for the money market

The Committee for the Development of the Debt Market had studied and recommended the modalities for the development for a benchmark rate for the call money market. Accordingly, NSE had developed and launched the NSE Mumbai Inter-bank Bid Rate (MIBID) and NSE Mumbai Inter-bank Offer Rate (MIBOR) for the overnight money market on June 15, 1998. The success of the Overnight NSE MIBID/MIBOR encouraged the Exchange to develop a
benchmark rate for the term money market. NSE launched the 14-day NSE MIBID/MIBOR on November 10, 1998 and the longer term money market benchmark rates for 1 month and 3 months on December 1, 1998.

The MIBID/MIBOR rate is used as a benchmark rate for majority of deals struck for Interest Rate Swaps, Forward Rate Agreements, Floating Rate Debentures and Term Deposits.

Fixed Income Money Market and Derivative Association of India (FIMMDA) has been in the forefront for creation of benchmarks that can be used by the market participants to bring uniformity in the market place. To take the process of development further, FIMMDA and NSEIL have taken the initiative to co-brand the dissemination of reference rates for the Overnight Call and Term Money Market using the current methodology behind NSE - MIBID/MIBOR. The product was rechristened as 'FIMMDA-NSE MIBID/MIBOR'. The 'FIMMDA-NSE MIBID/MIBOR' is now jointly disseminated by FIMMDA as well as NSEIL through their websites and other means and simultaneous dissemination of the information would be as per international practice.

**MIBID / MIBOR Methodology**

The Committee for the Development of the Debt Market studied various alternative methodologies, which could be used for compiling a true reference rate in the market. This market is characterized by limited number of participants, who at times, take a unidirectional view of the market. Some of the methodologies studied by the committee are as under:

**Volume weighted average (VWA)** is calculated by averaging the reported trades after weighting them with their respective volume. The VWA needs price volume data of all executed deals and is a reliable measure of the market sentiment. However the calculation of VWA has some constraints in the Indian context, as most participants prefer to keep their transactions
confidential. Moreover, this method can give results only at the close of the market and therefore tends to give post-facto information and cannot be used to gauge the market mood at a point of time.

**Polling (Delphic oracle)** is used for obtaining reference rates by polling a few market participants and summarizing the prices they report. The highly liquid CME Eurodollar contract uses this method for its futures contract. The procedure involves querying bid and offer prices from eight market participants.

The basic question that is asked about this approach is, what motivates the respondents to report accurately? It is hard to design an incentive structure whereby the respondent does participate, and produces accurate information. Full transparency would clearly help- if all eight quotes along with the name of the respondents are reported through a transparent medium, it would generate pressure to report fair prices. At the same time, this degree of public visibility might deter some players from participating. This is particularly a problem in an illiquid market, where various participants could have genuine or selfish reasons for reporting widely differing rates. Dealers have an incentive to falsify the reported rates to inject noise into the decision making of the market participants who use the reported reference rate or to gain from positions on derivative contracts which calculate payoffs using the reference rate.

**Identifying and isolating noise in data:** Having selected an appropriate technique for collecting data, one has to devise methods to identify and isolate the noise in data so as to minimise the impact of the extreme values on the final result, i.e. the reference rate. The most commonly used methods for this purpose are discussed hereunder:

**Traded mean:** Calculated fixed trimmed mean of the reported rates have been used by some organizations which need to use a reference rate, e.g. the CME for its Eurodollars contract, the CBOT for its Municipal Bond Index, etc. They collect rates from individual dealers and compute a reference rate as the
trimmed mean is obtained after deleting "n" highest and lowest observations. For example, at CME Eurodollar, the two highest and two lowest quotes are rejected and the rest of the quotes averaged to get a reference rate.

The major concerns in such a trimming procedure are vulnerability to market manipulation of the rates and the amount of sampling noise. Secondly, excessive trimming may lead to loss of information, whereas too little trimming may lead to excessive influence of the extreme values on the reference rate. Thirdly, the sample sizes are typically very small and hence statistics based on the assumptions of normal distribution give wrong inferences.

**Bootstrapping:** The bootstrap technique is a non-parametric method for computing the test statistics, i.e.

(i) Computing the reference rate as an average of the polled rates after an appropriate amount of trimming to minimise noise.

(ii) Computing a measure of dispersion i.e. the confidence intervals for the trimmed means.

In order to arrive at an efficient estimate of the reference rate, from the bid and offer rates collected from a known sample of dealers, the outliers or extreme values are identified. This is required so that the reference rate, which is a mean of the polled rates, is not unduly influenced by extreme observations, which are likely to be noisy.

A user is also interested in knowing the efficiency of this mean value. That is to say, he is interested in knowing the probability that the estimated trimmed mean lies in a given range. Thus, the standard deviation of the mean has to be estimated. Since the call market is heterogeneous, constrained by limited participants and dealers, the underlying distribution of the offer and bid
rates is not normal and hence the usual measures of efficiency of the mean rate, i.e. the standard deviation, is not valid.

The bootstrap method does not make any assumptions about the distribution from which the trimmed mean is drawn. The bootstrap method facilitates construction of the entire distribution for the mean and hence all the required parameters can be calculated from this constructed distribution. Since the observations are drawn at random and the number of simulations is very high, the probability of any extreme observations affecting the mean value and its standard deviation is extremely minimal.

The procedure for choosing an adaptive 'n' as opposed to using a fixed 'n' allows for reduction of sampling noise and hence makes the estimated mean more efficient.

As discussed above, the "Polling" with "Bootstrapping" scores over the other alternatives to collect data in a limited data set and to isolate the extreme values. FIMMDA-NSE MIBID/MIBOR therefore, uses polling to collect data from the market participants. While the quotes for the overnight money are polled between 0940-0945 hours, quotes for the other terms are polled between 1130-1140 hours to capture the market sentiment in a short interval of time. Thereafter, the data so collected is subjected to bootstrapping to identify the extreme values.

The bootstrapping technique involves generating multiple data sets based on the rates polled, wherein the number of iterations required is determined dynamically and could be as high as 10,000. Based on the means generated from these multiple data samples, the standard deviation is calculated. The bootstrapping technique is also used to identify the outliers in the polled data. This is done by trimming the data set of its extreme values and again using a bootstrapped sample to calculate the standard deviation. Bootstrapping ensures that the data sets are drawn at random and this guards
against the possibility of cartelisation and of extreme observations influencing the mean. The mean corresponding to the lowest standard deviation is finally reported by ensuring acceptability of at least 14 observations each for bid and offers. The standard deviations associated with FIMMDA-NSE MIBID/MIBOR are also reported to help the market in assessing the distribution of rates.

Thus, the methodology adopted by FIMMDA-NSE MIBID/MIBOR not only seeks to tackle the limitation of the polling method but also uses adaptive trimming to identify and isolate the extreme value to derive a true representative benchmark for the market. Moreover, the entire process of polling and processing of data is completed in a time-bound schedule and the reference rates are released to the market every day.

FIMMDA-NSE MIBID MIBOR Panel of Participants

- Public Sector Banks
- Private Sector Banks
- Foreign Banks
- Primary Dealers

Public Sector Banks

- Bank of Baroda
- Bank of India
- Canara Bank
- Central Bank of India
- Indian Bank
- Indian Overseas Bank
- Punjab National Bank
- State Bank of India
- State Bank of Hyderabad
- State Bank of Indore
- State Bank of Patiala
- Syndicate Bank
- Corporation Bank
- Union Bank of India
- UCO Bank

**Private Sector Banks**

- HDFC Bank Ltd.
- ICICI Bank Ltd.
- IndusInd Bank Ltd.
- IDBI Limited
- Kotak Bank
- Axis Bank Ltd.

**Foreign Banks**

- ABN AMRO Bank N.V.
- American Express Bank Ltd.
- Bank of America
- CitiBank N.A.
- Deutsche Bank AG
- HSBC
- Standard Chartered Bank
Primary Dealers

- SBI DFHI Ltd.
- Gilt Securities Trading Corporation Ltd. (Gilts).
- ICICI Securities Ltd. (I-Sec).
- PNB Gilts Ltd.
- Securities Trading Corporation India Ltd. (STCI).

Dissemination of NSE MIBID MIBOR

FIMMDA-NSE MIBID MIBOR rates are broadcasted through the NEAT-WDM trading system immediately on release. The NSE website carries the daily rates as well as the historical data on the FIMMDA-NSE MIBID MIBOR. The FIMMDA also disseminates the FIMMDA-NSE MIBID MIBOR rates through its website and other means.

In addition leading information vendors viz. Reuters on its news information page, Bridge News Service (Knight Ridder) on page no.2811, Bloomberg on its money market page as well as a news story and PTI on its money market page, carry these rates on a daily basis.

FIMMDA-NSE MIBID MIBOR rates are also carried by all leading financial dailies including Economic Times, Financial Express, Business Standard and Business Line.

In addition to the above, FIMMDA-NSE MIBID MIBOR rates are released to contributors and users through E-mail.
Products linked to FIMMDA-NSE MIBID/MIBOR

Floating Rate Notes
1. GE Capital

Corporate Debentures
1. L&T
2. GE Capital

Term Deposit
1. ICICI bank

Interest Rate Swaps
1. Parties: Standard Chartered Bank & Multinational entity
2. Parties: HSBC & Corporate entity
3. Parties: HDFC Bank & KEC International
4. Parties: ABN AMRO N. V. & Multinational entity
5. Parties: ABN AMRO N. V. & Reliance Industries
6. Parties: ABN AMRO N. V. & Multinational entity
7. Parties: Deutsche Bank & ICICI Ltd.
8. Parties: Deutsche Bank & Multinational entity

Forward Rate Agreements
Bank: HSBC

2.4 DATA SEGREGATION AND ELIMINATION

The model has many basic principles and assumptions as explained in Chapter 1 and paragraph 2.2.3 above. To include the observed data in the sample of the empirical study, it should be verified if the data satisfy the conditions made in the assumptions. Otherwise, the data which violate any of the assumptions of the model should be removed from the sample. This
exercise to be made very carefully and cautiously, which are narrated below in steps.

2.4.1 TRADED DATA

Almost 14,29,532 call options were offered by NSE for the said 28 company’s stocks during the study period of 1.1.2002 to 31.10.2007. When options are not traded, the settlement price of the options are not practical ones but theoretical and cannot be used for empirical study. Only the traded options have the correct prices of options, thus the non - traded options were eliminated from the above data. About 83.30% of the data were eliminated and only 2,38,699 call options that were traded were taken for the study.

2.4.2 NON – DIVIDEND PAYING STOCKS

Black and Scholes assumed that the stocks pay no dividend. Hence the call options related to the stocks which have cum-dividend\(^2\) during the life of the options were eliminated from the sample. The process is easy to understand but very difficult to comply with.

The dividend declaration details like the date of the Board meeting at which the dividends are declared and the ex-dividend dates for the above 28 companies from 1.1.2002 to 31.10.2007 were collected from NSE / company sources (Appendix 1). Then the call options related to the stocks having cum dividend during the life of the options were eliminated. About 58,567 call options were of cum dividend category and were eliminated from the sample, which works out to about 24.54% of the traded call options.

\(^2\)cum - dividend: when a buyer of a security is entitled to receive the dividend that has been declared, but not paid.
2.4.3 USING EUROPEAN FORMULA FOR AMERICAN OPTIONS

The BS model has been designed for the European type options which will be exercised only on the expiration date. But, the Indian stock options are of American type, which can be exercised any time on or before the expiration date. Hence, strictly speaking, one can not use the formula in Indian options market. But, thanks for the fact that “It is never optimal to exercise early for an option that pays no dividend”. Because of this, if we eliminate all arbitrary opportunities of American options, then as per the above fact, one will not exercise the options early hence can be treated like European options.

In view of the above, all risk-free arbitrage opportunities, if any, to be eliminated from the sample to make use of the BS model for American type options also. Only a few of them were there in the sample and they were eliminated. Thus, for the sample taken from Indian stock options, Black-Scholes formula can be used theoretically as well as practically.

2.4.4 LIQUIDITY BIAS

The price of any asset should be determined without any biases and should be based on the intrinsic value. Securities with short life span tend to show biases due to its liquidity. These biases may give wrong results in any empirical studies and hence to be avoided. To avoid them, call options with life less than 5 days were eliminated as advocated in many foreign research papers [11, 48, 53, 76, and 123] published.

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3Hull, John, C. “Options, Futures & Other Derivatives” (2003), Prentice Hall of India, 5e. pp 175 -177
2.4 5 PRICE DISCRETENESS

Any low priced securities have a tendency to appreciate more and may be priced higher compare to high priced securities, the other things being constant. Stock-splits are made based on the above concept only. To avoid such a bias, the options with price less than Rs. 6 were eliminated.

The above two steps 4 and 5 were in line with the research papers by Bakshi, Gurdip, Cao, Charles, and Chen, Zhiwu [10], Eraker, Bjorn [48], Huang, Jing - Zhi and Wa, Lieuren, (2004) [70], Shastri, Kuldeep, and Tandon, Kishore (1986) [123] published in the world No.1 Journal, “The Journal of Finance”. Fortune, Peter [53] in his research paper “Anomalies in option pricing: the Black-Scholes model revisited” taken the data “The criteria were that the option had 45 to 75 calendar days to expiration (the average was 61 days) and that it be near the money (defined as a spread between S&P 500 and strike price no more than 2.5 percent of the S&P 500)”.

2.5 MONEYNESS

As the BS model is a stochastic process, and the payoff / return is the difference in the Stock price and the Exercise Price, normally comparing the options are done for the same proportionate of the Stock price and the Exercise Price. Many researchers use many proportions like i) \( S_0 / X e^{-\frac{rT}{2}} \) by Ball, Clifford A. and Torous, Walter N. [11], ii) \( \ln (X / S_0) \) by J Huang, Jing - Zhi and Lieuren Wa, [70], iii) \( X / S_0 \) by Eraker, Bjorn [48], iv) \( S_0 / X \) by Naik, Vasanttilak [107], and Bakshi, Gurdip, Cao, Charles, and Zhiwu Chen [10], in their research papers. In our research, moneyness is defined as \( S_0 / X \). If it is more than one it is In - the Money (ITM) option, less than one Out-of–Money (OTM) and if equal to one it is known as At–the–Money (ATM) option.
2.6 VOLATILITY CALCULATIONS

The call options under study have the underlying assets as the shares of the companies mentioned above in the table. One of the five variables of the BS option pricing is the volatility (standard deviation) of the stock returns. As per the model, volatility is calculated using the historical stock prices. When company exercise stock splits or issue bonus shares, the stock prices have to be adjusted for when calculating the returns. To identify such actions of the companies, charts are made for each stock and observed for clue for possible stock splits, issue of bonus shares etc. The charts of the stock prices of thirty companies were given below from Chart No. 2.1 to 2.30.

CHART 2.1
SHARE PRICES OF AMBUJA CEMENT
FROM 1.1.2002 TO 31.10.2007

From the above chart, it is observed that the share price of Rs. 415.55 on 17-6-2005 has decreased to Rs.59.35 on next working day of 26-06-05. The
reason being the company went for a stock-split\(^4\) from Rs. 10 per share to Rs.2 per share and issued bonus shares one for each two shares. In this case, if we calculate stock return on 26-06-05 as 0.869 and log return as -0.1409 it will be wrong. Hence, calculation of the volatility \(\sigma\) will be wrong. In addition using the share price on 17-6-2005 for the call options with the expiration of 30-6-2005 would be wrong. Therefore, the stock prices are adjusted in the proportionate of stock split / bonus shares before calculating the volatility of the stock returns.

\[\text{CHART 2.2} \]

SHARE PRICES OF ANDHRA BANK
FROM 1.1.2002 TO 31.10.2007

\[\text{ANDHRA BANK}\]

\[\begin{array}{c}
\text{0} \\
\text{20} \\
\text{40} \\
\text{60} \\
\text{80} \\
\text{100} \\
\text{120} \\
\text{140}
\end{array}\]

\[\begin{array}{c}
\text{12/01/02} \\
\text{24/03/02} \\
\text{27/05/02} \\
\text{02/08/02} \\
\text{16/10/02} \\
\text{02/03/03} \\
\text{10/05/03} \\
\text{22/07/03} \\
\text{15/09/03} \\
\text{06/11/03} \\
\text{26/01/04} \\
\text{19/03/04} \\
\text{02/05/04} \\
\text{15/07/04} \\
\text{08/09/04} \\
\text{22/11/04} \\
\text{13/01/05} \\
\text{06/03/05} \\
\text{26/05/05} \\
\text{19/07/05} \\
\text{11/09/05} \\
\text{04/11/05} \\
\text{17/01/06} \\
\text{09/03/06} \\
\text{22/05/06} \\
\text{15/07/06} \\
\text{08/09/06} \\
\text{17/11/06} \\
\end{array}\]

\[\begin{array}{c}
\text{16/01/07} \\
\text{08/03/07} \\
\text{21/05/07} \\
\text{14/07/07} \\
\text{27/09/07} \\
\text{10/11/07} \\
\text{03/01/08} \\
\end{array}\]

\(^4\)Gujarat Ambuja Cement Ltd has informed the Exchange regarding the resolutions passed by the shareholders at the EGM held on May 26, 2005 approving the following:

1) Stock-split from Rs.10/- per share to Rs.2/- per share and consequent amendment to the Memorandum of Association.

2) Issue of bonus shares in the ratio of 1 share for each 2 shares.

3) The company has further informed that they have filed the requisite form with the registrar of companies for increase in Authorised Share Capital on May 26, 2005.
CHART 2.5
SHARE PRICES OF BANK OF BARODA
FROM 1.1.2002 TO 31.10.2007

CHART 2.6
SHARE PRICES OF BANK OF INDIA
FROM 1.1.2002 TO 31.10.2007
In the above three charts, there was no such sudden drop in share prices due to either stock split or issue of bonus shares. However, ex-dividend dates need to be taken care off which is dealt in detail in the next section.

CHART 2.7
SHARE PRICES OF BHEL
FROM 1.1.2002 TO 31.10.2007

In the case of Bharat Heavy Electricals Limited, on 01-06-2007, the share price dropped to Rs.1399.10 from Rs.2767.80 on the previous date 31-05-2007. On verification it is noted that the phenomenon is due to issue of 1:1 bonus shares with the record date as 01-06-2007 (Appendix 1). As explained earlier therefore, the stock prices are adjusted in the proportionate of bonus shares before calculating the volatility of the stock returns and was proceeded further to the second stage of data analysis.
CHART 2.8
SHARE PRICES OF BPCL
FROM 1.1.2002 TO 31.10.2007

CHART 2.9
SHARE PRICES OF CANARA BANK
FROM 1.1.2002 TO 31.10.2007
In this case, Cipla Limited, a leading pharmaceutical company had two of such drop in prices one in May 2004 and the other in April 2006 due to bonus issues and stock split. As envisaged, the stock prices are adjusted in the proportionate of stock split / bonus shares before calculating the volatility of the stock returns.
Dr. Reddy's Laboratories Limited decided to issue one bonus share for each one equity share at its Board meeting on 28-07-2006. Consequently, on 28-08-2006, the share price dropped to Rs. 714.15 from its previous day level of Rs. 1443.10. Therefore, the stock prices were adjusted in the proportionate of stock split / bonus shares before calculating the volatility of the stock returns.
**CHART 2.12**

SHARE PRICES OF GRASIM

FROM 1.1.2002 TO 31.10.2007

**CHART 2.13**

SHARE PRICES OF HINDUSTAN UNILEVER

FROM 1.1.2002 TO 31.10.2007
CHART 2.14
SHARE PRICES OF ICICI BANK
FROM 1.1.2002 TO 31.10.2007

CHART 2.15
SHARE PRICES OF INFOSYS
FROM 1.1.2002 TO 31.10.2007
Infosys Technologies Limited is the one company that consistently offering bonus shares during April 2003, June 2004 and July 2006. The share price went up each time almost to the previous level in a year or so. Thus, the theory of bonus stocks proved to fuel faster growth rate and maximizes the wealth of its shareholders. Hence, as usual, the stock prices were adjusted in the proportionate of bonus shares before calculating the volatility of the stock returns.

CHART 2.16
SHARE PRICES OF ITC
FROM 1.1.2002 TO 31.10.2007

ITC limited has implemented a stock split from Rs. 10 to 1 per share and also issued bonus one share for each two existing shares on 21st September 2005. The share price has dropped from Rs.1929.60 to Rs. 140.20 on that day. Therefore, the stock prices were adjusted in the proportionate of stock split / bonus shares before calculating the volatility of the stock returns.
Mahindra & Mahindra Limited, a leading automobile company issued one bonus share for each share with the record date of 01-09-2005 and the price fell
by around 50 percent. Therefore, the stock prices are adjusted in the proportionate of bonus shares before calculating the volatility of the stock returns and the call option price.

**CHART 2.19**
SHARE PRICES OF ONGC
FROM 1.1.2002 TO 31.10.2007

**CHART 2.20**
SHARE PRICES OF PUNJAB NATIONAL BANK
FROM 26.4.2002 TO 31.10.2007
CHART 2.21
SHARE PRICES OF RANBAXY LABORATORIES
FROM 1.1.2002 TO 31.10.2007

CHART 2.22
SHARE PRICES OF RELIANCE INDUSTRIES
FROM 1.1.2002 TO 31.10.2007
CHART 2.23
SHARE PRICES OF SATYAM COMPUTER SERVICES
FROM 1.1.2002 TO 31.10.2007

CHART 2.24
SHARE PRICES OF SHIPPING CORPORATION OF INDIA
FROM 1.1.2002 TO 31.10.2007
CHART 2.25
SHARE PRICES OF SYNDICATE BANK
FROM 1.1.2002 TO 31.10.2007

CHART 2.26
SHARE PRICES OF TATA STEEL
FROM 1.1.2002 TO 31.10.2007
CHART 2.27
SHARE PRICES OF UNION BANK OF INDIA
FROM 1.1.2002 TO 31.10.2007

CHART 2.28
SHARE PRICES OF WIPRO
FROM 1.1.2002 TO 31.10.2007
From the above charts, when keenly observed the share prices of companies ONGC, Ranbaxy Laboratories Ltd., Satyam Computer Services Ltd. and Wipro Ltd., it was noticed that the share prices fell one-half or one-third or one-fourth on a particular day. This is due to either stock split or issue of bonus shares. If that day comes within the life of the options then normal assumption of stock price will yield a wrong BS call price. The stock prices are adjusted as required in each case and used in the BS formula to calculate call option price.

**2.7 PROCESS SOFTWARES**

Planning needs elaborate studies of the literature, statistical procedures, collection of details of pundits in the area of research and normally difficult. But in implementing the research plan, there were many hurdles especially in the empirical studies like this. The data are in millions, calculations are thousands of millions and the logical procedures need culling out and elimination of data from the sample.

When options details are downloaded from the NSE websites, it includes all the call options that are offered by the stock exchange. As narrated in the first chapter, only about 16.43% of the options offered are traded and the remaining is unutilized by the investors. In a single day, there are as many as 30 call options are offered with different time to expiration and different strikes for each company stock. All the offered call options cannot be used for the empirical study, as non-traded call options cannot reflect the true prices. Hence, out of these options the non-traded options need to be eliminated and they are as high as 25 per day and more than 11 lakhs and 90 thousands for the entire period of our study. For this, software was developed using Visual Basic macro for Excel.

Secondly, the options related to the cum-dividend stocks during the life of the option are to be eliminated from the sample. For this, the details of the board meetings, ex-dividend dates and record dates of the all the twenty eight
companies were collected. Then the call options with cum-dividend were identified and removed from the sample of about 2,38,000. This is really a very laborious and cumbersome procedure. Manually in a single day, only about 200 to 500 data only can be eliminated. More than 58,000 options are to be culled out and eliminated. For this also, software was designed in dotnet platform, tested and used successfully.

Next, to calculate the BS option price, one has to calculate the standard deviation of the stock returns for each company, for each day. In other words, more than 41,100 standard deviations (volatility) were calculated to find out theoretical BS call option prices (Appendix 8). Standard deviation was calculated each day, using the past 90 day’s stock returns for each company. The daily volatilities were annualized. After this, the other four determinants of risk-free-interest rate appropriate for that day, the annualized time to expiration, stock price and strike price are taken. Then, $d_1$ and $d_2$ were calculated using the formula as explained in the formula 1.3.35 and 1.3.36 (pp 39-40) and normal distribution function of $d_1$ and $d_2$ were calculated. Finally, the call option price was calculated. Risk-free-interest rate has to be taken for each day from appropriate table and used. To this the third software was designed, developed, tested and used in Visual Basic Application for Macro.

The last one is so tedious that it requires a trial and error method and BS call option price to be calculated at least ten to fifteen times before final implied volatility prediction. In this way more than 95,550 implied volatility values were calculated, tabulated and analyzed. This alone involves more than 20 lakhs calculations. This is impossible without special software. These softwares were not readily available in the market, but specially planned, developed and tested by the researcher with the help of software experts.