# THESIS ON

## Determining the efficiency of the Black & Scholes Model in pricing of Nifty stock options after addressing the negative cost of carry problem

**submitted in fulfilment of the requirement of the degree of**

## DOCTOR OF PHILOSOPHY

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**by**

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# DEDICATION

I dedicate this thesis to my very loving daughters Avni, Apurva and Smriti.

# DECLARATION

I hereby declare that this thesis entitled Determining the efficiency of the Black & Scholes Model in pricing of Nifty stock options after addressing the negative cost of carry problem by Rajesh Kumar, being submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy in Management under Faculty of Management Studies of J.C. Bose University of Science & Technology YMCA, Faridabad, during the academic year 2018 is a bona fide record of my original work carried out under guidance and supervision of Dr. Rachna Agrawal, Associate Professor, Department of Management Studies and has not been presentedelsewhere.

I further declare that the thesis does not contain any part of work which has been submitted for the award of any degree either in this university or in any other university.

Rajesh Kumar
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# CERTIFICATE

This is to certify that this thesis entitled "Determining the efficiency of the Black & Scholes Model in pricing of Nifty stock options after addressing the negative cost of carry problem" by Rajesh Kumar, submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in Management of Department of Management Studies of J.C. Bose University of Science & Technology YMCA, Faridabad, during the academic year 2018, is a bonafide record of work carried out under our guidance andsupervision.

We further declare that to the best of my knowledge, the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any otheruniversity.

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# ABSTRACT

This research study has been motivated by the pricing errors produced by the Black-Scholes model used for pricing stocks and S&P CNX Nifty index options. The Black-Scholes option pricing model is considered as a significant breakthrough in the field of financial derivatives and has occupied important place in derivative market but this model also misprices option considerably. “Can option pricing errors of the B&S model be minimized? is a big question faced by the participants of the derivatives market. This research makes an attempt to answer this question to some extent.

A visual inspection reveals that 42.15% of the total observations for stock call options, 51.20% of the total observations for index Nifty 50 call options, 41.95% of the total observations for stock put options and 51.20% of the total observations for index Nifty 50 put options are likely to be affected by the negative cost of carry problem. Hence, to address the negative cost of carry problem, the discounting value of future price has been used under the Black-Scholes model in the place of spot price for the calculation of option prices. It is observed by researchers that mispricing in one instrument influence pricing of other instrument in financial derivative market. Hence, the primary objective of this research is to determine the efficiency of the Black-Scholes model in pricing of Nifty stock options after addressing the negative cost of carry problem.

This research work consistently goes through the three stages to achieve its objective; Stage first deals with the error matrices of the Black-Scholes (B&S) model for call and put options using spot price, stage second deals with the error matrices of the B&S model after replacing Sport price (S) by the discounted value of Future price ($Fe^{-(r-y)t}$) to address the negative cost of carry problem (modified B&S model) and stage third makes comparison of pricing errors between the B&S Model and modified B&S model to show that the model after addressing the cost of carry problem provides better result in comparison to the original Black-Scholes model for pricing options in the Indian derivatives market. Options subgroups have been also analysed.

The Mean Error (ME), Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Thiel’s U statistic and Mean Absolute Percentage Error (MAPE) have been primarily used to know the magnitude of the produced errors and to compare model produced errors.

For this purpose, sample consists of closing prices of 83,725 options contracts, written on underlying stocks of 22 companies and Index Nifty 50, for the time period ranging from April 1, 20012 to March 31, 2016, have been collected and analysed. These twenty-two companies are selected from thirteen different sectors. The prices of 83,725 option contracts are calculated under the B&S model in stage first using the underlying spot prices and compares to market closing price to gauge the pricing efficiency of the B&S model. The same number of option contracts goes in stage second under the modified B&S model where discounting value of future prices have been used instead of underlying spot prices and again compares to market closing price to gauge the pricing efficiency of the modified B&S model.

The overall Improvements have been found in pricing stock call and index call option when they have been priced under the modified Black-Scholes model, after replacing spot price by the discounting value of future prices to address the negative cost of carry problem.

The Modified Black-Scholes model shows lower pricing errors for stock call OTM and ITM options and higher errors for stock call ATM options. Regarding the maturity bias, the Modified Black-Scholes model also shows lower pricing errors for the stock call near month and next month options contracts and higher errors for stock call far month options contracts.

The Modified Black-Scholes model shows lower pricing errors for index call OTM and ITM options. Regarding the maturity bias, the modified Black-Scholes model shows lower pricing errors for the index call next month and far month options contracts and higher errors for index call near month options contracts.

However, the modified Black-Scholes model does not provide overall better result in comparison to the Black-Scholes Model for pricing stock put options in Indian market. Hence, the B&S model is suitable for pricing stock put options. Similarly, the modified Black-Scholes model also does not provide overall better result in comparison to the Black-Scholes model for pricing Index Nifty 50 put options in Indian market. Hence, the B&S model is suitable for pricing index put options.

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# LIST OF ABBREVIATONS

| | |
|---|---|
| AXISBANK | Axis Bank Ltd. |
| ATM | At-The-Money |
| AME | American Stock Exchange |
| ASX | Australian Securities Exchange |
| BHARTIARTL | Bharti Airtel Ltd. |
| BHEL | Bharat Heavy Electricals Ltd. |
| BSE | Bombay Stock Exchange |
| CAIRN | Cairn India Ltd. |
| CBOE | Chicago Board of Option Exchange |
| CME | Chicago Mercantile Exchange |
| COMEX | Commodity Exchange of New York |
| COC | Cos of Carry |
| DLF | DLF Ltd. |
| DVFP | Discounting Value of Future Price |
| FUTSTK | Futures on Stocks |
| GARP | Global Association of Risk Professionals |
| FUTIDX | Futures on Index. |
| HDFC | Housing Development Finance Corporation Ltd. |
| HDFCBANK | HDFC Bank Ltd. |
| HINDALCO | Hindalco Industries Ltd. |
| HINDUNILVR | Hindustan Unilever Ltd. |
| ICICIBANK | ICICI Bank Ltd. |
| IDFC | IDFC Ltd. |
| INFY | Infosys Ltd. |
| ITC | ITC Ltd. |
| ITM | In-The-Money |
| JPASSOCIAT | Jaiprakash associates Ltd. |
| LT | Larsen & Toubro Ltd. |
| ME | Mean Error |
| MAPE | Mean Absolute Percentage Error |
| MM | Market Maker |
| M&M | Mahindra & Mahindra Ltd. |
| MTM | Marking to Market |
| NSE | National Stock Exchange |
| OCT | Over-The-Counter |
| OPTSTK | Options on Stock |
| OPTIDX | Options on Index |
| OTM | On-The-Money |
| RBI | Reserve Bank of India |
| RELIANCE | Reliance Industries Ltd. |
| RELINFRA | Reliance Infrastructure Ltd. |
| RMSD | Root Mean Square Deviation |

| | |
|---|---|
| RMSE | Root Mean Square Error |
| SBIN | State Bank of India |
| SIMEX | The Singapore International Monetary Exchange |
| SPSS | Statistical Package for the Social Sciences |
| TATAMOTORS | Tata Motors Ltd. |
| TATASTEEL | Tata Steel Ltd. |
| TCS | Tata Consultancy Services Ltd. |

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## ***CHAPTER 1:*** **INTRODUCTION**

Fisher Black and Myron Scholes developed a model for pricing a European style of option. The Black-Scholes option pricing model (from here onwards called the B&S model) was published in the Journal of Political Economy, 1973 which is considered as a significant breakthrough in the field of financial derivatives. The pricing theories of stock options under the Black-Scholes model has occupied an important place in derivative market but this model also misprices option considerably. “Can option pricing errors produced under the B&S model be minimized?,” is a big questions faced by the participants of the derivatives market. This research makes an attempt to answer this question of some extent.

**1.1. NEED OF THE STUDY**

Pricing of an option is the central to the theory of financial derivatives and risk management. The Black-Scholes model is widely used by the leading stock exchanges, traders, investors and investment banks etc., for pricing options contract written on stocks and index but this model exhibits certain pricing biases. One of the possible reasons for the option pricing bias can be attributed to the negative cost of carry phenomenon associated with the Indian market (Varma, 2002). It has been found that, index Nifty futures also suffer from the ‘cost of carry’ bias. Usually, the future prices of index Nifty are quoted less than Nifty spot prices (Mitra, 2008 and 2012) which obviously causes difference between the actual prices of options and prices of options calculated under the B&S model for the European style of index options and hence, needs to be shown but the studies were not conducted on the European style of stock. The extant literature reviews the B&S model in the context of other markets and specially in the context of the developed market, but there are only few studies on index options in the Indian context. Particularly, to our knowledge, there is no study which tests the predictability of the B&S model after replacing the stock spot price with the corresponding DVFP for stock options traded on NSE. One of the possible reasons for this might be that a European style of equity options contract on individual security has been introduced from 27$^{th}$ January, 2011 by NSE in India. What the importance of cost of carry is in options pricing models, need to be shown to the traders and investors because the spot and futures prices are linked by a cost of carry relationship and hence futures prices may contribute to the discovery of new price (Lin and Stevenson,1999).

This study focuses on mispricing of options because the negative cost of carry problem is found in Indian market derivative market [Varma (2002) and Mitra (2006 & 2012)]. Varma (2002) and Mitra (2006 & 2012) have addressed negative cost of carry problem by replacing spot price with the DVFP in pricing index options traded on NSE in India. Similar, the negative cost of carry situations are often observed in the commodity derivatives market. To address this effect, Black

(1976) very scientifically used the forward prices in place of sport prices for commodity derivative. In this study, an attempt is made to determine the efficiency of the Black-Scholes model after addressing the negative cost of carry problem in pricing Nifty stock and index options and comparing the accuracy of the same with that of the original Black-Scholes model.

## 1.2. FUTURES AND OPTIONS

**Futures:** A futures contract is a standardized financial contract between two parties where both parties agree to honour the contract written on a particular asset at a predetermined price and at a specified date in future. Hence, the buyer of the futures contract is taking on the obligation to buy the underlying asset at the predetermined price when the contract expires while the seller of the future contract, on the other hand, is taking on the obligation to provide the underlying asset at the predetermined price when contract expires.

### Option

An option is a right to buy or sell a security at a predetermined price within a specified time frame. An option is a standardized financial contract, which gives the buyer (owner) the right, but not the obligation, to buy or sell specified quantity of a defined asset, at a strike price on or before the expiration date. There are two types of option- call and put option. A call option gives the buyer the right to buy whereas the put option gives the right to sell. Here, the asset is called underlying asset or underlying security or simply underlying. The underlying assets may be physical commodities like wheat, rice, cotton etc. or financial instruments like equity stocks, stock index, bonds etc.

## 1.3. BLACK-SCHOLES MODEL AND ITS ALTERNATIVES

Fisher Black and Myron Scholes developed a mathematical model for pricing a European style option and published in 1973 in an article titled “The Pricing of Options and Corporate Liabilities”. This option pricing model was a landmark in the history of financial modelling and continues to be the preferred model for theoretical valuation of option prices. This model is based on following assumptions:

1. The asset price follows a random walk in continuous time and thus the distribution of stock prices is log normal.
2. There are no transaction costs or taxes. It means there are no transaction cost in buying or selling the stock or option.

3. There are no riskless arbitrage opportunities.
4. The risk-free interest rate is constant. It is assumed that the short-term interest rate is constant through time.
5. There is no penalties to short selling.
6. There is no dividend during the life of the option paid by the underlying asset.
7. The option is exercised at the time of maturity i.e., The option is a European style of option, that is, it can only be exercised at maturity.

The pair formula for the prices of European stock call and put options respectively constitutes the Black-Scholes Model-

$$c = SN(d_1) - Xe^{-rt}N(d_2)$$
$$p = Xe^{-rt}N(-d_2) - SN(-d_1)$$

Where,

$$d_1 = \frac{ln\frac{S}{X} + (r + 0.5\sigma^2)t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{ln\frac{S}{X} + (r - 0.5\sigma^2)t}{\sigma\sqrt{t}}$$

The variables are-

$c$ = Call Price

$p$ = Put Price

$S$ = Current Stock price or underlying assets price

$X$ = Exercise price

$t$ = Time remaining until expiration, expressed as a percent of a year

$r$ = continuously compounded risk-free interest rate

$\sigma$ = standard deviation of the continuously compounded annual rate of return

$N$(d) = value of Cumulative normal distribution evaluated at d.

$ln(\frac{S}{X})$ = natural logarithm of $(\frac{S}{X})$

The Black-Scholes model has been modified and extended by various authors to price options. These modifications include Merton (1973) who modified for dividend, Black (1976) who modified for option on commodity by replacing spot price by the discounting value of future price and Garman and Kohlhagen (1983) modified for option written on currency using an approach very similar to Black-Scholes (1973). Similarly, In India, Khan (2013) who modified Black-Scholes model for risk-free rate of interest.

## 1.4. COST OF CARRY

The cost of carry model is largely preferred for pricing futures contracts (Chow, McAleer and Sequeira, 2000). The financial futures contacts are priced under the cost of carry model (Kaldor, 1939). The relationship between future price and spot price is summarized in the terms of cost of carry. The price of a futures contract is the sum of spot price and cost of carry. The cost associated with carrying the investment and consumption asset fall into four groups: storage cost, insurance cost, transportation cost, and financing cost. The investment asset particularly attracts financing cost.

Hence, for the investment asset, if cost of carry is defined as ‘c’, the futures price (Hull, 2007, pp. 140) is

$$F_0 = S_0 e^{ct}$$

Where,
$F_0$: Forward or Futures Price today of an underlying future contract
$S_0$: Price of the asset underlying the forward or futures contract today
$t$: Time until delivery date in a forward or futures contract (in year)
$e$: a mathematical constant whose value is 2.7183
For the invest asset, cost of carry (c) is the interest rate (r) that is paid to finance the asset less the income (dividend yield) earned on the asset. Now the above equation for futures price, $F_0$, for the investment asset would be given by the following formula (Vohra and Bagri, 2002, pp. 87)

$$F_0 = S_0 e^{(r-y)t}$$

Where,

$r$: Risk-free rate of interest with continuous compounding and

$y$: Dividend yield with continuous compounding

It should be noted that the term $y$ is also denoted as q for the calculation of the index futures price where q is dividend yield because income is earned at the rate q on the asset (Cornell and French, 1983).

An assumption of the COC model is that the futures and spot market are perfectly efficient, and hence, act as perfect substitute [(Bhatia, (2007) and Lin and Stevenson, (1999)] and hence, they can be substituted. Accordingly, the spot price of index CNX Nifty has been replaced by their corresponding discounting value of futures price (DVFP) by Black (1976), Verma (2002) and Mitra (2008 & 2012) for the calculation of option prices. In perfect efficient markets profitable arbitrage should not exist because prices adjust themselves instantaneously in markets and fully to new information (Raju and Karande, 2003).

In the normal market, the futures contracts written on stocks and equity index are priced according to the cost of carry equation. Hence, the pricing of futures contracts follows a process by which a risk-averse seller of the contracts buys the security, incurring the cost of an interest rate in the process. According to Vohra and Bagri (2002), "The dividends, if any, resulting from holding the security, during the currency of the contract, represent negative cost (called carry return) are netted from the interest cost and the net cost is effectively the cost of maintaining a risk-free position."

## *CHAPTER 2:* REVIEW OF LITERATURE

The future prices of underlying asset stock and index have been taken as an input for the calculation of stock and index option prices traded on NSE in India. Hence, the study of literature review has been broadly divided into following two parts to get insight knowledge about the existing research reports related to the central theme of this research: First Reviews of spot and futures pricing literature and second reviews of options pricing literature

### 2.1. REVIEWS OF SPOT PRICE AND FUTURES PRICING LITERATURE

A key question in financial derivative is the existence or non-existence of lead-leg relationship between futures prices and spot prices because mispricing in one instrument influence pricing of other instrument in derivative market. A lead-leg relationship states which, between two markets, reflects information faster than the other one, as a result of that a lead-leg relationship between two markets exists. Conventional wisdom among professional traders dictates that movements in S&P 500 futures price affect market expectations of subsequent movements in cash prices. Numerous articles have focused on the empirical study of the lead-leg relationship between future and spot prices of the underlying assets.

Kawaller, Koch and Koch (1988) concluded that the Lead-leg relationship exists between the price movements of S&P 500 traded on NYSE. Index futures and S&P 500 Index and future price trading contributes in price discovery.

The lead-lag relationship between index futures price and spot price in Indian stock market has been also empirically tested by Thenmozhi (2002) on CNX Nifty50 futures and CNX Nifty Index and observed that the futures market transmits information to cash market and future market is faster than spot market in processing information consequently inception of futures trading in India has reduced the volatility of spot index returns. Raju and Karande (2003) findings are in line with Thenmozhi (2002) study conducted on NSE.

Mukherjee and Mishra (2006) found that the spot market played a comparatively stronger leading role in disseminating information available to the market and therefore said to be more efficient. Hence, the role of the futures market in the matter of price discovery tends to weaken and sometime disappears after the release of major firm-specific announcements.

Bhatia (2007) examines the intraday lead-lag relationship between S&P CNX Nifty futures and S&P CNX Nifty index and her findings lend support to Thenmozi's (2002) study conducted on NSE. But Srivasan's (2010) study found different results. He found that there is a bidirectional relationship between spot and futures markets in case of five selected IT stocks traded on NSE. Choudhary and Bajaj (2012) findings lend support to Srivasan's (2010) study.

Kapoor's (2016) findings are in line with Mukherjee and Mishra (2006) study. Chiraz (2016) found that the futures have a stabilizing effect on the underlying spot market because the futures contain valuable information for modeling and forecasting stock returns. Pradhan (2017) examined the price discovery between the S&P CNX Nifty index spot futures market traded on NSE and found that the spot market disseminated new information stronger than the futures prices.

## 2.2. REVIEWS OF OPTIONS PRICING LITERATURE

The Black-Scholes option pricing model exhibits certain biases on several parameters used in the model. Large number of researches was carried out to test the validity and applicability of this model on the basis of its assumptions and inputs. The following are the brief reviews of empirical developments related to the central theme of this research:

Black-Scholes (1973) empirically examine the accuracy of their own model and they found that "the actual prices, at which options are bought and sold, deviate in certain systematic ways from the values predicted by the formula." Furthermore, they have observed that the option buyers pay prices that are consistently higher than those calculated under the model.

Black (1975) himself was one of the persons who observed stock call option pricing biases in the Black-Scholes option pricing model. He states that "The actual prices on listed options tend to differ in certain systematic ways from the values given the formula." Three important conclusions have been drawn from his study are out-of-the-money options tend to be overpriced, in-the-money options tend to be underpriced and options less than three month to maturity tend to be overpriced.

Latane and Rendleman (1976) found that model may not fully capture the process determining option prices in the actual market. Macbeth and Merville (1979) found that out-of-the-money options are overpriced and in-the-money options are underpriced by Black-Scholes model.

Bhattacharya (1980) found that the model overvalued call ITM options with negative sign while call near-the-money options are overvalued by the model.

Rubinstein (1985) found pricing bias produced under the B&S model. Similarly, Fortune (1996) found systematic and sizable errors in the model and the stock put options are relatively overpriced by the B&S model as compare to the stock call options. Furthermore, study did not conform to the normality assumption.

Raj and Thurston (1998) studied the applicability of the Black model using future price on the Singapore International Monetary Exchange (SIMEX) and found that the model underprices both call and put options. Overall, the maturity bias and moneyness bias have been found to be monotonic with options in all data categories being underpriced. The model underprices both in-the-money and out-of-money options significantly, but predicts the prices of at-the-money option most efficiently. The maturity bias has been found to be monotonic as all three maturity categories are significantly underpriced. However, he calculated mean error by subtracting actual price from the predicted price.

At the very initial stage of the introduction of derivatives segment in India, Varma (2002) observes that the volatility is severely mispriced under the B&S model and option market moved toward the Black model. The market is learning and this is a matter requiring further research using longer time periods. In particular, as found by him, option is severally underpriced for both call and put options. He observed that Nifty Futures trade at a discount to the underlying because of the negative cost of carry phenomenon and partly short sale restriction in the cash market. He used discounted value of futures price in Black model on underlying index for the calculation of index option prices. However, options written on underlying stocks traded on NSE have not been tested.

Kakati (2006) Examines the overall pricing accuracy, call to put bias, Moneyness bias and maturity bias produced under the Black-Scholes model for pricing call and put options contracts written on ten Indian stocks and BSE index SENSEX traded on BSE from Jul 2001 to March 2003. He found that stock put options are overpriced while stock call options are underpriced by the Black-Scholes model using historical volatility and hence, the early exercise feature of American options is not being accounted. Therefore, the magnitude of error for stock call option is comparatively higher than stock put option. The Black-Scholes model has overpriced both BSE index SENSEX call and put options but the magnitude of error for index call option is also found higher than the index put. It has been observed that the stock call ATM and ITM options are overvalued while OTM options are undervalued by the Black-Scholes model. But stock put ATM, ITM and OTM options are overvalued. For both stock call and put, ITM options are comparatively highly overvalued. The near month and next month stock call options are undervalued while fare month stock options are overvalued by the Black-Scholes model. However, the Black-Scholes model with implied volatility instead of historical volatility shows less pricing error. McKenzie, Gerace, and Subedar (2007) found that the Black-Scholes model is relatively accurate for pricing call options.

Comparing the Nifty call option pricing accuracy between Black model and Black-Scholes model, Mitra (2008) also observes, consistent with Verma's research (2002), that 81% of the total observations on Nifty futures, quoted on NSE from October 1, 2005 to September 30, 2006, are traded below the Nifty spot value and hence suffers from the negative cost of carry problem. His study addresses the issue related to mispricing of Nifty call options on account of negative cost of carry phenomenon observed on NSE by replacing Nifty spot price by the discounting value of futures price in the original Black-Scholes model as it is believed that futures prices not only incorporate cost of carry problem but also capture impact of other market sentiment. It is found in his research when the discounting value of future prices compared with the corresponding spot prices that 98% of the total observations are likely to be affected on negative cost carry bias. Therefore, use of discounting value of future price in the place of spot price produces less pricing errors for the calculation of Nifty call options prices but it has not been tested on European style stock options.

Barunikova (2009) found that the Black-Scholes model shows lower pricing errors but exhibits Index call maturity and moneyness biases. For index put options, model show higher pricing errors as compare to index call options. This finding is contradicting to Kakati's (2006) finding in the context of Indian derivatives market.

Shehgal and Narayanamurthy (2009) found that the Black-Scholes model is a good descriptor of S&P CNX Nifty Index call and put option pricing.

Singh and Ahmad (2011) found that the Black-Scholes model shows maturity and moneyness biases in pricing S&P CNX Nifty index options. Kala and Pandey (2012) found that the Black-Scholes model is more usefull in call option pricing than the put option pricing.

Mitra (2012) studies the theoretical prices of Nifty index call options using both Black model and Black-Scholes model and compared with actual prices in the market. Since the beginning of the Nifty index trading in India, Index Nifty suffers from the negative cost of carry effect and sometimes trade below the Nifty spot value. He analyzed 29,724 option quotes from 1$^{st}$ July, 2008 to 30$^{th}$ June, 2011 using both the B&S model and Black model and found, similar to his previous study, that the Black model produces better alternative than the B&S model when Nifty future prices have been replaced by the Nifty spot prices. From the analysis of error, furthermore, it is verified in his study that the Black model produces less error than that of the B&S model and for that reason use of the Black model is more fitting than that of the B-S model in pricing Nifty index call options traded on NSE. But the applicability of the Black-Scholes model for pricing individual stock option traded on NSE, after replacing spot prices by the discounting value of future prices, has not been conducted under his study.

Khan, Gupta and Siraj (2013) suggest modification, in the original Black-Scholes model adding new variable related to the calculation of risk-free interest rate in the context of NSE derivative market in India.

Panduranga (2013 a & b) and found that Black-Scholes model is suitable for pricing banking and cement sectors stock options traded on NSE. Results of the paired sample t-test revealed there is no significant difference between expected option prices calculated under the Black-Scholes model and market prices of options, in three out of four cases.

Nagendran and Venkateswar (2014) found that the B&S model is robust in pricing Indian stock call options and option pricing is improved by incorporating implied volatility into the B&S model.

Mugwagwa, Ramiah and Moosa (2015) found that OTM options have an increased sensitivity to changes in the underlying stock price and that ITM options are less sensitive, particularly to call options.

Singh and Dixit (2016) found that the Black-Scholes model shows consistent overpricing with more than 90% call options. Furthermore, CNX Nifty call OTM and put OTM options are highly mispriced. Sudhakar and Srikanth (2016) found that the Black-Scholes performed well in predicting the market price of the index Nifty50 call options except in the case of options which belong to out-of-the-money.

**2.3. RESEARCH GAP**

During the literature review it has been found that the majority of studies in great detail are empirically conducted in the developed market, there are very few studies in developing market. The number of similar studies in Indian derivatives market is even less specially for stock options after the introduction of the European style stock options on NSE on 27th January, 2011.The majority of researches in the Indian market are conducted on the American style of stock options before 27th January, 2011 because before this period stock options were American style of options traded on NSE which is not as per the assumptions of the Black-Scholes option pricing model. The B&S model assumes that option should be a European style. However, the index Nifty 50 options traded on NSE are of the European style.

A few researches conducted by Verma (2002) and Mitra (2008 & 2012) have brought modification because CNX Nifty index suffers from the negative cost of carry problem and found improvement in the original Black-Scholes model after replacing the CNX Nifty Index spot price with the Discounting Value of Future Price (DVFP) of CNX Nifty index but they have not experimented on the European style of stock options. It appears based on the reviewed literature that only a few researches have been conducted in the Indian derivatives market replacing the CNX Nifty index spot price by the respective index discounting value of future price in the original Black-Scholes model. However, a study on the replacing stock spot price with the respective stock Discounting Value of Future Price (DVFP) in the original Black-Scholes model for pricing the European style options is missing. In other words, the Black-Scholes model after modification has not been yet empirically tested on the European style stock options as it has been introduced on NSE since 27th January, 2011 to our knowledge. A possible reason might be due to non-availability of the European style of stock options on NSE.

In summary the empirical research concede that the Black-Scholes model produces bias in the calculation of the option prices. Now question is that whether pricing errors for stock and Index options could be minimised. If yes, then how it could be possible. This research makes an attempt to answer this question to some extent. It has been found, while searching answers to these questions, that stock future prices and index Nifty 50 Future prices are traded below their corresponding spot prices because of the negative cost of carry problem. “Mispricing in one instrument influences pricing of other instrument (Mitra, 2012)”. If spot prices are replaced with the corresponding discounting value of future prices in the model, as this is assumed under the cost of carry model that the futures and spot markets are perfectly efficient and hence, there is no lead-lag relationship between futures and spot prices (Shalini Bhatia, 2007), then improvement can be obtained in the original Black-Scholes model used for pricing stock and Index options.

Given the literature gap as mentioned above, it becomes imperative to conduct a comprehensive research on the given model after replacing underlying spot price with their respective discounting value of future price (DVFP) in the original Black-Scholes model in this context. It should be noted that the Black equations are exactly what one would obtain if in the Black Scholes formula stock price (S) is replaced by replaced by $F*e^{-rt}$ (Varma, 2002).

## *CHAPTER 3:* RESEARCH OBJECTIVES AND METHODOLOGY

This research study has been motivated by the pricing errors produced by the Black-Scholes model used for pricing stocks and S&P CNX Nifty index options. It has been usually observed that the index Nifty 50 future prices are traded below their corresponding spot prices on NSE and hence, to address the negative cost of carry problem, the discounting value of future price has been used in the place of spot price for the calculation of the Nifty 50 index options in India by

Varma, (2002), Mitra, (2008 & 2012) and by Black (1976) in USA for commodity. Varma, (2002) and Mitra, (2008 & 2012) used DVFP in the place of spot price to address the negative cost of carry problem in pricing the European style of index Nifty 50 options. The primary objective of this research study is to determine the efficiency of the Black & Scholes model, i.e., magnitude of errors, in pricing Nifty fifty stock options and S&P CNX Nifty index options, henceforth, it will be known as Nifty 50, option after addressing the negative cost of carry problem and comparing the accuracy of the same with that of the original Black-Scholes model.

The Mean Error (ME), Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Thiel's U statistic and Mean Absolute Percentage Error (MAPE) have been primarily used for the comparison of pricing accuracy in each objective. These values have been calculated with the help of excel.

### 3.1. RESEARCH OBJECTIVES

The Black-Scholes options pricing model exhibits certain biases on several parameters used in the model. This research study has been motivated by the pricing errors produced under the Black-Scholes model. This research deals with the following objectives:

(1) To investigate the pricing errors produced by the Black-Scholes model due to negative cost of carry phenomenon observed in the Indian derivatives market.

(2) To investigate three biases of the option pricing model: Moneyness bias, Maturity bias and Call to Put bias (subgroups under the B&S model & modified B&S model.)

(3) To address the cost of carry bias by replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) in the original Black-Scholes model in the Indian derivatives market.

(4) To show that the model after addressing the cost of carry problem provides better result in comparison to the original Black-Scholes model for pricing options in the Indian derivatives market.

**Description-** It should be noted that objective (2) is the subgroup of option, hence, no separate hypothesis has been formulated.

### 3.2. PROPOSED HYPOTHESIS

The study proposes to test the following hypotheses to meet the objectives of the study-

(a) The prices of individual stock options of companies under Nifty fifty and S&P CNX Nifty index option, calculated under the Black-Scholes model, do not suffer from the cost of carry problem.

(b) There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on reducing the cost of carry problem in the Black-Scholes model.

**3.2.1. Interpretation of the Objectives and Hypotheses**

The Indian derivatives market suffers from the cost of carry problem and hence due to this when option prices are calculated using spot prices under the B&S model (1973), it produces errors [objective (1) and hypothesis (a)].

To minimize the magnitude of the pricing errors, various authors have tried to addressed the cost of carry problem by replacing underlying spot prices by their corresponding DVFP [objective (3) and Hypothesis (b)]

Major inputs for the development of objectives and hypothesis have been taken from the studies of the following authors:

Varma (2002) states that "It is well known that severe mispricing prevails in India's nascent derivatives market. The mispricing that has been most commented upon is the negative cost of carry phenomenon in which the future trades at a discount to the underlying. Globally, also, it has been observed that futures trade below fair value (though not usually below underlying) in the presence of acute short sale restrictions".

Mitra (2008) finds that "The Black and Scholes option pricing formula exhibits certain biases on several parameters used in the model. Nifty options also suffer from cost of carry bias as future prices of Nifty are usually less than Nifty spot prices plus interest element. Since the inception of Nifty futures trading in India, Nifty futures even traded below the Nifty spot value. These deformities obviously cause difference between the actual prices of Nifty options and the prices calculated using the Black-Scholes formula. Black (1976) tried to address this problem of negative cost of carry by using forward prices in the in the option pricing model instead of spot prices".

Mitra (2012) finds that "Stock index futures sometimes suffer from 'a negative cost-of-carry' bias, as future prices of stock index frequently trade less than their theoretical value that include carrying costs. Since commencement of Nifty future trading in India, Nifty future always traded below the theoretical prices. This distortion of future prices also spills over to option pricing and increase difference between actual price of Nifty options and the prices calculated using the famous Black-Scholes formula".

There are some other authors who have used also used future prices instead of spot prices in analysing put-call-parity in other markets. Some of them are; Lee and Nayar (1993) tested the efficiency of index options traded on Chicago Board Options Exchange (CBOE) and Chicago Mercantile Exchange (CME) of USA using futures prices and found that violations are much less in frequency and magnitude for PCP. Fung and Chan (1994) and Garay, Ordonez and Gonzalez (2003) used futures prices instead of spot prices and their study also found less put-call-parity violation in the U.S. market. However, Bharadwaj and Wiggins (2001) found violations in using this approach in the US market. Less violation Same results have been found by Draper and Fung (2002) in the U.K. market, and Fung, Cheng and Chan (1997), Fung and Fung (1997), Fung and Mok (2001) and Lung and Marshall (2002) in the Hong Kong market.

The research objectives and hypotheses formulated in section 3.1 and 3.2 are based on the above stated reasons and explanations. Above authors views can be summarised in the following ways; options prices calculated under the B & S model using underlying spot prices, produces pricing error due to cost of carry problem. The cost of carry problem or bias, here, is taken as negative. To address this cost of carry problem, the DVFP is used instead of the underlying spot price. Hence, the cost of carry has not been tested separately [Varma, 2002].

The pricing efficiency of the models have been evaluated for call and put options written on stocks and Nifty 50 index traded on NSE. The above stated hypotheses have been mainly grouped in to the following three parts and extended to meet the stated objectives of the study separately for stock call, index Nifty 50 call, stock put and index Nifty 50 put option:

**3.2.2. Group (a)** [for objectives (1) and (2)]

**Hypothesis for Stock Call Options:**

$H_{01}$: The prices of individual stock call options of companies under Nifty50, calculated under the Black-Scholes model, do not suffer from the pricing errors, i.e., there is no significant difference between the mean values of the stock call options closing price and calculated price under the B&S model.

**Hypothesis for Index Call Options:**

$H_{02}$: The prices of S&P CNX Nifty index call options, calculated under the Black-Scholes model, do not suffer from the pricing errors. i.e., there is no significant difference between the mean values of the S&P CNX Nifty index Call options closing price and calculated price under the B&S model.

**Hypothesis for Stock Put Options:**

$H_{03}$: The prices of individual stock put options of companies under Nifty fifty, calculated under the Black-Scholes model, do not suffer from the pricing errors. i.e., there is no significant difference between the mean values of the stock put options closing price and calculated price under the B&S model.

**Hypothesis for Index Put Options:**

$H_{04}$: The prices of S&P CNX Nifty index put options, calculated under the Black-Scholes model, do not suffer from the pricing errors. i.e., there is no significant difference between the mean values of the S&P CNX Nifty index put options closing price and calculated price under the B&S model.

**3.2.3. Group (b)** [for objectives (2) and (3)]

**Hypothesis for Stock Call Options:**

$H_{05}$: There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on the prices of individual stock call options in the Black-Scholes model. i.e., there is no significant difference between the mean values of the stock call options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

**Hypothesis for Index Call Options:**

$H_{06}$: There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on the prices of S&P CNX Nifty index call options in the Black-Scholes model. i.e., there is no significant difference between the mean values of the S&P CNX Nifty index call options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

**Hypothesis for Stock Put Options:**

$H_{07}$: There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on the prices of individual stock put options in the Black-Scholes model. i.e., there is no significant difference between the mean values of the stock put options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

**Hypothesis for Index Put Options:**

$H_{08}$: There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on the prices of S&P CNX Nifty index put options in the Black-Scholes model. i.e., there is no significant difference between the mean values of the S&P CNX Nifty index put options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

**3.2.4. Group (C)**[for objective (4)]

**Hypothesis for Stock Call Options:**

$H_{09}$: The model after addressing the cost of carry problem does not provide better result in comparison to the original Black-Scholes model for pricing stock call options in Indian market. i.e., there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock call options in the Indian derivatives market.

**Hypothesis for Index Call Options:**

$H_{010}$: The model after addressing the cost of carry problem does not provide better result in comparison to the original Black-Scholes model for pricing S&P CNX Nifty index call options in Indian market. i.e., there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing Index Nifty50 call options in the Indian derivatives market.

**Hypothesis for Stock Put Options:**

$H_{011}$: The model after addressing the cost of carry problem does not provide better result in comparison to the original Black-Scholes model for pricing stock put options in Indian market. i.e., there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock put options in the Indian derivatives market.

**Hypothesis for Index Put Options:**

$H_{012}$: The model after addressing the cost of carry problem does not provide better result in comparison to the original Black-Scholes model for pricing index Nifty 50 put options in Indian market. i.e., there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing S&P CNX Nifty index put options in the Indian derivatives market.

## 3.3. RESEARCH METHODOLOGY

### 3.3.1. SAMPLING FRAMEWORK

For this research the number of qualified stocks of companies are selected from the list of Nifty 50 stocks which consists of 50 actively traded stocks of companies. Here, the stock of the company is the underlying asset for option. Secondly, the magnitude options pricing errors have been also empirically evaluated for index options. Here, the equity index Nifty 50 of NSE has been selected for the study as it is one of the most actively traded derivative index contracts in the world.

Data have been framed by applying the following criteria:

**3.3.2. Underlying Assets Data:** Indian Security in equity segment selected from the list of Nifty50 companies for instruments OPTSTK & FUTSTK and stock index Nifty 50 (old name S&P CNX Nifty) for instruments OPTIDX & FUTIDX. Options are of European style.

The trading of qualified stocks of the companies must be traded in the both markets i.e., in option market and future market because the Discounting Value of Future Price (DVFP) has been used in the place of spot price for the calculation of option price in the model. While sorting and matching the data, the options and futures contracts with the same maturity have been selected.

**3.3.3. Minimum Number of Options Contracts and period of study:** The companies for the study are qualified if their option contracts trading is in the minimum 200 number of contracts for each call and put option, accessed on 1st April, 2012 and once a company qualify, it will remain in study period unless until its trading has been suspended. In other words, options with number of contracts less than 200 are excluded from the sample. The data cover a sample period of four year from 1st April, 2012 to 31st March, 2016 for this research. Options and futures contracts traded for only near month, next month and far month are considered.

Hence, the total 22 companies have been qualified for stock options from the list of 50 companies (given in Appendix 1 of thesis) taken from the Nifty 50 based on the above-mentioned criteria. List of qualified companies has been given in Appendix 2 of thesis.

## 3.4. RESEARCH DESIGN

A detailed blueprint has been prepared under the research design which guides this research to achieve its stated objectives. Hence, this research work consistently goes through the following three stages:

Stage 1. Error matrices of the B&S model for call and put options using spot price.

Stage 2. Error matrices of the B&S model after replacing Sport price (S) by the discounted value of Future price ($Fe^{-(r-y)t}$).

Stage 3. Comparison of pricing errors between the B&S Model and modified B&S model.

## 3.5. SAMPLE SIZE

Equity options and equity index Nifty 50 options written over the underlying equity of the companies and equity index Nifty 50 respectively have been used in this research for the empirical evaluation of magnitude of the pricing errors. This study investigates 78,069 options (call and put option) written on underlying stocks of 22 companies, which are taken from the list Nifty 50 stock and 5,656 options (call and put options) written on underlying index Nifty 50 (Total 83,725 observations), for a period of 4 years, dated from April 1, 2012 to March 31, 2016.

## 3.6. SOURCE OF DATA COLLECTION

Secondary data have been collected and used for the purpose of the calculation of the theoretical predicted premium prices, risk-free rate of interest as well as for the standard deviation of the stock option from www.nseindia.comaandwww.rbi.org.in

Other parameters required for estimating theoretical call option prices with the Black-Scholes and the modified Black-Scholes models are obtained as follows-

## 3.7. BLACK-SCHOLES MODEL AND REPLACEMENT OF SPOT PRICE

### 3.7.1. Black-Scholes Model

The Black-Scholes call and put options pricing model used in this research are given as:

$$c = SN(d_1) - Xe^{-rt}N(d_2)$$

$$p = Xe^{-rt}N(-d_2) - SN(-d_1)$$

The variables and assumptions of the model have been discussed in detail in chapter 1, section [1.3].

**3.7.2. Cost of Carry:** The future prices of stock and index should be higher than their corresponding spot prices because of the interest rate element under the cost of carry model. Based on the COC model the spot and future act as substitute [(Bhatia, (2007) and Lin and Stevenson, (1999)] and hence, they can be substituted. The future prices, in this research have been discounted on risk free rate of interest with dividend yield (Appendix4 and 5 in thesis). The discounting Value of Future Price has been calculated from the following cost of carry equation [Vohra and Bagri, (2007), pp. 87]:

$$F_0 = S_0 e^{(r-y)t}$$

Hence, Spot price will be

$$S_0 = F_0 e^{(r-y)t}$$

### 3.7.3. Replacing Spot price by DVFP in Black-Scholes model

The spot price ($S_0$) of the stock and index has been replaced by their corresponding Discounting Value of Future Price (DVFP) as it is used by Black (1976) in pricing commodity options, Varma (2002) and Mitra (2008 & 2012) in pricing index Nifty 50 traded on NSE. The formula for the prices of European stock call and put options are as follows:

$$C = F_0\, e^{-rt}.N\,(d_1) – X.e^{-rt}N\,(d_2)$$

$$P = X.e^{-rt}N\,(-d_2) - F_0\, e^{-rt}.N\,(-d_1)$$

All other parameters of Black-Scholes (1973) are kept unchanged and the futures prices have the same lognormal property as the Black-Scholes model assumed [Hull, (2007), pp. 354]. It should be noted that the Black equations are exactly what one would obtain if in the Black Scholes formula stock price (S) is replaced by replaced by $F^*e^{-rt}$ (Varma, 2002).

## 3.8. RISK-FREE RATE RETURN

The 91day T. Bill yield has been considered as the risk-free rate of interest taken from RBI website www.rbi.org.in for the respective period under the study.

### 3.9. VOLATILITY

The volatility using closing prices is used in the Black-Scholes model. The historical volatility under this research has been calculated by considering the qualified stocks and Nifty50 index prices movement for each selected period. For the computation of stocks and index annual volatility, first daily return of the stocks and index has been calculated by the following formula, using the logarithmic difference of the closing prices (Quigley and Ramsey, 2008 and Kumar, Das and Reza, 2013):

$$r(t) = ln\left(\frac{P_t}{P_{t-1}}\right)$$

Where,

$r(t)$ is the log return of an asset,

$r(t)$ is the asset price at time t and

$P_{t-1}$ is the asset price at the previous step in time

Then daily standard deviation has been converted in to annual volatility for each selected stocks and index by using the following formula [Hull, (2007), pp. 310]:

Volatility per annum = volatility per trading day × √number of trading days per annum.

It may be noted that under the COC model the volatility of the futures price is the same as the volatility of the underlying asset [Hull, (2007), pp. 355], hence separate volatility for futures have not been used.

### 3.10. STATISTICAL MEASURES FOR RESULTS COMPARISON

It is now possible after gathering all the required data to calculate options prices by using both the Black-Scholes model and the model after replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) in the original Black-Scholes Model. The various forecast statistics used by researchers are the Mean Error (ME), Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Thiel's U statistic and Mean Absolute Percentage Error (MAPE). These methods are suggested by Cook (2006). These forecast evaluation statistics have been used to know the magnitude of the produced errors and to compare model produced errors. These values have been calculated with the help of excel.

The paired sample t-test has been also used to obtain the p-value under the SPSS version 21 to support hypotheses as a secondary tool. If p-value is found greater than 0.05 then null hypothesis is accepted and if p-value is found less than 0.05 then the null hypothesis is rejected.

## *CHAPTER 4:* DATA ANALYSISAND INTERPRETATION

This chapter calculates and discusses the magnitude of pricing error produced under the Black-Scholes model using both spot prices and discounting value of future prices.

### 4.1. COMPARISON BETWEEN UNDERLYINGS' FUTURE AND SPOT PRICES

#### 4.1.1. Comparison between stocks' future and spot prices for Stock Call Options:

The NSE stock future and spot prices have been compared for stock call options to see whether the future prices are greater than their corresponding spot prices. It has been found, that the total 6,634 stock future prices out of total 40,653 observations have been quoted lower than their corresponding stock spot prices. In other words, 16.32% of the total observations, the stock future prices have been traded below their corresponding stock spot prices.

The stocks' future prices have been discounted and compared to their corresponding stocks' spot prices for addressing negative cost of carry problem for stock call options. When the stocks' future prices have been discounted, then 17,137 out of total 40,653 observations are found lower than their corresponding spot prices (table 4.2 in thesis). In other words, 42.15% of the total observations, the stocks' DVFP have been traded below their corresponding stock spot prices. Hence, comparing the discounting value of the futures prices of stocks with their corresponding spot prices, a visual inspection reveals that 42.15% of the total observations for stock call options are likely to be affected by the negative cost of carry problem.

#### 4.1.2. Comparison between index Nifty 50 future and spot prices for index Nifty 50 call options:

The options pricing models have been also tested for the equity index Nifty 50 call options. The NSE equity index Nifty 50 future and spot prices have been compared for index Nifty 50 call options to see whether the future prices are greater than their corresponding spot prices.

It has been found that the total 124 equity index Nifty 50 future prices out of total 2,824 observations have been quoted lower than their corresponding Nifty 50's spot prices. In other words, 4.39% of the total observations, the Nifty 50 stock future prices have been traded below their corresponding Nifty 50 spot prices.

The equity index Nifty 50 future prices have been discounted and compared again to their corresponding Nifty 50 spot prices for addressing negative cost of carry problem for index call options.

When the equity index Nifty 50 future prices have been discounted, then 1,446 out of total 2,824 observations are found lower than their corresponding spot prices. In other words, 51.20% of the total observations, the Nifty 50's DVFP have been traded below their corresponding Nifty 50 spot prices. Hence, comparing the discounting value of the futures prices of index nifty 50 with their corresponding spot prices, A visual inspection reveals that 51.20% of the total observations for index Nifty 50 call options are likely to be affected by the negative cost of carry problem.

#### 4.1.3. Comparison between stocks' future and spot prices for stock put options:

The NSE stock future and spot prices have been compared for stock put options to see whether the future prices are greater than their corresponding spot prices. It has been found that the total 6,206 stock future prices out of total 37,416 observations have been quoted lower than their corresponding stock spot prices. In other words, 16.59% of the total observations, the stock future prices have been traded below their corresponding stock spot prices.

The stocks future prices have been discounted and compared to their corresponding stocks spot prices for addressing negative cost of carry problem for stock put options.

When the stocks future prices have been discounted, then 15,713 out of total 37,416 observations are found lower than their corresponding spot prices. In other words, 41.95% of the total observations, the stocks DVFP have been traded below their corresponding stock spot prices. Hence, comparing the discounting value of the futures prices of stocks with their corresponding spot prices, a visual inspection reveals that 41.99% of the total observations for stock put options are likely to be affected by the negative cost of carry problem.

#### 4.1.4 Comparison between index Nifty 50 future and spot prices for index Nifty 50put options:

The options pricing models have been also tested for the equity index Nifty 50 call and put options. The NSE equity index Nifty 50 future and spot prices have been compared for index

Nifty 50 put options to see whether the future prices are greater than their corresponding spot prices.

It has been found that the total 125 equity index Nifty 50 future prices out of total 2,832 observations have been quoted lower than their corresponding Nifty 50 spot prices. In other words, 4.41% of the total observations, the Nifty 50's future prices have been traded below their corresponding Nifty 50 spot prices.

The equity index Nifty 50 future prices have been discounted and compared to their corresponding Nifty 50 spot prices for addressing negative cost of carry problem for index Nifty 50 put options.

When the equity index Nifty 50 future prices have been discounted, then 1,446 out of total 2,824 observations are found lower than their corresponding spot prices. In other words, 51.20% of the total observations, the Nifty 50 DVFP have been traded below their corresponding Nifty 50 spot prices. Hence, comparing the discounting value of the futures prices of index Nifty 50 with their corresponding spot prices, A visual inspection reveals that 51.20% of the total observations for index Nifty 50 put options are likely to be affected by the negative cost of carry problem.

A visual inspection reveals that 42.15% of the total observations for stock call options, 51.20% of the total observations for index Nifty 50 call options, 41.95% of the total observations for stock put options and 51.20% of the total observations for index Nifty 50 put options are likely to be affected by the negative cost of carry problem and hence, this bias is bound to influence options pricing. These findings are consistent with results from Mitra (2008 & 2012) for the index Nifty 50.

## 4.2. TEST OF NORMALITY

The B&S model is based on seven assumptions and testing of its all assumption will divert the main objectives of this research. One of the main assumptions of the B & S model is that stock returns follow log normal distribution. Hence, this important condition is tested empirically in this research. The daily log-returns for all twenty-two companies and index Nifty 50 are calculated using the formula ln ($S_t$ / $S_{t-1}$). Then the distribution of log-returns is tested to check whether they satisfy the normal distribution criteria. The normal distribution can be tested by many methods. Histograms are easy testing tools for testing the normality of a distribution. The mean-based statistics like mean, standard deviation, skewness and kurtosis are also commonly used as the normality testing tools by researchers.

Mean-based statistics have been used to test normality. The Mean-based statistics depend on four measures namely the mean (to know the centre), the standard deviation (to know the spread), the coefficient of skewness (to know the symmetry), and the coefficient of kurtosis (to know the heavy or thin tails). Histograms have also been used for identifying the normality of a distribution.

Histograms are generated and mean-based statistical values of the mean, standard deviation, skewness and Kurtosis have been calculated to check for the normality of the distribution of the log-returns of all the twenty-two companies and index Nifty 50. The values of mean-based statistics are presented in the table 4.9 in thesis.

From the given table in thesis (table 4.9), it has been found that the mean returns are almost zero in all cases and standard deviations are around 0.0 to 0.0309. That indicates the logarithmic returns of the stock of the companies are more or less normally distributed.

The skewness figures are slightly high for some cases like AXISBANK; 0.5511, CAIRN; -0.4552, HINDUNILVRE; 0.7264, IDFC; -0.3882, ITC; -0.3570, JPASSOCIATE; -0.4870, SBIN; 0.3061 These deviations may be because of some outliers in the data. Hence, it may be inferred that though, there are asymmetry in the distribution they are low.

The kurtosis figures are slightly high for some companies like AXIS BANK; 5.5135, BHEL; 3.3731, CAIRN; 3.3922, HDFC; 3.1339, HINDUNILVRE; 3.8628, IDFC; 4.6227, INFY; 5.9054, ITC; 3.6711, LT; 3.8074, TCS; 3.9011 which show slightly peakedness in the histogram. For a normal distribution the value of kurtosis should be three. Most, 7 out of 23 companies have shown the value of kurtosis little bit more than three except AXISBANK, IDFC and INFY. As far as location of the symmetry of the distributions are concerned, they satisfy the norms of a normal distribution. This is evident from the corresponding histograms shown in thesis.

The log normal assumptions of the model are mostly care taken but peakedness of the distribution is found. However, the mean of log-returns for all companies and index Nifty 50 is zero. Hence, Except the kurtosis all other tests point the log-returns are normally distributed. The corresponding histograms of all selected twenty-two companies and index Nifty 50 are given in Appendix 8 in thesis.

## EFFICIENCY OF BLACK-SCHOLES MODEL USING SPOT PRICE AND DVFP

The empirical analysis starts with stage 1st where the pricing efficiency of the Black-Scholes model for call and put options written on stocks and index has been tested using underlying spot price. In stage 2nd, the pricing efficiency of the Black-Scholes model has been tested using DVFP instead of spot price of the underlying assets while stage 3rd makes comparison between the models to show which model exhibits less pricing errors.

## STAGE FIRST

## 4.3. ERROR MATRICES OF THE B&S MODEL USING SPOT PRICE

**In stage 1st**, the pricing accuracy of the Black-Scholes model for call and put options written on stocks and index have been tested using spot price.

### 4.3.1. For Stock call options under the Black-Scholes model

During the study period, a significant difference has been found (for the objective 1 and Hypothesis $H_{01}$) between the mean values of the stock call options closing price and calculated price under the B&S model. The theoretical prices of stock call options have been calculated under the Black-Scholes model by using the stock spot prices. It has been found that the Black-Scholes model considerably overprices stock call option with a ME of -2.6325 when it is calculated using spot price of the stock. So, it is more likely to reject the null hypothesis for stock call options.

The subgroup measures of moneyness bias (for objective 2) have been found for each category such as OTM, ATM and ITM for stock call options under the original Black-Scholes model. The original Black-Scholes model consistently overprices across all categories of moneyness.

The maturity biasness (for objective 2) for the near month, next month and far month expiration stock call options contracts have been found whose prices are calculated under the Black-Scholes model using the stock spot prices. The magnitude of mispricing increases as maturity increases in pricing stock call option under the Black-Scholes model.

### 4.3.2. For Index Call Options under the Black-Scholes model

It has been found (for the objective 1 and Hypothesis $H_{02}$) that there is a significant difference between the mean values of the index call options closing price and calculated price under the B&S model. The results of entire samples pricing errors produced under the Black-Scholes model shows that the model considerably overprices index call option with a ME of -3.408. So, it is more likely to reject the null hypothesis for index call options. The original Black-Scholes model also consistently overprices across all categories of given moneyness and maturity (objective 2). The magnitude of mispricing increases as maturity increases in pricing index call option under the Black-Scholes model.

### 4.3.3. For Stock Put options under the Black-Scholes model

During the study period it has been found (for the objective 1 and Hypothesis $H_{03}$) that there is a significant difference between the mean values of the stock put options closing price and calculated price under the B&S model. The Black-Scholes model considerably overprices stock put option with a ME of -1.5727. So, it is more likely to reject the null hypothesis for stock put options. The model also overprices across all categories of moneyness. The values of mean errors show that the options prices calculated under the Black Scholes model using the stock spot prices for stock put options consistently overprices across all maturity (objective 2).

During the study period regarding the stock call to put bias under the Black-Scholes model, it has been found that the B&S model shows higher magnitude of errors in pricing of stock call as compare to pricing put options (objective 2).

### 4.3.4. For Index Put Options under the Black-Scholes model

During the study period, a significant difference has been found (for the objective 1 and Hypothesis $H_{04}$) between the mean values of the S&P CNX Nifty index put options closing price and calculated price under the B&S model. It has been found that the model produces pricing errors for index put option and overall index put options are underpriced with the mean error of 7.2097by the original Black-Scholes model during the study period of this research. Therefore, it is more likely to reject the null hypothesis for index put options. It is evident that the original Black-Scholes model also consistently underprices across all categories of given moneyness. similarly, the next month and far month expiration index put options contracts whose prices are calculated under the Black-Scholes model using the index spot prices are underpriced while the near month contracts are overpriced by the model (objective 2).

During the study period regarding the index call to put bias under the Black-Scholes model, it has been found that the magnitude of errors for pricing Index Nifty50 put options is relatively higher under the Black-Scholes model (objective 2).

**STAGE SECOND**

## 4.4. ERROR MATRICS OF THE B&S MODEL AFTER REPLACING SPOT PRICE BY THE DISCOUNTING VALUE OF FUTURE PRICE ($Fe^{-rt}$)

In stage 2nd, an empirical analysis of the Black-Scholes model after bringing modification has been conducted by replacing Sport price (S) by the discounted value of Future price ($Fe^{-rt}$) for call and put options written on stocks and index have been tested.

### 4.4.1. For Stock call options under the modified Black-Scholes model

During the period of this research, a significant difference has been found (for the objective 3 and Hypothesis $H_{05}$) between the mean values of the stock call options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model also produces pricing errors and overall stock call options are also overpriced by the modified Black-Scholes model when DVFP is used during the study period of this research. The modified Black-Scholes model considerably overprices stock call option with a ME of -2.3028. So, it is more likely to reject the null hypothesis for stock call options.

The negative ME has been produced by the modified Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock call options are overpriced with a ME of -5.9201, -2.0522 and -4.8459, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of moneyness (objective 2).

Pricing errors calculated on the basis all parameters state that mispricing increases as maturity increases under the modified B&S model. The ME for the near month, next month and far month stock call options contracts are -2.8774, -7.3341 and -9.9988, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the discounting value of futures price for stock call options also consistently overprices across all maturity (objective 2).

### 4.4.2. For Index Call Options under the modified Black-Scholes model

During this research period, a significant difference has been found (for the objective 3 and Hypothesis $H_{06}$) between the mean values of the S&P CNX Nifty index call options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably overprices index call option with a ME of -2.7506. So, it is more likely to reject the null hypothesis for index call options. The negative ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index call options. The OTM and ITM index call options both are overpriced with a ME of -0.1964 and -6.0846, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of given moneyness (objective 2).

The ME for the near month, next month and far month index call options contracts are -4.0651, -1.9345 and -2.417, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using discounting value of futures price for index call options consistently underprices across all maturity (objective 2).

### 4.4.3. For Stock Put Options Under the Modified Black-Scholes Model

During this research period, a significant difference has been found (for the objective 3 and Hypothesis $H_{07}$) between the mean values of the stock put options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably overprices stock put option with a ME of -1.7469. So, it is more likely to reject the null hypothesis for stock put options. It is, hence, evident that model produces pricing errors and overall stock put options are also overpriced by the modified Black-Scholes model during the study period of this research.

The OTM, ATM and ITM stock put options are overpriced with a ME of -3.3020, -0.6960, and -0.8374, respectively. Hence, it is evident that the original Black-Scholes model consistently overprices across all categories of moneyness. However, The OTM options have been highly overpriced with the ME of -5.2865 (objective 2).

The ME for the near month, next month and far month stock put options contracts are -0.6426, -2.7822 and -4.0052, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the stock DVFP for stock put options consistently overprices across all maturity. the magnitude of mispricing increases as maturity increases in pricing stock put option under the Black-Scholes model (objective 2).

During the study period regarding the stock call to put bias under the modified B&S model, it has been found that the modified Black-Scholes model shows higher magnitude of errors in pricing of stock call as compare to pricing put options (objective 2).

#### 4.4.4. For Index Put Options Under the Modified Black-Scholes Model

During this research period, a significant difference has been found (for the objective 3 and Hypothesis $H_{08}$) between the mean values of the index put options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably underprices index put option with a ME of 7.0762. So, it is more likely to reject the null hypothesis for the S&P CNX Nifty index put options. Hence, model produces pricing errors and overall stock put options are underpriced by the modified Black-Scholes model during the study period.

The positive ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index put options. The OTM and ITM index put options both are underpriced with a ME of 3.0606 and 8.807, respectively (objective 2).

The ME for the near month, next month and far month index put options contracts are -0.2645, 5.1989 and 15.3879, respectively. On the basis of mean error, the index put next month options contracts are overpriced with a lowest mean error of -0.2645 while far month options contracts are underpriced with a highest mean error of 15.3879 (objective 2).

During the study period regarding the index call to put bias under the modified B&S model, it has been found that the magnitude of error for pricing Index Nifty 50 put options is relatively higher under the modified B&S model (objective 2).

## STAGE THIRD

### 4.5. COMPARISON OF PRICING ERRORS BETWEEN THE B&S MODEL AND MODIFIED B&S MODEL

Stage 3rd makes comparison between the models to show which model exhibits less pricing errors.

#### 4.5.1. For Stock call options under the Black-Scholes model and modified Black-Scholes model

The original Black-Scholes and modified Black-Scholes models both show the significant differences in their mean values in pricing stock call options ($H_{01}$ and $H_{05}$). This section empirically compares the pricing errors produced under the both models to show which model produces lower pricing errors in pricing stock call options and the same can be considered as a better model.

During the study period of this research, a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock call options has been found (for the objective 4 and Hypothesis $H_{09}$) with the ME value of (-) 0.3322. So, it is more likely to reject the null hypothesis for stock call options. The overall stock call options are overpriced under the both cases with the mean errors of -2.6325 and -2.3028 but overpricing is improved by (-) 0.3322 if it is priced using the DVFP instead of spot price. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing stock call options are (-) 0.3322, 0.2652, 22.2905, 0.4915, 0.0027 and 1.3648, respectively. The comparative Improvements have been exhibited on the all the used parameters. Hence, the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing stock call options in the Indian derivatives market.

The overall improvements regarding ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing OTM stock call options are (-) 0.1672, 0.0875, 22.8638, 0.3183, 0.0004 and 1.2689, respectively. It may be noted that OTM stock call options are also overpriced under the both cases with the mean errors of -6.0873 and -5.9201 but overpricing is improved by (-) 0.1672 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters. The improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM stock call options in the Indian derivatives market (objective 2).

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing ATM stock call options are -0.0261, 0.0413, -1.9199, -0.2225, -0.0059 and 1.2557, respectively. ATM stock call options are also overpriced under the both cases with the mean errors of -2.0261 and -2.0522 but the magnitude of overpricing is higher by -0.0261 if it is priced using the DVFP instead of spot price. The comparative Improvements have not been found for stock call ATM options on the parameters of ME, MSE, RMSE and Theil’s u statistic. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing ATM stock call options in the Indian derivatives market (objective 2).

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil’s u statistic and MAPE for pricing ITM stock call options are (-) 0.5316, 0.5067, 33.3913, 0.5643, 0.0021 and 1.2292, respectively. ITM stock call options are also overpriced under the both cases with the mean errors of -5.3775 and -4.8459 but overpricing is improved by (-) 0.5316 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM stock call options in the Indian derivatives market (objective 2).

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil’s U statistic and MAPE for pricing the near month stock call options are (-) 0.1480, 0.2650, 12.7499, 0.2862, 0.0016 and 0.9716, respectively. The near month stock call options are also overpriced under the both cases with the mean errors of -3.0254 and -2.8774 but overpricing is improved by (-) 0.1480 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. The performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the near month stock call options in the Indian derivatives market (objective 2).

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil’s u statistic and MAPE for pricing the next month stock call options are (-) 0.4235, 0.3120, 40.2494, 0.5182, 0.0022 and 1.5424, respectively. The next month stock call options are also overpriced under the both cases with the mean errors of -7.7576 and -7.3341 but overpricing is improved by (-) 0.4235 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month stock call options in the Indian derivatives market (objective 2).

For far month stock call, the overall improvements with regard to ME, MAE, MSE, RMSE, Theil’s u statistic and MAPE for pricing the far month stock call options are (-) 0.9214, 0.0653, 41.1277, 0.4105, -0.0005 and 1.1604, respectively but the value of Theil’s u statistic does not support. The comparative Improvements has not been found. Hence, the performance of the Black-Scholes model based on the DVFP is not superior to that of the Black-Scholes model based on the spot price for pricing the far month stock call options in the Indian derivatives market (objective 2).

#### 4.5.2. For Index Nifty 50 call options under the Black-Scholes model and modified Black-Scholes model

The original Black-Scholes and modified Black-Scholes models, hence, both show the significant differences in their mean values in pricing index Nifty 50 call options ($H_{02}$ and $H_{06}$). This section empirically compares the pricing errors produced under the both models to show which model produces lower pricing errors in pricing index Nifty 50 call options and the same can be considered as a better model.

The calculated theoretical prices of index Nifty 50 call options under the Black-Scholes model and modified black-Scholes model have been compared to show which model exhibits less pricing errors.

During this research period the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing index Nifty 50 call options differs with a ME value of (-) 0.6574 (for the objective 4 and Hypothesis $H_{10}$). So, it is more likely to reject the null hypothesis for index call options. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistics and MAPE for pricing index call options are (-) 0.6574, 2.0106, 136.4566, 2.3940, 0.0019 and 1.5671, respectively. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing OTM index call options are (-) 0.4954, 0.5898, 31.1609, 0.6603, 0.0034 and 2.1759, respectively. It may be noted that OTM index call options are also overpriced under the both cases with the mean errors of -0.6918 and -0.1964 but overpricing is improved by (-) 0.4954 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM index call options in the Indian derivatives market (objective 2).

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing ITM index call options are (-) 0.8687, 3.8652, 273.8998, 4.0478, 0.0021 and 0.7721, respectively. It may be noted that ITM index call options are also overpriced under the both cases with the mean errors of -6.9533 and -6.0846 but overpricing is improved by (-) 0.8687 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM index call options in the Indian derivatives market (objective 2).

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the near month index call options are -0.8276, 1.7173, 71.5409, 1.9627, 0.0012 and -0.3311, respectively. It may be noted that the near month index call options are also overpriced under the both cases with the mean errors of -3.3974 and -4.0651 but overpricing is not improved if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters except ME and MAPE. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing near month index call options in the Indian derivatives market (objective 2).

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the next month index call options are (-) 0.3040, 1.9690, 185.3783, 3.0125, 0.0027 and 1.476, respectively. It may be noted that the next month index call options are also overpriced under the both cases with the mean errors of -2.2385 and -1.9345 but overpricing is improved by (-) 0.3040 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month index call options in the Indian derivatives market (objective 2).

For the far month index option, overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month index call options are (-) 2.1770, 2.3100, 144.2601, 2.1764, 0.0020 and 3.3261, respectively. It may be noted that the far month index call options are also overpriced under the both cases with the mean errors of -4.5940 and -2.4170 but overpricing is improved by (-) 2.1770 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the far month index call options in the Indian derivatives market (objective 2).

### 4.5.3. For Stock put options under the Black-Scholes model and modified Black-Scholes model

The original Black-Scholes and modified Black-Scholes models both show the significant differences in their mean values in pricing stock put options ($H_{03}$ and $H_{07}$). This section empirically compares the pricing errors produced under the both models to show which model produces lower pricing errors in pricing stock put options and the same can be considered as a better model.

During the study period of this research, a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock put options has been found (for the objective 4 and Hypothesis $H_{11}$) with the ME value of - 0.1742. The overall improvements with regard to ME, MSE, RMSE, Theil U statistics and MAPE for pricing stock put options have not been found except MAE if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on all the selected mentioned parameters except MAE. The Black-Scholes model based on the spot price produces overall lower pricing error for pricing stock put options in the Indian derivatives market. In other words, modification is not suitable for pricing stock put option. Hence, the improvements regarding its subgroups have not been discussed further.

### 4.5.4. For Index Nifty 50 put options under the Black-Scholes model and modified Black-Scholes model

The original Black-Scholes and modified Black-Scholes models, hence, both show the significant differences in their mean values in pricing index Nifty 50 put options ($H_{04}$ and $H_{08}$). This section empirically compares the pricing errors produced under the both models to show which model produces lower pricing errors in pricing index Nifty 50 put options and the same can be considered as a better model.

During this research period the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing index Nifty 50 put options differs with a ME value of -0.0784 (for the objective 4 and Hypothesis $H_{10}$). So, it is more likely to reject the null hypothesis for index put options. Here, the modified B&S model exhibits lager mean error. The overall improvements with regard to ME and RMSE for pricing index put options have not been found if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters. The Black-Scholes model based on the spot price produces overall lower pricing error for pricing index put options in the Indian derivatives market. In other words, modification is not suitable for pricing index put option. Hence, the improvements regarding its subgroups have not been discussed further.

**SPSS Output**

The paired sample t-test has been also conducted to obtain the p-value in each stage. It may be noted that the error metrics have been calculated on the entire sample which consist with twenty-two companies. These twenty-two selected companies are from thirteen different sectors such as Bank & Finance, Telecommunication, Electrical Equipment, Oil Exploration, Construction, Aluminium, Computer Software, Cigarettes, Diversified, Automobiles, Engineering, Refineries, Steel. It may be noted that the value of standard deviation is relatively high in each stage. It might be because of the pricing errors of twenty-two stocks for four years have been pulled together then their respective single error has been calculated on the entire sample. These twenty-two selected stocks are from thirteen different sectors.

## *CHAPTER 5:* FINDINGS AND CONCLUSION

### FINDINGS

### 5.1. COMPARISION BETWEEN UNDERLYING FUTURE AND SPOT PRICES

During the comparison of future price and spot price for addressing negative cost of carry problem following points have been observed:

#### 5.1.1 For stock call options

The Future prices of 6,634 out of total 40,653 observations (16.32%) have been quoted lower than their corresponding spot prices.

When the stocks' future prices have been discounted, then17,137 out of total 40,653 observations are found lower than their corresponding spot prices. In other words, 42.15% of the total observations, the stocks' DVFP have been traded below their corresponding stock spot prices. Hence, comparing the discounting value of the futures prices of stocks with their corresponding spot prices, a visual inspection reveals that 42.15% of the total observations for stock call options are likely to be affected by the negative cost of carry problem.

#### 5.1.2. For Index Nifty 50 call options

The Future prices of 124 out of total 2,824 observations (4.39%) have been quoted lower than their corresponding spot prices.

When the equity index Nifty 50 future prices have been discounted, then 1,446 out of total 2,824 observations are found lower than their corresponding spot prices. In other words, 51.20% of the total observations, the Nifty 50's DVFP have been traded below their corresponding Nifty 50 spot prices. These findings are consistent with the findings of Mitra (2008 & 2012). Hence, comparing the discounting value of the futures prices of index nifty 50 with their corresponding spot prices, a visual inspection reveals that 51.20% of the total observations for index Nifty 50 call options are likely to be affected by the negative cost of carry problem. These findings are consistent with the Varma (2002), Mitra (2008 & 2012).

#### 5.1.3. For stock put options

The Future prices of 6,206 out of total 37,416 observations (16.59%) have been quoted lower than their corresponding spot prices.

When the stocks future prices have been discounted, then15,713 out of total 37,416 observations are found lower than their corresponding spot prices. In other words, 41.95% of the total observations, the stocks DVFP have been traded below their corresponding stock spot prices. Hence, comparing the discounting value of the futures prices of stocks with their corresponding spot prices, A visual inspection reveals that 41.99% of the total observations for stock put options are likely to be affected by the negative cost of carry problem.

#### 5.1.4. For Index Nifty 50 put options

The Future prices of 125 out of total 2,832 observations (4.41%) have been quoted lower than their corresponding spot prices.

When the equity index Nifty 50 future prices have been discounted, then 1,446 out of total 2,824 observations are found lower than their corresponding spot prices. In other words, 51.20% of the total observations, the Nifty 50 DVFP have been traded below their corresponding Nifty 50 spot prices. Hence, comparing the discounting value of the futures prices of index Nifty 50 with their corresponding spot prices, a visual inspection reveals that 51.20% of the total observations for index Nifty 50 put options are likely to be affected by the negative cost of carry problem. These findings are consistent with the findings of Mitra (2008 & 2012).

Futures prices have been used by various authors in derivatives products such by Draper and Fung (2002), Fung and Mok (2001) and Lung and Marshall (2002), Varma (2002), Garay, Ordonez and Gonzalez (2003), Lee and Nayar (1993), Sternberg (1994), Fung and Chan (1994), Fleming, Ostdiek, and Whaley (1996), Fung, Cheng and Chan (1997), Fung and Fung (1997), Mitra (2008 and 2012). However, Bharadwaj and Wiggins (2001) found violations in using this approach in the US market.

## 5.2. STAGE FIRST: ERROR MATRICES OF THE B&S MODEL FOR CALL AND PUT OPTIONS USING SPOT PRICE

### 5.2.1. Stock Call Option

During the study period, a significant difference has been found between the mean values of the stock call options closing price and calculated price under the B&S model. The theoretical prices of stock call options have been calculated under the Black-Scholes model by using the stock spot prices. It has been found that the Black-Scholes model considerably overprices stock call option with a ME of -2.6325 when it is calculated using spot price of the stock (objective 1). This finding is inconsistent with Kakati (2006) that call options are underpriced.

The subgroup measures of moneyness bias have been found for each category such as OTM, ATM and ITM for stock call options under the original Black-Scholes model. The original Black-Scholes model consistently overprices across all categories of moneyness (objective 2). The finding regarding ATM and OTM stock option is consistent with Kakati (2006) that the stock call ATM and ITM options are overvalued. Macbeth and Merville (1979) study also found that B&S model overprices OTM stock call options. The finding regarding stock call ITM is consistent with Bhattacharya (1980) that stock call ITM options are overvalued.

The maturity biasness for the near month, next month and far month expiration stock call options contracts have been found whose prices are calculated under the Black-Scholes model using the stock spot prices. The magnitude of mispricing increases as maturity increases in pricing stock call option under the Black-Scholes model. Stock call options are consistently overprices across all maturity under the B&S model (objective 2). However, the stock call near month options contracts are overpriced with a lowest mean error of -3.0254, consistent with result from Kakati (2006) while far month options contracts are overpriced with a highest mean error of -10.9202. Panduranga (2013a & b) found that B&S model is suitable for pricing stock call option written on banking and cement industries.

### 5.2.2. Index Nifty 50 Call Option

It has been found that there is a significant difference between the mean values of the index call options closing price and calculated price under the B&S model. The results of entire samples pricing errors produced under the Black-Scholes model shows that the model considerably overprices index call option with a ME of -3.408. (objective 1) This is in line with the findings of Singh and Dixit (2016) that the Black-Scholes model shows consistent overpricing with more than 90% call options as overpriced.

The original Black-Scholes model also consistently overprices across all categories of given moneyness and maturity (objective 2). The magnitude of mispricing increases as maturity increases in pricing index call option under the Black-Scholes model. This confirms the literature of Kakati (2006). This also confirms the literature of Barunikova (2009) that the Black-Scholes model exhibits Index call maturity and moneyness biases.

### 5.2.3. Stock Put Option

During the study period it has been found that there is a significant difference between the mean values of the stock put options closing price and calculated price under the B&S model. The Black-Scholes model considerably overprices stock put option with a ME of -1.5727 (objective 1). This confirms the literature of Fortune (1996) that the stock put options are overpriced by the B&S model.

The model also overprices across all categories of moneyness. The values of mean errors show that the options prices calculated under the Black Scholes model using the stock spot prices for stock put options consistently overprices across all maturity (objective 2).These all findings confirm the literature of Kakati (2006) that stock put options, its moneyness and all categories of maturity are also overpriced.

During the study period regarding the stock call to put bias under the Black-Scholes model, it has been found that the B&S model shows higher magnitude of errors in pricing of stock call as compare to pricing put options (objective 2). This finding is consistent with Berg, Brevik and Saettem (1996) and Kakati (2006) that the magnitude of error for stock call option is comparatively higher than stock put option. But this finding is also inconsistent with the findings of Kala and Pandey (2012) that the Black-Scholes model is more useful in call option pricing than the put option pricing.

### 5.2.4. Index Put Option

During the study period, a significant difference has been found between the mean values of the S&P CNX Nifty index put options closing price and calculated price under the B&S model. It has been found that the model produces pricing errors for index put option and overall index put options are underpriced with the mean error of 7.2097 by the original Black-Scholes model during the study period of this research (objective 1). This finding is contradicting to Shehgal and Narayanamurthy (2009) finding.

It is further evident that the original Black-Scholes model also consistently underprices across all categories of given moneyness (objective 2). This finding is in line with the findings of Singh and Ahmad (2011) that the Black-Scholes model shows maturity and moneyness biases in pricing index options. Similarly, the next month and far month expiration index put options contracts whose prices are calculated under the Black-Scholes model using the index spot prices are underpriced while the near month contracts are overpriced by the model (objective 2).

During the study period regarding the index call to put bias under the Black-Scholes model, it has been found that the magnitude of errors for pricing Index Nifty 50 put options is relatively higher under the Black-Scholes model (objective 2). This finding is in line with the findings of Kala and Pandey (2012) that the Black-Scholes model is more usefull in call option pricing than the put option pricing. This finding is inconsistent with Kakati (2006) study on BSE and Kala &

Pandey (2012) study on NSE. But this finding is also inconsistent with Puttonen (1993) and Dixit, Yadav and Jain (2009) studies where they have found that the B&S model shows higher magnitude of pricing error in pricing index call option as compare to index put option.

## 5.3. STAGE SECOND: ERROR MATRICES OF THE B&S MODEL AFTER REPLACING SPOT PRICES (S) BY THE DISCOUNTED VALUE OF FUTURE PRICE ($Fe^{-(r-y)t}$)

### 5.3.1. Stock Call Option

During the period of this research, a significant difference has been found between the mean values of the stock call options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model also produces pricing errors and overall stock call options are also overpriced by the modified Black-Scholes model when DVFP is used during the study period of this research. The modified Black-Scholes model considerably overprices stock call option with a ME of -2.3028 (objective 3).

The negative ME has been produced by the modified Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock call options are overpriced with a ME of -5.9201, -2.0522 and -4.8459, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of moneyness (objective 2).

Pricing errors calculated on the basis all parameters state that mispricing increases as maturity increases under the modified B&S model. The ME for the near month, next month and far month stock call options contracts are -2.8774, -7.3341 and -9.9988, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the discounting value of futures price for stock call options also consistently overprices across all maturity (objective 2). This confirms the literature of Raj and Thurston (1998) that the all three maturity categories are significantly overpriced under the Black model for index call option.

### 5.3.2. Index Call Option

During this research period, a significant difference has been found between the mean values of the S&P CNX Nifty index call options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably overprices index call option with a ME of -2.7506 (objective 3). This confirms literature of Raj and Thurston (1998) that the model overprices index call options. But this finding is also inconsistent with the finding of Varma (2002) that the model underprices index call option.

The negative ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index call options. The OTM and ITM index call options both are overpriced with a ME of -0.1964 and -6.0846, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of given moneyness (objective 2). This finding also is consistent with the finding of Raj and Thurston (1998) that the model overprices all categories moneyness for index call option.

The ME for the near month, next month and far month index call options contracts are -4.0651, -1.9345 and -2.417, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using discounting value of futures price for index call options consistently underprices across all maturity (objective 2). This finding also is consistent with the finding of Raj and Thurston (1998) that the model overprices all categories maturity for index call option.

### 5.3.3. Stock Put Options

During this research period, a significant difference has been found between the mean values of the stock put options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably overprices stock put option with a ME of -1.7469. It is, hence, evident that model produces pricing errors and overall stock put options are also overpriced by the modified Black-Scholes model during the study period of this research (objective 3).

The OTM, ATM and ITM stock put options are overpriced with a ME of -3.3020, -0.6960, and -0.8374, respectively (objective 2). Hence, it is evident that the modified Black-Scholes model consistently overprices across all categories of moneyness. However, The OTM options have been highly overpriced with the ME of -5.2865.

The ME for the near month, next month and far month stock put options contracts are -0.6426, -2.7822 and -4.0052, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the stock DVFP for stock put options consistently overprices across all maturity (objective 2). the magnitude of mispricing increases as maturity increases in pricing stock put option under the Black-Scholes model.

During the study period regarding the stock call to put bias under the modified B&S model, it has been found that the modified Black-Scholes model shows higher magnitude of errors in pricing of stock call as compare to pricing put options (objective 2).

### 5.3.4. Index Put Option

During this research period, a significant difference has been found between the mean values of the index put options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably underprices index put option with a ME of 7.0762. Hence, model produces pricing errors and overall index put options are underpriced by the modified Black-Scholes model during the study period(objective 3). This finding is inconsistent with the finding of Raj and Thurston (1998) that the model overprices index put options.

The positive ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index put options. The OTM and ITM index put options both are underpriced with a ME of3.0606 and 8.807, respectively (objective 2). This finding also is inconsistent with the finding of Raj and Thurston (1998) that the model overprices all categories moneyness.

The ME for the near month, next month and far month index put options contracts are -0.2645, 5.1989 and 15.3879, respectively (objective 2). On the basis of mean error, the index put next month options contracts are overpriced with a lowest mean error of -0.2645 while far month options contracts are underpriced with a highest mean error of 15.3879. The near month finding is consistent with the finding of Raj and Thurston (1998)

During the study period regarding the index call to put bias under the modified B&S model, it has been found that the magnitude of error for pricing Index Nifty 50 put options is relatively higher under the modified B&S model (objective 2).

## 5.4. STAGE THIRD: COMPARISON OF PRICING ERRORS BETWEEN B&S MODEL AND MODIFIED B&S MODEL

### 5.4.1. Stock Call Option

During the study period of this research, a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock call options has been found with the ME value of (-) 0.3322. The overall stock call options are overpriced under the both cases with the mean errors of -2.6325 and -2.3028 but overpricing is improved by (-) 0.3322 if it is priced using the DVFP instead of spot price. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing stock call options are (-) 0.3322, 0.2652, 22.2905, 0.4915, 0.0027 and 1.3648, respectively. The comparative Improvements have been exhibited on the all the used parameters (objective 4). Hence, the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing stock call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE and Theil's U statistic for pricing OTM stock call options are (-) 0.1672, 0.0875, 22.8638, 0.3183, 0.0004 and 1.2689, respectively. It may be noted that OTM stock call options are also overpriced under the both cases with the mean errors of -6.0873 and -5.9201 but overpricing is improved by (-) 0.1672 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters (objective 2). The improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM stock call options in the Indian derivatives market.

ATM stock call options are also overpriced under the both cases with the mean errors of -2.0261 and -2.0522 but the magnitude of overpricing is higher by -0.0261 if it is priced using the DVFP instead of spot price. The comparative Improvements have not been found for stock call ATM options. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing ATM stock call options in the Indian derivatives market (objective 2).

ITM stock call options are also overpriced under the both cases with the mean errors of -5.3775 and -4.8459 but overpricing is improved by (-) 0.5316 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM stock call options in the Indian derivatives market (objective 2).

The near month stock call options are also overpriced under the both cases with the mean errors of -3.0254 and -2.8774 but overpricing is improved by (-) 0.1480 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. The performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the near month stock call options in the Indian derivatives market (objective 2).

The next month stock call options are also overpriced under the both cases with the mean errors of -7.7576 and -7.3341 but overpricing is improved by (-) 0.4235 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month stock call options in the Indian derivatives market (objective 2).

For far month stock call, the overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month stock call options are (-) 0.9214, 0.0653, 41.1277, 0.4105, -0.0005 and 1.1604, respectively but the value of Theil's u statistic does not support. The comparative Improvements has not been found. Hence, the performance of the Black-Scholes model based on the DVFP is not superior to that of the Black-Scholes model based on the spot price for pricing the far month stock call options in the Indian derivatives market (objective 2).

### 5.4.2. Index call option

During this research period the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing index Nifty 50 call options differs with a ME value of (-) 0.6574. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistics and MAPE for pricing index call options are (-) 0.6574, 2.0106, 136.4566, 2.3940, 0.0019 and 1.5671, respectively. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing index call options in the Indian derivatives market (objective 4). This finding is consistent with Mitra (2008 & 2012) study on index Nifty 50 call option traded. This finding is also in line with the finding of Raj and Thurston (1998) that model overprices call and put options traded on the Nikkei.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing OTM index call options are (-) 0.4954, 0.5898, 31.1609, 0.6603, 0.0034 and 2.1759, respectively. It may be noted that OTM index call options are also overpriced under the both cases with the mean errors of -0.6918 and -0.1964 but overpricing is improved by (-) 0.4954 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM index call options in the Indian derivatives market (objective 2). This finding is in line with the finding of Raj and Thurston (1998) there is some evidence that the model overprices ITM and OTM options.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing ITM index call options are (-) 0.8687, 3.8652, 273.8998, 4.0478, 0.0021 and 0.7721, respectively. It may be noted that ITM index call options are also overpriced under the both cases with the mean errors of -6.9533 and -6.0846 but overpricing is improved by (-) 0.8687 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM index call options in the Indian derivatives market (objective 2). This finding is in line with the finding of Raj and Thurston (1998) there is some evidence that the model overprices ITM and OTM options. But this finding is inconsistent with the finding of whaley (1996) there is some evidence that the model underprices in-the-money options in USA.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the near month index call options are -0.8276, 1.7173, 71.5409, 1.9627, 0.0012 and -0.3311, respectively. It may be noted that the near month index call options are also overpriced under the both cases with the mean errors of-3.3974 and -4.0651 but overpricing is not improved if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters except ME and MAPE (objective 2). Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing near month index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the next month index call options are (-) 0.3040, 1.9690, 185.3783, 3.0125, 0.0027 and 1.476, respectively. It may be noted that the next month index call options are also overpriced under the both cases with the mean errors of -2.2385 and -1.9345 but overpricing is improved by (-) 0.3040 if it is priced using the DVFP instead of spot price. This finding is in line with the finding of Raj and Thurston (1998) there is some evidence that the model overprices next month options contract. The comparative Improvements have been found on the all selected parameters (objective 2). Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month index call options in the Indian derivatives market.

For the far month index option, overall improvements with regard to ME, MAE, MSE, RMSE, Theil’s u statistic and MAPE for pricing the far month index call options are (-) 2.1770, 2.3100, 144.2601, 2.1764, 0.0020 and 3.3261, respectively. It may be noted that the far month index call options are also overpriced under the both cases with the mean errors of -4.5940 and-2.4170 but overpricing is improved by (-) 2.1770 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the far month index call options in the Indian derivatives market (objective 2). These findings regarding next month and far month are consistent with the finding of Raj and Thurston (1998) that model overprices across all categories of maturity.

### 5.4.3. Stock Put Option

During the study period of this research, the overall improvements with regard to ME, MSE, RMSE, Theil U statistics and MAPE for pricing stock put options have not been found except MAE if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters except MAE (objective 4). The Black-Scholes model based on the spot price produces overall lower pricing error for pricing stock put options in the Indian derivatives market. In other words, modification is not suitable for pricing stock put option. Hence, the improvements regarding its subgroups have not been discussed further.

### 5.4.4. Index Put Option

During the study period of this research, the overall improvements with regard to ME and RMSE for pricing index put options have not been found if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters (objective 4). The Black-Scholes model based on the spot price produces overall lower pricing error for pricing index put options in the Indian derivatives market. In other words, modification is not suitable for pricing index put option. Hence, the improvements regarding its subgroups have not been discussed further. This finding is in line with the findings of Shehgal and Narayanamurthy (2009) stated that the Black-Scholes model is a good descriptor of S&P CNX Nifty Index option pricing subjective to the trading asymmetry condition (short selling restrictions) prevailing in India.

**CONCLUSION**

Future prices of stock and index Nifty 50 quoting below the underlying spot prices are a common phenomenon in the Indian derivatives market. A visual inspection reveals stock and index Nifty 50 options are likely to be affected by the negative cost of carry problem.

## 5.5. CONCLUSION FROM STAGE FIRST: ERROR MATRICES OF THE B&S MODEL FOR CALL AND PUT OPTIONS USING SPOT PRICE

The Black-Scholes model overall suffers from the pricing errors for the calculation of the prices of Stocks and Index Nifty 50 options using underlying spot price. It has been observed that stock call, index call and Stock put options are overpriced while index put options are underpriced by the Black-Scholes model.

### 5.5.1. Stock and Index Nifty 50 Moneyness Bias Under the B&S Model:

1. Stock call ITM, OTM and ATM options are overpriced by the B&S model.
2. Index call ITM and OTM options are overpriced by the B&S model.
3. Stock put ITM, ATM and OTM options are overpriced by the B&S model.
4. Index put ITM and OTM options are underpriced by the B&S.

### 5.5.2. Stock and Index Nifty 50 Maturity Bias Under the B&S Model:

1. Stock call Near Month, Next Month and Far Month options are overpriced by the B&S model.
2. Index call Near Month, Next Month and Far Month options are overpriced by the B&S model.

3. Stock put Near Month, Next Month and Far Month options are overpriced by the B&S model.
4. Index put Near Month option is overpriced while Next Month and Far Month options are underpriced by the B&S model.

**5.5.3. Stock Call to Put Bias:** Stock call and put options both are overpriced by the B&S model. However, the B&S model shows high magnitude of errors in pricing of stock call as compare to pricing put options on the basis of Mean Error.

**5.5.4. Index Nifty 50 Call to Put Bias:** Index Nifty 50 call options are overpriced while Index put options are underpriced by the B&S model. However, the magnitude of error for pricing Index Nifty50 put options is relatively high on the basis of Mean Error.

## 5.6. CONCLUSION FROM STAGE SECOND: ERROR MATRICES OF THE B&S MODEL AFTER REPLACING SPORT PRICE (S) BY THE DISCOUNTED VALUE OF FUTURE PRICE ($FE^{-(R-Y)T}$)

The Modified Black-Scholes model also overall suffers from the pricing errors for the calculation of the prices Stocks and Index Nifty50 options using underlying DVFP instead of spot price. It has been observed that stock call, index call and Stock put options are overpriced while index put options are underpriced by the modified Black-Scholes model.

### 5.6.1. Stock and Index Nifty 50 Moneyness Bias Under the Modified B&S Model:

1. Stock call ITM, ATM and OTM options are overpriced by the modified B&S model.
2. Index call ITM and OTM options are overpriced by the modified B&S model. ATM option trading data have not been found for Index Nifty50 call option under the modified B& S model.
3. Stock put ITM, ATM and OTM options are overpriced by the modified B&S model.
4. Index put ITM and OTM option are underpriced by the modified B&S.

### 5.6.2. Stock and Index Nifty 50 Maturity Bias Under the Modified B&S Model:

1. Stock call Near Month, Next Month and Far Month options are overpriced by the modified B&S model.
2. Index call Near Month, Next Month and Far Month options are overpriced by the modified B&S model.

3. Stock put Near Month, Next Month and Far Month options are overpriced by the modified B&S.
4. Index put Near Month option is overpriced while the Next Month and Far Month options are underpriced by the modified B&S model.

**5.6.3. Stock Call to Put Bias:** For stock option, the modified B&S shows high magnitude of errors in pricing of stock call as compare to pricing put options.

**5.6.4. Index Nifty 50 Call to Put Bias:** For index Nifty 50 option, the modified B&S shows high magnitude of errors in pricing of index Nifty 50 put options as compare to call options.

## 5.7. CONCLUSION FROM STAGE THIRD: COMPARISON OF PRICING ERRORS BETWEEN B & S MODEL AND AFTER BRINGING MODIFICATION IN B & S MODEL

**5.7.1. For Stock Call Options:** The Modified Black-Scholes model provides overall better result in comparison to the Black-Scholes Model for pricing stock call options in Indian market. The Modified Black-Scholes model shows lower pricing errors for stock call OTM and ITM options and higher errors for ATM options. Regarding the maturity bias, the Modified Black-Scholes model also shows lower pricing errors for the stock call near month and next month options contracts and higher errors for stock call far month options contracts.

**5.7.2. For Index Call Options:** The Modified Black-Scholes model provides overall better result in comparison to the Black-Scholes Model for pricing Index Nifty 50 call options in Indian market. The Modified Black-Scholes model shows lower pricing errors for index call OTM and ITM options. Regarding the maturity bias, the modified Black-Scholes model shows lower pricing errors for the index call next month and far month options contracts and higher errors for index call near month options contracts.

**5.7.3. For Stock Put Options:** The Modified Black-Scholes model does not provide overall better result in comparison to the Black-Scholes Model for pricing stock put options in Indian market. Hence, the B&S model is suitable for pricing stock put options.

**5.7.4. For Index Put Options:** The Modified Black-Scholes model does not provide overall better result in comparison to the Black-Scholes Model for pricing Index Nifty 50 put options in Indian market. Hence, the B&S model is suitable for pricing index put options.

During the study period of this research, it has been observed that stock and index futures sometimes suffer from a negative cost-of-carry bias, as future prices of stock and index trade below their corresponding spot prices. The Black-Scholes model overall suffers from the pricing errors for the calculation of the prices of Stocks and Index Nifty 50 options using underlying spot price. It has been observed that stock call, index call and Stock put options are overpriced while index put options are underpriced by the Black-Scholes model. Stock call ITM, OTM and ATM options are overpriced by the B&S model and its Near Month, Next Month and Far Month options are overpriced by the B&S model. Index call ITM and OTM options are overpriced by the B&S model and its Near Month, Next Month and Far Month options are overpriced by the B&S model. Stock put ITM, ATM and OTM options are overpriced by the B&S model and its Near Month, Next Month and Far Month options are overpriced by the B&S model. Index put ITM and OTM options are underpriced by the B&S and its Near Month option is overpriced while Next Month and Far Month options are underpriced by the B&S model. Stock call and put options both are overpriced by the B&S model.  However, the B&S model shows high magnitude of errors in pricing of stock call as compare to pricing put options on the basis of Mean Error. Index Nifty 50 call options are overpriced while Index put options are underpriced by the B&S model. However, the magnitude of error for pricing Index Nifty50 put options is relatively high on the basis of Mean Error.

The Modified Black-Scholes model, after replacing spot price by the discounting value of future prices to address the negative cost of carry problem, also overall suffers from the pricing errors for the calculation of the prices Stocks and Index Nifty 50 options. It has been observed that stock call, index call and Stock put options are overpriced while index put options are underpriced by the modified Black-Scholes model. Stock call ITM, ATM and OTM options are overpriced by the modified B&S model and its Near Month, Next Month and Far Month options are overpriced by the modified B&S model. Index call ITM and OTM options are overpriced by the modified B&S model its Index call Near Month, Next Month and Far Month options are overpriced by the modified B&S model. Stock put ITM, ATM and OTM options are overpriced by the modified B&S model and Stock put Near Month, Next Month and Far Month options are overpriced by the modified B&S. Index put ITM and OTM option are underpriced by the modified B&S. ATM option trading data have not been found for Index Nifty50 put option under the modified B& S model and its Near Month option is overpriced while the Next Month and Far

Month options are underpriced by the modified B&S model. When Call to Put Bias has been analysed under the modified Black-Scholes model, it has been found that the modified B&S shows high magnitude of errors in pricing of stock call as compare to pricing put options. For index Nifty 50 option, the modified B&S shows high magnitude of errors in pricing of index Nifty 50 put options as compare to its own call options.

The overall Improvements have been found in pricing stock call and index call option when they have been priced under the modified Black-Scholes model, after replacing spot price by the discounting value of future prices to address the negative cost of carry problem. The Modified Black-Scholes model shows lower pricing errors for stock and index call OTM and ITM options and higher errors for stock call ATM options. Regarding the maturity bias, the Modified Black-Scholes model also shows lower pricing errors for the stock call Near month and next month options contracts and higher errors for stock call far month options contracts. For index call option, the modified Black-Scholes model shows lower pricing errors for the index call next month and far month options contracts and higher errors for index call near month options contracts. However, the modified Black-Scholes model does not provide overall better result in comparison to the Black-Scholes Model for pricing stock put options in Indian market. Hence, the B&S model is suitable for pricing stock put options. Similarly, the modified Black-Scholes model also does not provide overall better result in comparison to the Black-Scholes Model for pricing Index Nifty 50 put options in Indian market. Hence, the B&S model is suitable for pricing index put options.

# CHAPTER 6: SUGGESTIONS, LIMITATIONS, CONTRIBUTION AND FURTHER SCOPE

## 6.1. SUGGESTION

The following suggestions can be given for pricing stock call, index call, stock put and index put option:

1. Stock Call option: Stock Call Options should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model.

1.1. Stock Call OTM and ITM Options should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model while ATM Options should be priced using the B&S model.

1.2. Stock Call Near Month and Next month Option should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model while far month options should be priced under the B&S model.

2. Index Nifty 50 Call option: Index Nifty 50 Call option should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model.

1.1. Nifty 50 Call ITM and OTM options should be priced under the modified B&S model as it shows less pricing error in comparison to the B&S model.

1.2. Nifty 50 Call Next month and Far month options should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model while the Near Month options should be priced under the B&S model.

3. Stock Put Options: Stock Put options should be priced under the B&S model as it shows less pricing error including its ITM, ATM, OTM, near month, next month and far month options contracts.

4. Index Nifty 50 Put options: Index Nifty50 Put options should be priced under the B&S model including its ITM, ATM, OTM, near month, next month and far month options contracts.

**6.2. LIMITATION**

1. The observed closing market prices of options (stock and index Nifty 50 options) traded on the NSE and theoretical options prices (stock and index Nifty 50 options) calculated under the models are compared to gauge the pricing accuracy. Hence, the stocks other than from the list of Nifty 50 and index other than Nifty 50 traded on the NSE have not been taken under this research during the period from 1st April, 2012 to 31st March, 2016.

2. The tests conducted in this research are based on only the closing prices of the underlying assets which are considered to be efficient. In other words, this research considers stocks closing price, stocks futures closing price, stocks options closing price, stock Nifty 50 closing price, stock Nifty 50 futures closing price and stock Nifty 50 options closing price. Here, stock means equity.

3. This research is conducted on NSE in India and hence, no comparison is made with foreign market. This research also assumes the impact of holidays on the stock exchange (NSE) as constant.

4. This study entirely focuses on the efficiency and the same has to be examined under the models and hence, the impacts on the efficiency caused by volatility, risk-free rate of interest, strike price, log normal distribution with constant volatility, transaction costs, arbitrage opportunities, short selling restriction of security in the Indian market, dividend and time to expiration of option have not been tested.

5. stock and future prices follow a random walk have not been tested.

6. The problem of Negative "cost of carry" has been addressed by replacing the spot price (S) by their respective discounted value of future price ($F.e^{-rt}$) in the original Black-Scholes model to minimize the pricing errors.

7. The residuals are assumed to be normally generated.

8. The market efficiency has not been teste as the specific focus of this research is on the pricing efficiency of the B&S model.

9. The cost of carry issue has not been tested at all in this research.

10. The data of stocks' and index's spot and futures prices are assumed to be stationary.

11. This research is not tested on the by-products of the model which are known as the Greeks such as Delta (sensitivity to underlying's price), Theta (sensitivity to time decay), Gamma (sensitivity to delta), Rho (sensitivity to interest rate) and Vega (sensitivity to underlying's volatility).

12. The mathematical derivation of the B&S model has not been conducted.

**6.3. CONTRIBUTION**

The purpose of derivative market is to provide product and techniques applicable for risk hedging, price discovery, and also for price accuracy. This research has entirely focused on the pricing errors of options produced by the B&S model and how pricing errors can be minimised. Less pricing errors will be produced, if traders and investors price Stock Call options and Index Nifty50 call options on the basis of discounting value of future price instead of spot price in the original B&s model. Hence, the model, which shows less pricing errors in the calculation of different types of options' prices written on different types of underlying assets, will create and maintain confidence level among the various stock market participants.

## 6.4. SCOPE FOR FURTHER WORK

The applicability of the Black-Scholes model can be tested on implied volatility with replacing spot price by the discounting value of future price. The produced pricing errors can also be empirically tested with relatively larger number of observations with increase in the number of contract size and period of study. Further research can be carried out by using conditional volatility or Skedastic function for calculating the future volatility to replace constant volatility in the Black-Scholes option pricing model. Research can be carried to exhibit the impact of major change in underlying spot price on the option price.

# *CHAPTER I*

# INTRODUCTION

In finance, an option is a standardized financial contract whose value depends upon the value of the underlying assets such as equity, bond, index commodity, etc. An option has no value without the underlying assets. Fisher Black and Myron Scholes developed a model for pricing a European style option. The Black-Scholes option pricing model (from here onwards called the B&S model) was published in the Journal of Political Economy, 1973 which is considered as a significant breakthrough in the field of financial derivatives. Rubinsstein (1994) states that the Black-Scholes model is widely viewed as one the most successful model in the social sciences for pricing options contracts. The pricing theories of stock options under the Black-Scholes model, for the purpose of risk management and trading, has occupied an important place in derivative market but this model also misprices option considerably (Kakati, 2006), "Can option pricing errors produced under the B&S model be minimized"? is abig questions faced by the participants of the derivative market.

This research makes an attempt to answer this question to some extent. This chapter provides an introduction to the areas of financial derivatives and accordingly consist of eleven sections: The **first** section defines some basic concepts used derivatives and Black-Scholes model. The **second** section explains reasons highlights the need of the study. The **third** section briefly explains the major participants in the derivatives market. The **fourth** section explains the in brief about the futures and options. The **fifth** section briefly explains the role of derivatives in an economy. The **sixth** section explains the history of the derivatives market abroad. The **seventh** section is about the commencement of the derivative segments in India. The **eighth** section explains the factors affecting prices of options. The section **ninth** introduces the Black-Scholes model and its alternative and modified models. The section **tenth** introduces the cost of carry model. The **eleventh** section describes in brief the chapterization of the study which is followed by the conclusion of this chapter.

## 1.1. DEFINITIONS

A derivative is a financial instrument whose value depends on or is derived from the value of another asset. Financial derivative is also called synthetic expressions of underlying price of financial security. These asset or derivative written on the asset is known as the underlying asset. Hence, a financial derivative is an instrument whose value is derived from basic variable or underlying which can be equity, bond, index commodity, currency, etc. However some more complicated financial products such as warrants, swaps, swaptions, collars, caps, floors, etc. are also known as Financial Derivative (Chance, 1997). A simple example of derivative is bread, which is a derivative of wheat. The price of bread depends upon the price of wheat and which in turn depends upon the demand and supply of wheat. Similarly, a stock option is a derivative whose value depends upon the price of stock.

In the Indian context, the Section 2(ac) of the Securities Contracts (Regulation) Act, 1956, (SC (R) Act) defines derivative as-

(a) "a security derived from a debt instrument, share, loan whether secured or unsecured, risk instrument or contract for differences or any other form of security"; (b) "a contract which derives its value from the prices, or index of prices, of underlying securities".

Derivatives products are treated as the securities under the SC(R) Act, 1956 and hence the trading of derivatives is governed by the regulatory framework under the SC(R) Act, 1956.

Derivatives are the standardized contracts between two parties which specify conditions of contract such as dates, values, volume, definition of underlying variables, and contractual obligations of parties, etc., under which payments are to be made between the buyer and sellers. A party who takes long position in market is called buyer of the derivatives contracts while other party who takes short position is called seller of the derivatives contracts.

There are two groups of trading derivative contracts: firstly, exchange traded derivative (ETD) contracts which are traded on the recognized stock exchange or derivatives exchange. The exchange traded derivative contracts such as futures and options are standardized financial contract. They are standardized in relation to the legal uniformity, process uniformity and product uniformity. In other words, the price, maturity, quantity, frequency, quality, and documentation etc., are standardized and defined by exchange. It should be noted that the clearinghouse guarantees that the other side of any derivatives contracts traded on ETD performs to its obligations. Secondly, the over-the-counter (OCT) contracts which are privately traded derivatives such as swap which does not go through an exchange. Trades on the OCT are executed through telephone and computer linked networks of the dealers. The dealers or usually financial institutions are known as the market makers (MM) who quote both a bid price and an offer price. The market makers are also called liquidity providers and they are appointed by the stock exchange. Abid price means a price at which the MM is ready to buy and an offer price means a price at which MM is ready to sell. The difference between the bid price and offer price is called bid-offer spread. The main advantage of the OCT is that they offer tailor made products for their corporate clients but this market also attracts credit risk. The telephonic conversations between the financial institutions or between one financial institution and its clients are taped and in the case of any dispute, this taped conversation is used to solve the dispute.

Financial derivatives offer different types of derivative products. The most common types of derivatives products traded in the market are futures, options, forwards and swaps which are briefly defined as follows:

**Futures:** A futures contract is a standardized contract and is traded on the recognized exchange. This is an agreement between two parties- a buyer and a seller to buy or sell at a future date at a price agreed today. Under the futures contract, both parties have obligation to honor the contract. This type of contract is subject to a daily settlement procedure and does not carry any credit risk because the clearing house works as counter-party to both parties in the contract.

**Options:** Options are a type of derivatives contract. It is a standardized contract which gives option in the hand of the buyer but not the obligation to buy or sell an underlying asset at a set price on or before a certain date but the seller has obligation to honor the contract. A call option gives the buyer the right to buy or not to buy while a put option gives the buyer the right to sell or not to sell an underlying asset.

**Forwards:** A forward contract is a customized contract between two parties- a buyer and a seller where settlement takes place on a specific date in future at a price agreed today and usually traded on the OCT. These types of contracts are bilateral contracts and hence exposed to counter-party risk in the market. The forwards contracts prices are generally not available in public domain and get settled by the delivery of asset on the expiration date.

**Swaps:** A swap is an OCT traded derivative contract made between two parties to exchange cash flows in the future according to a prearranged formula. The two popularly used swaps contracts areinterest rate swaps and currency swaps which are traded between financial institutions through the OCT. Swaps derivative contracts are not traded on the recognized exchanges and Retail investors usually do not trade in swaps.

The price or cost of an option is an amount of money paid by the buyer of the option as a premium to the option seller in exchange for the right granted by the option. The premium or the price of an option has two components, namely, the intrinsic value and time value which are defined as follows:

**Option premium:** Option price which is paid to the option seller by the option buyer is called option premium. This is a price of an option that the option buyer pays and the option seller receives for the rights granted under the option contract. In other words, the option price is called option premium. It is made up of two components, namely, the intrinsic value and the time value. The premium amounts for call and put options are denoted by ‘C’ and ‘P’ respectively

**Intrinsic value:** For an option, the intrinsic value means the amount by which an option is in the money if it is in-the-money (Vohra and Bagri 2007). Therefore, an option, call and put, which is out-of-the-option or at-the-money option has a zero intrinsic value.

The intrinsic value of a call option which is in-the-money is the excess of stock price ($S_0$) over the exercise price (E) or the strike price. The intrinsic value is zero if the call option is at-the-money or out-of-the-money. It is calculated by the following formula:

$$\text{Intrinsic value of a call option} = \text{Stock Price } (S_0) - \text{Exercise Price } (E)$$

The intrinsic value of a put option which is in-the-money is the excess of exercise price (E) over the stock price ($S_0$). The intrinsic value is zero if the put option is at-the-money or out-of-the-money. It is calculated by the following formula:

Intrinsic value of a put option = Exercise Price (E) - Stock Price ($S_0$)

**Time value:** The difference between the option premium and the intrinsic value of the option is called the time value of an option. If both call or put option are at-the-money or out-of-the-money, the entire premium amount becomes time value because their intrinsic values are zeros. The time value is calculated by the following formula:

Time value of a call option: Premium of a call option - Intrinsic value of a call option.

Time value of a put option: Premium of a put option - Intrinsic value of a put option.

**Cost of carry:** According to the BSE cost of carry (COC) is the cost of carrying or holding a position from the date of entering into the transactionupto the date of the maturity of the contract. It includes the storage cost plus interest that is paid to finance the asset less any income earned on the asset. As far as equity derivative is concerned the cost of carry represents the interest cost incurs to finance funds.

**Moneyness of an option:** Moneyness is a description of an option related to its exercise price (or strike price) to the market price of its underlying asset. Moneyness, simply, tells option holder whether the immediate exercising of an option will lead to a profit. An option (call and put), at the time of writing a contract, on the basis of its moneyness can be- ITM (In-The-Money) option or OTM (Out-of-The-Money) option or ATM (At-The-Money) option.

A call option is said to be In-The-money (ITM) if the stock price ($S_0$) (of any underlying) is greater than the exercise price (E), while if the stock price ($S_0$) is smaller than the exercise price the call option is said to be Out-of-The-Money (OTM) option. The reverse holds true for the put option. In other words, a put option is said to be In-The-Money (ITM) if the exercise price (E) is greater than stock price ($S_0$), while if the exercise price (E) is smaller than stock price ($S_0$) the put option is said to be Out-of-The Money (OTM) option. An option either call or put option is said to be At-The-Money (ATM) if stock price ($S_0$) is equal to exercise price (E). The above-mentioned same conditions are applied for option written on stock index Nifty 50. The condition and concept of ITM, OTM and ATM for call and put options can be briefly explained through the following table [Vohra and Bagri, (2007), pp. 137]

| Table 1.1: Conditions for ITM, OTM and ATM options | | |
|---|---|---|
| Condition | Call option | Put option |
| $S_0 > E$ | ITM | OTM |
| $S_0 < E$ | OTM | ITM |
| $S_0 = E$ | ATM | ATM |
| Source: Compiled by Researcher from Vohra and Bagri, (2007) | | |

Hence, call and put options will be ITM and OTM respectively when $S_0 > E$. Call and put options will be OTM and ITM options respectively when $S_0 < E$ while call and put option will be ATM options when $S_0 = E$.

**Maturity of an option:** At any point of time of writing a contract, an option (call and put) and stock futures traded on NSE, on the basis of its maturity and delivery can be near month contract or next month contract or far month contract. The near month, next month and far month contracts are for one month, two months and three months respectively. The stocks and stock index Nifty 50 options and futures contracts expire on the lastThursday of the expiry month. If the last Thursday is a holiday, the contracts expire on the previous trading day and a new contract is introduced on the trading day following the expiry of the near month contract.

**Discounting Value of Future Price:** The future price is discounted at a discount rate to know the its present value. Discounting means bringing the increased amount back to the present value at a particular interest rate. Discounting of a value is opposite to the compounding process of a value and is needed when some money to be received in future is to be expressed in terms of the present time.

### 1.2. NEED OF THE STUDY

The Indian capital market has been undergoing the phase of reformation since 1991. Introduction of derivatives in the capital market is an important episode in the reform process. Risk hedging, price discovery and accuracy are the pivotal roles of the derivatives. Therefore, an effective security market provides three principal opportunities- trading equities, debt securities and derivative products. For the purpose of risk management and trading, the pricing theories of stock options have occupied important place in derivative market. The participants of the derivative market enter in the market after realizing the fact that the concern option pricing model exhibits less errors and transparency has been maintained. it is important for the participants to adopt that model which exhibits less pricing error and helps to create and maintain confidence level among the various stock market participants.

Hence, Pricing of an option is the central to the theory of financial derivatives and risk management. These theories range from relatively undemanding binomial model to more complex B&S Model (1973). The Black-Scholes model is widely used by the leading stock exchanges, traders, investors and investment banks etc., for pricing options contract written on stocks and index but this model exhibits certain pricing biases on several parameters used in the model such as pricing biasness, money biasness, and maturity biasness, etc. It has been generally observed, during the literature review that the B&S model misprices options considerably and the volatilities are high for in the money options and low for out of the money options indicating that the B&S model under prices in the money options and over prices out of the money options. One of the possible reasons for the option pricing bias can be attributed to the negative cost of carry phenomenon associated with the Indian market (Varma, 2002). It has been found that, index Nifty futures also suffer from the ‘cost of carry’ bias. Usually, the future prices of index Nifty are quoted less than Nifty spot prices (Mitra, 2008) which obviously causes difference between the actual prices of options and prices of options calculated under the B&S model for the European style of index options and hence, needs to be shown but the studies were not conducted on the European style of stock. The extant literature reviews the B&S model in the context of other markets and specially in the context of the developed market, but there are only few studies on index options in the Indian context. Particularly, to our knowledge, there is no study which tests the predictability of the B&S model after replacing the stock spot price with the corresponding DVFP for stock options traded on NSE. One of the possible reasons for this might be that a European style of equity options contract on individual security has been introduced from 27th January, 2011 by NSE in India. What the importance of cost of carry is in options pricing models, need to be shown to the traders and investors because the spot and futures prices are linked by a cost of carry relationship and hence futures prices may contribute to the discovery of new price (Lin and Stevenson,1999).

This study focuses on mispricing of options due to 'negative cost of carry' associated in Indian market. Similar, the negative cost of carry situations are often observed in the commodity derivatives market. To address this effect, Black (1976) very scientifically used the forward prices in place of sport prices for commodity derivative. In this study, an attempt is made to determine the efficiency of the Black-Scholes model after addressing the negative cost of carry problem in pricing Nifty stock and index options and comparing the accuracy of the same with that of the original Black-Scholes model. This research study has to examine the pricing accuracy after addressing the problem of 'negative cost of carry' by using discounting value of future prices in the option pricing model instead of spot prices. In the other words, the spot price (s) is replaced by the discounted value of future price ($F.e^{-rt}$) in the original Black & Scholes model. In this research study, the theoretical options prices of Nifty fifty stocks options and Index options on S&P CNX Nifty are calculated under both the Black & Scholes model and after addressing the negative cost of carry problem by replacing the Spot price (S) by the discounted value of future price ($F.e^{-rt}$) in the original B&S model. These theoretical prices are compared with the actual quoted prices in the market to gauge the pricing accuracy and to recommend about superiority of a model as an alternate in the hand of investors and traders.

### 1.3. MAJOR PARTICIPANTS IN DERIVATIVES MARKET

The derivatives products like futures, options etc. are used by banks, financial institutions, corporates, brokers and individuals for the purposes to hedge, speculate and arbitrage in the derivatives market. The derivatives products are primarily used by participants for managing risk (hedging) by those who manage funds. But during the trading of derivative products, market participants get the opportunities of making risky profit by taking risk on the movement of underlying assets' prices (speculation) or get the opportunities of making riskless profit by simultaneous taking two opposite positions in markets to take the advantage of price differential (arbitrage). The following are the major market participants in derivatives market:

**Hedger:** when a trade is designed to cover against losses or to reduce losses because of price changes is called hedging. Hence, hedger is an individual who works as a risk minimizer. For minimizing risk, hedger takes long or short positions according to his exposure. Hedging is considered as the primary reason behind the creation of the derivative market. Hedging can be done in the areas of stock futures, index futures, commodity futures, stock option, index option, commodity option, stock spot, index spot, commodity spot prices, and forex market etc. a hedger engaged in any business activity as mentioned above where there is a chance of an unacceptable price movements. Hedger protects his position by taking an opposite position in derivatives market. This means that if he has a long position, he has to create a shot position and vice-versa. Here, it will be instructive to illustrate it with some examples. For example, suppose an individual buyer has taken a long position in stock cash market, if, here, price moves up, it will generate profit to him but if it goes down, it will create a loss. If his position is not covered by hedging, an unacceptable price movement will create a loss. Here, hedger will protect against changing in pricing by buying put option. The total number of put option contract and its prices can be calculated under the Black-Scholes model. The delta, a byproduct of the Black-Scholes model, also works as a hedge ration. In the Black-Scholes model, ($Nd_1$) also works as a hedge ration. Therefore, the participant expects that the price of the option either call or put should be fairly priced under the Black-Scholes model or under any other model. Similarly, in the context of futures market, suppose a farmer wants to sell wheat at fair price ofRs.1800 per quintal. The farmer may go for hedging in futures market by selling the futures contracts. Suppose this is February now and the April month contract of wheat is being traded for Rs.1800 per quintal and farmer finds this price is attractive to him. He now wants to eliminate the price risk associated with abundant supply of wheat. He can hedge the price risk by taking a short position for the April month expiry contract at Rs. 1800 per quintal to someone who, on the opposite side, wants to take a long position on the same agreed price and month of expiry. In this way, the farmer is secured on this price for his crops and will not be worried if the price were fall subsequently because of the abundant supply of wheat. Similarly, stock index futures contracts traded on NSE are highly used for hedging purpose. For example, if an investor has a portfolio of investment and he wants to minimize his risk. Here, he can hedge by shorting index futures or buying index put options.

**Speculator:** The participant as the speculators are the individuals who take a view on the movement of the direction of prices. They expect that price would rise or fall and accordingly they take short or long position in the futures and options market to generate profit from the movement of price of the underlying assets. Speculators in the derivatives market are willing to bear risk and hence they are called risk taker. They generally try to project in what direction market would go by using technical and fundamental analysis. In this way they register substantial gain or losses during their strategies for profit maximization within a short term. In this way, their activity enhance liquidity in the market. The speculators have completely opposite views as compared to the hedgers. The hedger works to minimize the unacceptable price risk, so they must find those who (speculators) are ready to take such risk. Hence, both hedger and speculator enter in transection for their own mutual benefits. A speculator takes long position in the futures market if he realizes that the prices of the underlying assets are expected to rise and takes a short position if he realizes that prices are expected to fall. For example, if price of SBI stock is expected to fall, a speculator prefers to short sell these shares in the derivative market without having the position in cash market. Here, if stock price falls according to his expectation, speculator will earn a sizeable profit but if does not fall, he will suffer from a commensurate loss. Another example can be taken from the option market for hedger and speculator; for example, if a trader has taken a long position in the stock cash market, he buys a put option to hedge his position from a fall in the stock cash market price. Where the hedger buys put option from. The speculator comes here as a counterparty and sells put option expecting that the price of the stock in cash market would not fall. If, at the time of maturity, stock price in the cash market does not fall, the hedger will not exercise his put option and speculator will make a sizeable profit from the premium received and the reverse holds true when the stock prices in cash market increases.

**Arbitrageur:** Arbitrage refers to a trade which leads to a risk-free profit with no cash outlay in market. The individuals involved in the trade of arbitrage are called arbitrageurs. This group of participants participate in an extremely rapid environment where they make decision to buy or sell at the blink of an eye. For it they continuously monitor the price movement in different market. The arbitrageur simultaneously takes two positions in the market; buying low priced stock in one market and selling the same in another market where it is high-priced on one asset for a profit without involvement of risk. Sometimes they also take multiple positions. Hence, they are also called opportunists. They do not take price risk like speculators do.They thrive on the imperfections of market and help in price discovery which leads to market efficiency. In the option market, the arbitrage opportunities appear when options are mispriced. Cash-futures arbitrage is another arbitrage opportunity which can be explored in the derivative market by arbitrageur. Hence, an arbitrageur comes in action to exploit the opportunities once he finds that the prices of the assets in the spot market and the futures market are deviating. For example, if an arbitrageur finds that prices of futures contracts with a certain maturity date is higher than what should it be in accordance with the price in the spot market, he would step in to short futures contracts and buy in the spot market. In other words, an arbitrageur snatches profit originated because of the price differences in the markets.

### 1.4. FUTURES AND OPTIONS

**Futures:** A futures contract is a standardized financial contract between two parties where both parties agree to honour the contract written on a particular asset at a predetermined price and at a specified date in future. Hence, the buyer of the futures contract is taking on the obligation to buy the underlying asset at the predetermined price when the contract expires while the seller of the future contract, on the other hand, is taking on the obligation to provide the underlying asset at the predetermined price when contract expires. The buyer of the contract is known as a long position or simply it is called long while the seller of the contract is known as a short position or simply it is called short. The underlying assets in the futures contracts can be individual stock, commodity, currency, bond etc. The futures prices are bound to change every day, hence, the difference in prices are settled every day from the margin amount. This process on the stock exchange is known as the Marking To Market (MTM). This MTM process reduces counter parties' risk. The futures contracts are generally used by hedgers who want to protect themselves from unfavorable price movement. Hence, a hedger works as a risk minimizer using different types of derivatives products. However, speculator also participates in this market who bets on the future price of the underlying assets that will move in a particular direction. A speculator works as an opportunist in the derivatives market. On the expiry of the futures contracts, NSE clearing marks all positions and the resulting profit/loss is settled in cash on the MTM process.

**Option**

Options contracts allow traders and investors to bet on the future events and to reduce their financial risk. An option is a right to buy or sell a security at a predetermined price within a specified time frame. An option is a standardized contract, which gives the buyer (owner) the right, but not the obligation, to buy or sell specified quantity of a defined asset, at a strike price on or before the expiration date. Here, the asset is called underlying asset or underlying security or simply underlying. The underlying assets may be physical commodities like wheat, rice, cotton etc. or financial instruments like equity stocks, stock index, bonds etc.

Options contracts traded on all stock exchanges are broadly classified based on the type of exercise. There are two types of options style- American options style and European options style. American options are options which can be exercised by its owner at any time upto its expiration date. In other words, an American option can be exercised during its whole life, this means from the moment an owner buys it till the moment it expires. This flexibility of early exercise of an American style (class) of option gives advantage over a European style of option. Options on individual security at NSE in India were American style of option before 27$^{th}$ January, 2011.

European style of options contracts does not offer the same flexibility for exercising American style of options contracts. European options are options contracts which can be exercised by its owner only on the expiration date of the contracts. In other words, a European option contract can be exercised at one single moment and that is its expiration date. When the holder of options contracts buys a European style of option, he will usually save money on the price of the contract, as the extrinsic value component is generally found less due to only an option be exercised by holder at the expiration date. While a writer of European style options contracts has the advantage of a fixed expiration date and less risk being involved because he is not exposed to the possibility of the option contracts being before its expiration date. All the index option traded on NSE in India are of European type of options since its inception. European style of equity options contracts on individual security has been introduced from 27$^{th}$ January, 2011 by NSE in India.

There are two types of option- call and put option. A call option gives the buyer the right to buy whereas the put option gives the right to sell. The call options give the owner the right but not the obligation to buy an underlying asset at a specified price, for a certain period of time. The specified price is known as strike price or exercise price. Hence, a call option holder has an option to enjoy his right to buy or not to buy the underlying assets. The call option buyer is paying (price) premium for buying the right to buy shares or any underlying on which option is written, at a certain price within a specified time frame. The holder of a call option enjoys his right to buy when the spot price of the underlying asset becomes higher than the exercise price of the underlying asset on the date of expiration of the option contract. But if the spot price of the underlying asset becomes lower than the exercise price of the underlying asset on the date of expiration of the option contract, the option holder does not exercise his right or simply call option contract in this case expires worthless. Here, in this case, the premium amount paid by the option holder is his maximum loss and the same amount will be the maximum income for the option writer. In other words, the maximum profit for call option writer is limited to the call premium. But if the spot price increases over the exercise price or strike price, the call option holder enjoys his right to buy and call option will lead to huge incomes for option holder and the option writer will suffer from huge losses. Selling an option is known as the writing an option. The writer of the call option is obligated to sell the underlying asset at the strike price. An investor buys call options when he thinks that the share price of the underlying asset will rise in near future or he can also sell call options if he thinks the share price will fall in near future.

The concept of put option is the exact opposite of the call option. The put option gives the option holder (owner) the right but not the obligation to sell an underlying asset at a predetermined price for a certain period of time. Here, the predetermined price means strike price. The holder of a put option enjoys his right to sell when the strike price (exercise price) of the underlying asset becomes higher than the spot price of the underlying asset on the date of expiration of the option contract. But if the strike price of the underlying asset becomes lower than the spot price of the underlying asset on the date of expiration of the option contract, the option holder does not exercise his right or simply put option contract in this case expires worthless. The writer of the put option is obligated to buy the underlying asset at the strike price. The put option holder buys right to sell the underlying asset and hence, for this right, holder pays premium to writer.

Therefore, the maximum profit for put option write is limited to the amount of put premium. But if the exercise price increases over the spot price, the put option holder enjoys his right to sell and put option will lead to huge incomes for option holder and the put option writer will suffer from huge losses. The traders and investors buy (long position) put options if they think the underlying asset spot price will fall. However, they can also sell (short position) the put options if they think that the underlying asset spot price rises.

## 1.5. ROLE OF DERIVATIVES

The role of any security market is to provide a facility in which prospective investors and enterprises can come together with confidence to create prosperity through sharing of risks and rewards. The security market helps in facilitating the flow of funds from investors to productive enterprises and this eventually stimulates economic growth. An effective security, which is judged through the pricing accuracy, liquidity and good risk-reward relationship, is a necessary condition for corporate vitality. It provides opportunities to the participants for trading Equity, Debt Securities, and Derivatives. The purpose of derivative market is to provide product and techniques applicable for risk hedging, price discovery, and price accuracy. The derivatives markets perform a number of roles in an economy:

**Price Discovery:** The futures and options market help in the price discovery. Derivatives products particularly, exchange traded, are intrinsically designed to aid in price discovery. When some new information arrives in the market, perhaps some good news about the economy, the individuals are inclined to participate in these markets to take the advantage of such information. Therefore, these markets indicate what is about to happen and help in price discovery and increasing liquidity in the market.

**Risk Transfer:** Derivatives products are intrinsically designed to transfer risk. These products allow hedgers to protect their positions. Hedgers use derivative product for the purpose of distributing the risk between the market participants against the unfavorable market movement. However, for this, they pay premium to those who are prepared to take risk.

**Market Completion:** The availability of the derivatives products helps to the degree of the market completion. In this market, the complete set of possible bets on the future state of the economy can be made with the existing assets without friction. Hence, here financial derivatives products can be developed to cover against all the possible adverse outcomes.

Derivatives also plays role in the price stabilization, exploit opportunities to increase returns and controlling market activities.

**1.6. HISTORY OF DERIVATIVES MARKET**

Trading was one of the most established practices for prehistoric people over a hundred thousand years ago. At that time people were exchanged goods and services before the invention of money. Ancient people used non-perishable goods such as wine, grain, or other objects as an intermediary store of value.

The history of derivative instruments can be traced back to 2500 years from the story of the Greek philosopher Thales. It is believed that the Greek philosopher Thales was the first person who introduced and used derivative instrument. Thales predicted an unusually large olive harvest during the winter time (Kummer, 2012). He seized the opportunity and negotiated with the olive press owners the right, but not the obligation He hired all the olive presses in the region for the following autumn. Thales made a cash deposit to secure his right.

Derivatives were continued to be an instrument facilitating trade in the middle ages. Italian merchants in the 10th century, were using derivatives called Commandas which were a kind of commercial partnership contract for sea or land venture. Antwerp, a centre for local and international traders in England, was sacked by Spanish troops in 1585 and Amsterdam emerged during the 17th century as a centre of stock derivatives trading.

One of the first records of an organised market for derivatives trading came from Osaka, Japan in the 17th century where rice was traded. At that time trading of rice was a big business in Japan and thus Dojima Rice Exchange was formed in 1730.

No one knows when option trading began but it is believed in the history that it is similar to that of the forward contract. In 1848, a first derivatives exchange was established in Chicago, United States. It is known as the Chicago Board of Trade (CBOT).  It the oldest organised futures market still operating in the world. However, CBOT had been merged with the Chicago Mercantile Exchange (CME) in 2007. The CBOT was originally formed as a market place for exchanging grain. The 20$^{th}$ century was the landmark where listed options were traded on CBOT in USA. The Chicago Board of Options Exchange (CBOE) was opened in April 1973 for diversifying options market and organized option trading was started. The first options market with guaranteed settlement and standardization of price, expiration, and contract size for all listed call options was initiated by CBOE on 26$^{th}$ April, 1973. The popularity of on-line trading with the help of computer gave a big momentum to the trading of derivatives.

## 1.7. COMMENCEMENT OF DERIVATIVE SEGMENTS IN INDIA

The Bombay Cotton Trade Association started trading of futures in 1875 in the areas of commodities. Early forward types of trading called Badla were traded in the equity market. The government banned cash settlement in 1952 and derivatives trading shifted to informal forwards markets. After the initiative of economic reform started from 1991, government has changed its policy regarding the derivatives market and consequently, imposed bans have been lifted. Government has established NSE in 1993 and prohibition on trading options was lifted by government in 1995. SEBI had set up a committee under the chairmanship of Dr. L. C. Gupta on November 18, 1996 to develop appropriate regulatory framework for regulating derivatives market in India. On the committee recommendation derivatives have been declared as securities. SEBI had also set up a committee under the chairmanship of Prof. J. R. Varma 1998, to recommend about risk containment in derivatives market. the committee recommendation operational details of brokers, initial margin, depository and real time monitoring.

Government amended the Securities Contract Regulation Act (SCRA) in 1999 and allowed to treat derivative as a security. Through the amendment, trading of derivatives brought under the regulatory framework. Now the trading of derivatives shall be legal and valid if these are traded on a recognized stock exchange.

The National Stock Exchange of India Limited (NSE) had commenced trading in derivatives segment with the launch of index futures on June 12, 2000. SEBI had granted permission to NSE and BSE for trading in derivative segments. The trading of futures contracts is based on the popular benchmark stock index of S&P CNX Nifty (Now Nifty50) and BSE-30 (SENSEX).The trading in BSE Sensex options commenced on June 4, 2001 and the trading in options on individual securities commenced in July 2001.

The trading of index options on stock index Nifty50 was introduced on June 4, 2001. NSE also became the first exchange to launch trading in the American style options on individual securities in India from July 2, 2001. Futures trading on individual securities had been introduced on November 9, 2001. However, the NSE has switched from the American style of options to the European style of options from 27th January, 2011. The exchange currently provides a variety of equity derivatives products for trading in Futures and Options segments which include individual securities, Nifty 50 Index, Nifty Midcap 50 Index, Nifty Bank Index, Nifty Infrastructure Index, Nifty IT Index, Nifty PSE Index and Nifty CPSE Index.

**1.8. FACTORS AFFECTING PRICES OF OPTIONS**

There are six primary factors such as underlying asset's spot price, strike price, time to maturity, volatility, and risk-free rate of interest that influence prices of options calculated under the Black-Scholes model. These factors are discussed below:

1. Underlying asset's spot price: An underlying asset, in derivative market, is the security on which an option contract is written or a derivative contract is based upon. Hence, an underlying asset's price is the market price of the underlying asset traded on exchanges. An underlying asset includes stock, commodity, index, currency etc. The underlying assets are used to determine the value of the option up till expiration. The value of an underlying asset may change up till expiration of the contract, consequently affects the price of the call and put option. The payoff resulting from the exercising of a call option is the excess of underlying asset price over the exercise price. Hence, a call option becomes more valuable when the underlying asset price increases and less valuable when underlying asset price decreases in the market. For a put option, on the other hand, the payoff resulting from exercising of a put option is the difference between exercise price (strike price) and the underlying asset price. Consequently, a put option is more valuable when the underlying asset price decreases and less valuable when it increases. Therefore,

it can be concluded that if the price of underlying asset increases, the value of call option increases and value of put option decreases but if the price of underlying asset decreases, the value of call option decreases and value of put option increases.

2. Strike Price: The strike price of an option is also known as exercise price. It is the price for which the owner of an option can buy or sell the underlying asset if the owner decides to exercise the option. The strike price of an option is fixed once the contract has been executed between both parties and does not change during the whole life of the option contract. At this strike price security can be bought for call option and sold for the put option. The strike prices of an option are fixed by the concerned stock exchange (NSE). An option is available for trading at different strike prices. The gap between two strike prices is called step value which is determined by NSE based on the volatility of the underlying asset. These step values can be reviewed and revised if required by the NSE. Earlier, step values between two strike prices were kept uniform.

The profit or loss between two parties is decided by the strike price (E) and spot price ($S_0$) of the underlying asset. ITM strike prices are those where the option owner makes money by exercising the option to buy or sell the option while ATM strike prices are those where the option owner neither makes a profit or a loss. OTM strike prices are those where the option owner never makes money and hence the same is never exercised.

A call option quoted with a higher exercise price can not be valued higher than another call option with the same parameters but with a lower exercise price. Hence, a call option with a higher exercise price cannot be valued higher. In other words, the value of a call option decreases as the exercise price increases. On the other hand, a put option quoted with a lower exercise price can not be valued higher than another put option with the same parameters but a higher exercise price. Hence, a put option with a lower price cannot be valued higher. In other words, the value of a put option generally increases as the exercise price increases. It should be noted that the payoff for call and put options are calculated from the spot value ($S_0$) of underlying asset and its exercise price (E) or strike price. Therefore, premiums (price of option) increase as call and put options become further in-the-money.

3. Time to maturity: Every option has limited life or a fixed expiration date. The length to time to expiration is known as the time to maturity in option pricing. If the time to expiration of an option increases, the value of option also increases. The longer expiration of an option gives chance that it will end up in-the-money i.e., chance of profitability. The logic behind it is that the underlying assets have more potential for movement and thus the options will have a greater value. But as the time to expiration of an option gets closer, the value of the same option starts to decrease. In other words, as expiration approaches, the option’s time value starts to decrease.

4. Volatility: Volatility is the only calculated factor in the Black-Scholes model. The degree to which price moves up or down is measured by volatility. Hence, the speed and magnitude of the underlying’s price change is measured by volatility. The Black-Scholes model uses historical volatility which is calculated over a specified time period. This is considered to be one of the important variables which affects the price of the options. If the underlying asset exhibits higher volatility, higher option premium (price) is expected by the traders and investor because the underlying asset has higher expected price fluctuations and if lower volatility is exhibited, lower option premium is expected. Hence, an increase in volatility, causes an increase in the price of both call and put option. The price of call option increases because the underlying asset’s price can increase to a higher price level due to high volatility of asset. For the put option, on the other hand, the price of put option increases because the underlying asset’s price can fall to a lower price level due to high volatility of asset.

5. Dividend: The price of option fluctuates when dividends are released on the underlying asset as dividend is not received on option. Companies generally release dividends on the ex-dividend date. An owner of the underlying on that date is awarded with dividend. But the value of the underlying asset decreases by the expected dividends consequently the value of a call option decreases while put option value increases. However, the model is get adjusted for dividend by subtracting the discounting value of future dividend from the stock price.

6. Risk-free rate of Interest Rate: The purchase of an option incurs either if the borrowed money is used (interest expense) or if the existing fund is used (lost interest income). The

value of a call option increases with an increase in the risk-free rate of interest while the value of a put option decreases with an increase in the risk-free rate of interest because of the associated interest cost. But on the other hand, fall in risk-free rate of interest has different impact on option price i.e., the value of a call option decreases with a decrease in the risk-free rate of interest while the value of a put option increases with a decrease in the risk-free rate of interest.

The value of a stock option is broadly affected by six factors: the market price of the underlying asset, strike price, expiration date, volatility, risk-free interest rate and the dividend if received. Hence, According to Hull, (2007) "the value of a call generally increases as the current stock price, the time to expiration, the volatility, and the risk-free interest rate increase. The value of call decreases as the strike price and expected dividends increase. The value of a put generally increases as the strike price, the time to expiration, the volatility, and the expected dividends increase. The value of a put decreases as the current stock price and the risk-free interest rate increase".

### 1.9. BLACK-SCHOLES MODEL AND ITS ALTERNATIVES

Fisher Black and Myron Scholes developed a mathematical model for pricing a European style option and published in 1973 in an article titled "The Pricing of Options and Corporate Liabilities". They have also published in 1972 titled "The Valuation of Option Contracts and a Test of Market Efficiency" in the Journal of Finance. Merton (1973) later published a follow-up paper expanding the mathematical understanding of the model for pricing options contracts. Merton gets credit for naming the model "Black-Scholes." This model is also referred to as the Black-Scholes-Merton model. The model has had a great influence on the way that traders and investors price options contracts. This option pricing model was a landmark in the history of financial modelling and continues to be the preferred model for theoretical valuation of option prices.The Nobel Memorial Prize in Economic Science in 1997 was awarded to R. C. Merton and M. Scholes for their work with model. However, F Black was mentioned as a contributor by the Swedish Academy. This model is based on following assumptions:

1. The asset price follows a random walk in continuous time and thus the distribution of stock prices is log normal.
2. There are no transaction costs or taxes. It means there are no transaction cost in buying or selling the stock or option.
3. There are no riskless arbitrage opportunities.
4. The risk-free interest rate is constant. It is assumed that the short-term interest rate is constant through time.
5. There is no penalties to short selling.
6. There is no dividend during the life of the option paid by the underlying asset.
7. The option is exercised at the time of maturity i.e., The option is a European style of option, that is, it can only be exercised at maturity.

The pair formula for the prices of European stock call and put options respectively constitutes the Black-Scholes Model-

$$c = SN(d_1) - Xe^{-rt}N(d_2) \qquad [1.1]$$

$$p = Xe^{-rt}N(-d_2) - SN(-d_1) \qquad [1.2]$$

Where,

$$d_1 = \frac{ln\frac{S}{X} + (r + 0.5\sigma^2)t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{ln\frac{S}{X} + (r - 0.5\sigma^2)t}{\sigma\sqrt{t}}$$

The variables are-

$c$ = Call Price

$p$ = Put Price

$S$ = Current Stock price or underlying assets price

$X$ = Exercise price

$t$ = Time remaining until expiration, expressed as a percent of a year

$r$ = continuously compounded risk-free interest rate

$\sigma$ = standard deviation of the continuously compounded annual rate of return

$N$(d) = value of Cumulative normal distribution evaluated at d.

$ln(\frac{S}{X})$ = natural logarithm of $(\frac{S}{X})$

The unknown parameter of this model is $\sigma$. Basically the Black-Scholes Model says that the option price, no matter it is call or put, is a function of asset price, exercise price, time to maturity, volatility of asset price and risk-free interest rate. All those variables except for the volatility are easily obtainable from the market. $\sigma$ is not a known factor in the formula. $\sigma$ is often assumed unchanged when forecasting option prices. Basically, estimating б falls into two approaches- historical and implied volatility approaches. The annualized standard deviation of historical daily returns is defined as the historical volatility. The historical approach is much simpler than the other one. The implied volatility is, however, computed out of the Black-Scholes Model in reverse. It is more commonly used method to estimate volatility since it looks more on the future.

In the above formula, the term $Xe^{-rt}$ denotes the present value of exercise price discounted at risk-free rate ‘r’ for the time left to maturity. From this expression it can be assumed that exercise price of the option at a future date contains an interest rate component over the intrinsic value of exercise price. It is also logical that, the future price will be higher than current price due to the positive interest rate component.

However, the future prices of S&P CNX Nifty index quoted in the market do not seem to follow the above argument. Actual Nifty future prices quotes are usually below their theoretical prices. One of the possible reasons of futures trading below fair value, (not always lower than the underlying securities), can be attributed to the short selling restrictions of underlying stock.

In practice, when future price is greater than $S.\ e^{rt}$ (i.e., $F > S.e^{rt}$) one can easily sell future and buy underlying stocks, conversely when future price is less than $S.e^{rt}$ ($F < S.e^{rt}$) stocks can be short sold (due to short sell restriction put by stock exchange in India). Due to this short selling restriction, future prices often trade less than the value of $S.e^{rt}$.

Before the development of the Black-Scholes model, some of the earlier works had been done by Sprenkle (1961), Boness (1964), Samuelson (1965) and Chen (1970). Some of them can be briefly described as:

**Sprenkle (1961)** developed option pricing formula based on the assumption that stock prices are lognormally distributed which can be written as:

$$C = e^{pt} S * N\left[\frac{\ln\left(\frac{S}{X}\right)+\left(p+\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}\right] - (1-z)X * N\left[\frac{\ln\left(\frac{S}{X}\right)+\left(p-\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}\right] \qquad [1.3]$$

Where,

$p$ is the average rate of growth of the share price and $z$is the degree of risk.

**Samuelson (1965)** developed the following formula for pricing warrant:

$$C = e^{(p-w)t} S * N\left[\frac{\ln\left(\frac{S}{X}\right)+\left(p+\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}\right] - e^{-wt} X * N\left[\frac{ln\left(\frac{S}{X}\right)+\left(p-\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}\right] \qquad [1.4]$$

Where,

$p$ is the average rate of growth of share price and $w$ is the average rate of growth of the value of call option.

The Black-Scholes model has been modified and extended by various authors to price options. These modifications include the following:

**(a) Merton (1973)** modified original Black-Scholes model for pricing European style stock or index call and put options which pays known dividend yield equal to q through the following formula:

$$c = Se^{-qt}N(d_1) - Xe^{-rt}N(d_2) \qquad [1.5]$$

$$p = Xe^{-rt}N(-d_2) - Se^{-qt}N(-d_1) \qquad [1.6]$$

These equations are very similar to the Black-Scholes model (1973) and all other parameters of Black-Scholes model (1973) are kept unchanged.

**(b) Black (1976)** modified original Black-Scholes model for pricing commodity options which is very similar to the Black-Scholes model. Fisher Black one of the co-authors of the Black-Scholes model found the negative cost of carry bias and attempted to address this problem of negative cost of carry by using forward (future) price in place of spot price in his model. He developed a mathematical model for pricing European style of commodity option and published in 1976 in an article entitled “The Pricing of Commodity Contracts”.

He in his article demonstrated how the Black-Scholes model could be modified in order to value a European call and put options. This model is a variation of the Black-Scholes model that allows for the valuation of European style options contract written on physical commodities, futures or forwards, bond and swaptions contracts.

Black (1976) tried to address the problem of negative cost of carry by using forward price in his option pricing model instead of ‘spot prices’. He argued that actual forward prices not only incorporate cost of carry but also capture various irregularities faced by market forces. In his model, he replaced sport price (S) by the discounted value of future price ($F.e^{-rt}$) in the original Black-Scholes model. This model is very useful for pricing options contracts written on physical commodities where negative cost of carry is common. The Black’s Model is widely used for valuing options on physical commodities as the discounted value of the future price is found to be a better proxy of current sport prices as an input to the Black-Scholes Model. In this research stock and index spot prices has been replaced by their corresponding DVFPs to as modified by F. Black for commodity.

The pair formula for the European style of commodity call (c) and put (p) options as per Black’s model can be determined by solving following equations assuming futures prices have the same lognormal property as the Black-Scholes model assumed [Hull, (2007), pp. 354]-

$$c = F\, e^{-rt} N(d_1) - X\, e^{-rt} N(d_2) \qquad [1.7]$$

The corresponding put price (P) is

$$p = X\, e^{-rt} N(-d_2) - F\, e^{-rt} N(-d_1) \qquad [1.8]$$

Where,

$$d_1 = \frac{ln\left(\frac{F}{X}\right) + \left(\frac{\sigma^2}{2}\right) t}{\sigma\sqrt{t}}$$

$$d_1 = \frac{ln\left(\frac{F}{X}\right) - \left(\frac{\sigma^2}{2}\right) t}{\sigma\sqrt{t}}$$

N(d) = the value of cumulative normal distribution evaluated at d

X = Strike price, it is denoted by K and

F = is the future price of the security having maturity 't', and all other parameters of Black-Scholes model (1973) are kept unchanged.

It should be noted that the Black equations are exactly what one would obtain if we used the Black Scholes formula with the stock price S replaced by $F{*}e^{-rt}$ (Varma, 2002).

**Similarity with Commodity Futures-** Similar situations are often found in trading of commodity futures, when F < $S.e^{rt}$, where r is the cost of carry. Though future prices are lower, the owners of physical commodity may not sell the commodity either for consumption purposes or for benefiting from temporary local shortages. In cases of many agricultural crops, sport prices before harvest rise due to shortages of the commodities, but prices fall just after harvest when fresh supplies arrive. The sport price of a commodity can well be more than future price in periods of shortage. The benefits of higher sport price are often referred as the convenience yield, provided by the product. The convenience yield is likely to remain positive if the demand of the commodity persists during the validity of the future contract. However, the concept of convenience yield cannot be extended to securities as temporary shortages and fresh arrivals are not applicable and accordingly, the convenience yield for securities such as Nifty must be zero.

**(c) Garman and Kohlhagen (1983)** modified Black-Scholes model for pricing European style of option written on currency using an approach very similar to Black-Scholes (1973) and Merton (1973) through the following formula:

$$C = e^{r_F t} S * N\left[\frac{ln\left(\frac{S}{X}\right)+\left(r_D - r_F + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}\right] - e^{r_D t} X * N\left[\frac{\ln\left(\frac{S}{X}+\left(r_D - r_F - \frac{\sigma^2}{2}\right)\right)}{\sigma\sqrt{t}}\right] \quad [1.9]$$

Where,

$r_F$ is the interest rate of foreign currency and

$r_D$is the interest rate of domestic currency

### 1.10. COST OF CARRY

The forward and futures contracts are generally priced under the two standard theories namely, the cost of carry and the risk premium hypotheses. These theories study the relationship between spot prices and forward/futures prices through the non-arbitrage conditions or the general equilibrium settings. However, the cost of carry model is largely preferred for pricing futures contracts (Chow, McAleer and Sequeira, 2000). The financial futures contacts are priced under the cost of carry model (Kaldor, 1939).

The cost of carry is the cost which incurs because of an investment opportunity over a period of time. The relationship between future price and spot price is summarized in the terms of cost of carry. The price of a futures contract is the sum of spot price and cost of carry.  This is based on the cost associated with carrying the underlying assets such as investment and consumption asset until the date of expiration of the contract. An investment asset is held for the purpose of investment by a significant number of investors. The consumption asset is held for the purpose of consumption. This, Generally, measures the storage cost plus the interest that is paid to finance the asset less the income earned on the asset. The user of the consumption assets feels that the ownership in spot market provides benefits that are not obtained from the holding of futures contracts. This benefit from holding the consumption asset of physical commodities is known as convenience yield. This research does not focus on consumption asset. The cost associated with carrying the investment and consumption asset fall into four groups: storage cost, insurance cost, transportation cost, and financing cost. The investment asset particularly attracts financing cost. The difference between futures price and spot price of the underlying asset reflects the carrying cost (Manu and Narayana, 2015).

Hence, for the investment asset, if cost of carry is defined as 'c', the futures price [Hull, (2007), pp. 140] is

$$F_0 = S_0 e^{ct} \qquad [1.10]$$

Where,

$F_0$: Forward or Futures Price today of an underlying future contract

$S_0$: Price of the asset underlying the forward or futures contract today

$t$: Time until delivery date in a forward or futures contract (in year)

$e$: a mathematical constant whose value is 2.7183

For the invest asset, cost of carry (c) is the interest rate (r) that is paid to finance the asset less the income (dividend yield) earned on the asset. Now the above equation for futures price, $F_0$, for the investment asset would be given by the following formula [Vohra and Bagri, (2007), pp. 87]:

$$F_0 = S_0 e^{(r-y)t} \qquad [1.11]$$

Where,

$r$: Risk-free rate of interest with continuous compounding and

$y$: Dividend yield with continuous compounding

It should be noted that the term $y$ is also denoted as q for the calculation of the index futures price where q is dividend yield because income is earned at the rate q on the asset (Cornell and French, 1983).

The pricing of future contract is done in such a way that no arbitrage opportunity arises. An assumption of the COC model is that the futures and spot market are perfectly efficient, frictionless and act as perfect substitute [(Bhatia, (2007) and Lin and Stevenson, (1999)] and hence, they can be substituted. Accordingly, the spot price of index CNX Nifty has been replaced by their corresponding Discounting Value of Futures Price (DVFP) by Verma (2002) and Mitra (2008 and 2012) for the calculation of option prices written on the index CNX Nifty traded on NSE in India. In perfect efficient markets profitable arbitrage should not exist because prices adjust themselves instantaneously in markets and fully to new information (Raju and Karande, 2003).

In the normal market, the futures contracts written on stocks and equity index are priced according to the cost of carry equation. Hence, the pricing of futures contracts follows a process by which a risk-averse seller of the contracts buys the security, incurring the cost of an interest rate in the process. According to N D Vohra and B R Bagri, “The dividends, if any, resulting from holding the security, during the currency of the contract, represent negative cost (called carry return) are netted from the interest cost and the net cost is effectively the cost of maintaining a risk-free position.”

But sometimes futures prices of stocks and index Nifty 50 are traded at the lower prices than their corresponding spot prices because of the transaction cost, margin size, short sales restriction imposed by the Securities and Exchange Board of India (SEBI) etc. The concept of short selling is used in developing some strategies involving futures arbitrage strategies. In short selling, an arbitrageur sells the securities which are not owned by him and buying them back on a later date.

The equity index Nifty futures are also traded at a discount to the underlying because of the short sale restriction in the cash market in India (Verma, 2002). It has been seen on NSE that the Nifty index futures prices quoting lower than their fair value were common during 2008-11 and hence this bias was bound to influence option pricing in the option market (Mitra, 2012).

The difference between the futures and spot prices is called the basis when the futures contract is on a financial asset. This is the definition of the basis for the financial asset. However, Basis is also defined as the difference between spot price and future price when the futures contract is written on the commodity (Hull, 2007). This basis can be positive or negative. In the normal market, the value of future contacts of equity Index and stocks would be quoted higher than their corresponding spot prices; consequently, it gives positive basis. However, it is not always found that the futures prices would be higher than their corresponding spot prices. Sometimes the futures prices of equity index and stock may be quoted lower than their corresponding spot prices. This type of situation is found in the inverted market where underlying assets' spot prices are found higher than their corresponding futures prices.  In normal market, the investors and traders sell the futures contracts who buy the same underlying on the spot market.

But in an inverted market, sometimes, the equity index futures and stock futures are traded at a discount in relation to the spot prices, it has the implication that some market players strongly believe that the market would experience a fall in the future. In such cases investors are usually seen to make a negative call on the market. Thus, selling of the equity index futures and stock futures at lower price than their corresponding spot prices is a bearish sentiment of the investors and traders about the market movement in the future. The Indian futures market has also witnessed positive and negative cost of carry.

## 1.11. CHAPTERISATION

The chapter wise summary of the thesis is given as follows:

### Chapter 1: Introduction

This chapter provides an overview of the basic definition used in the derivatives market which is followed by the Need of the study, Major participants in the derivatives market, Futures and options, role of security market, History of derivatives market, Commencement of derivative segments in India, factors affecting the price of options, Black-Scholes model, modified and extended Black-Scholes model by other authors, Black (1976) model for commodity and cost of carry. This chapter, at the end, also discusses the chapter wise organization of thesis.

**Chapter 2: Review of Literature**

This chapter is a review of literature on the option and futures pricing related to the present study. This chapter has two section: firstly, Reviews of spot and futures pricing literature Secondly, Reviews of Options Pricing Literature. This provides in detail about the relevant literature study which has been carried out to understand the insight knowledge about the existing research works related to the Black-Scholes options pricing model, futures pricing and relationship between futures and spot price movements. Majority of literature reviews has been found on developed market and few on the developing market. Few authors are in the favour of the model. A handful studies have been found in context of India regarding the predictability of the B&S model. Different authors' findings identify different conclusions in over or under pricing options by the B&S model. Some authors found that OTM options are overpriced and ITM options are underpriced by the model while some authors suggest modification in the model. This chapter, at the end, also discusses the research gap.

**Chapter 3: Research objectives and Methodology**

This chapter deals with the research objectives formulated on the basis of research gap followed by research methodology used to achieve the stated objectives scientifically. It includes proposed hypothesis, grouping of hypotheses with description, sampling framework, research design, and statistical measures for result comparison for options pricing accuracy. The Mean Error (ME), Mean Absolute Error (MAE), Mean Square Error (MSE), Root Mean Square Error (RMSE) and Theil's U statistic and Mean Absolute Percentage Error (MAPE) have been used as the statistical measures for result comparison.

**Chapter 4: Data Analysis and Interpretation**

This chapter starts with the procedures involved in the visual inspection regarding how many times stock and index futures prices are traded lower than their corresponding spot price and then the futures prices have been discounted and again compared with spot prices. The efficiency of

B&S model for options pricing has been tested in three stages. In stage first options prices have been calculated based on the spot prices and compared with the market closing prices to identify the pricing errors. In stage second stage, a modification has been done, options prices have been calculated based on the DVFP, after replacing spot prices to address the negative cost of carry problem and compared with the market prices to identify the pricing errors. Stage third deals with the comparison between the original Black-Scholes model and modified Black-Scholes model. In other words, options prices calculated on the basis of spot prices and options prices calculated on the basis of DVFPs have been compared.

**Chapter 5: Findings and Conclusion**

This chapter includes findings obtained during the data analysis and interpretation. This includes: first findings are drawn from stage first regarding the efficiency of the Black-Scholes model, stage second after replacing spots prices by their corresponding futures prices and stage third in which the pricing accuracy calculated under the stage first and second has been compared. It includes over and under valuation of options. The findings of Options subgroups such as OTM, ATM, ITM, Near Month, Next Month and Far Month and call to put bias have been also included in this chapter. Conclusion part deals with the conclusion of all the work done in the previous chapters. It includes and provides the major conclusion regarding the various objectives stated in the study.

**Chapter 6: Limitation, Suggestion, Contribution and Scope**

This chapter describes the limitation of study. Suggestions have been also drawn from the finding. The contribution of this research regarding the efficiency of option pricing has been discussed. At the end scope for further study has been outlined.

Option pricing is one of the important parts of financial derivatives. The price of an option is broadly affected by the underlying spot price, strike price, time to maturity, dividend and risk-free rate of interest. For the purpose of risk management and trading, the pricing theories of options under the celebrated Black-Scholes model has occupied important place in derivative market. Before the development of the Black-Scholes model, some other authors such as Sprenkle (1961), Boness (1964), Samuelson (1965) and Chen (1970) had developed model for pricing options contracts. But this model also misprices option considerably. "Can option pricing errors of the B&S model be minimized?," is a big questions faced by the participants of the derivatives market. This research makes an attempt to answer this question to some extent. The Black-Scholes model has been also modified by various authors. Few of them are Merton (1973), Black (1976) and Garman and Kohlhagen (1983).

It has been found that, index Nifty futures suffer from the 'cost of carry' bias. Usually, the future prices of stocks and index Nifty are less than Nifty spot prices. Hence, an extensive literature review has been done to identify the research gap and understand the research work on the relationship between spot and futures prices and pricing options contracts written on stocks and index Nifty 50 traded on NSE in India. To minimize the pricing errors, the spot prices have been replaced by their corresponding DVFPs in the Black-Scholes model.

# *CHAPTER II*

# REVIEW OF LITERATURE

In this chapter, an extensive literature review has been done to understand the research work done by various researchers in the areas of identifying relationship between spot and futures prices and pricing options contracts. More than one hundred twenty research reports from the areas of futures and options written over the underlying assets stock and index have been studied where eighty-one stated research reports have been found relevant. The future prices of underlying asset stock and index have been taken as an input for the calculation of stock and index option prices traded on NSE in India. Hence, the study of literature review has been broadly divided into following two parts to get insight knowledge about the existing research reports related to the central theme of this research:

a) Reviews of spot and futures pricing literature
b) Reviews of options pricing literature

This study tests the efficiency of the B&S model for pricing stocks and index, therefore, studies related to efficiency of B&S model on assets other than stocks and index are not emphasised. The present chapter consists of three sections; The section **first** deals with the reviews of spot and futures pricing. The section **second** deals with the reviews of options pricing regarding the efficiency of the B&S model conducted in different markets. The section **third** deals with the research gap identified from the literature reviews.

## 2.1. REVIEW OF SPOT PRICE AND FUTURES PRICING LITERATURE

The relationship between futures and spot prices has been intensively examined and continues to be an area of interest for researchers, practitioners and regulators. It has been examined because they play an important role in the assimilation of information and price discovery in the stock and commodity market. A key question in financial derivative is the existence or non-existence of lead-leg relationship between futures prices and spot prices. A lead-leg relationship states which, between two markets, reflects information faster than the other one, as a result of that a lead-leg relationship between two markets exists. “Conventional wisdom among professional traders dictates that movements in the S&P 500 futures price affect market expectations of subsequent movements in cash prices.”[1] Numerous articles have focused on the empirical study of the lead-leg relationship between future and spot prices of the underlying assets.

Kawaller, Koch and Koch (1988) explore the relationship between S&P 500 Index futures and S&P 500 Index traded over the New York Stock Exchange and measure the change in relationship as futures expiration day approaches. The S&P 500 futures price and underlying index respond to market information simultaneously and the index shows lags up to 45 minutes behind the futures. The magnitudes of the contemporaneous effects on different days are found consistently much larger than the lagged effects.  Further, they find that consistency in lagged relationship over the day approaching expiration day and on expiration day also indicate that the pattern of lags between futures and index are not disturbed by the closing out of the arbitrage positions. Hence, they conclude that the Lead-leg relationship exists between the price movements of S&P 500. Index S&P 500 and S&P 500 Index trading contributes in price discovery.

The lead-lag relationship between index futures price and spot price in Indian stock market has been also empirically tested by researchers. Thenmozhi (2002) examines the existence of lead-lag relationship between the price movements of CNX Nifty50 futures and CNX Nifty Index considering the daily closing prices for the period 15th June 1998 to 26th July 2002. It has been observed by her that the futures market transmits information to cash market and future market is faster than spot market in processing information consequently inception of futures trading in India has reduced the volatility of spot index returns. Hence, the future returns lead the spot market returns but her study could not establish the lead time.

Raju and Karande (2003) examine the price discovery between the S&P CNX Nifty and its corresponding futures prices during the period 2000-2002 based on cointegration analysis which measures the extent to which two markets have achieved long run equilibrium and explicitly allows for divergence from equilibrium in the short run. Their results indicate that the information flows from one market to another market and future markets have its desired impact on cash market. Any regulatory initiative such as change in contract size, change in margin and other have their impact on the cash market.

The relationship between stock futures price and stock spot price has been also examined by researchers on Indian stock market. Sadath and Kamaiah (2007) empirically examine the effect of stock futures expiration on both price and volume of underlying stocks traded on NSE in India. It is found that futures expiration resulted in positive price and volume effects during the days leading to the expiration date due to the unwinding of arbitrage position in the spot market. Hence, the unwinding of arbitrage in an enormous scale in the same direction would stimulate price and volume effects.

However, it does not always seem true that futures market works as the price discovery vehicle for the spot market. Few researchers have empirically examined the lead-leg relationship between futures and spot markets and have summarised with diametrically different views as compare to others.

Mukherjee and Mishra (2006) have examined lead-leg relationship on the intraday trading at NSE by using cross correlation and error correction model. They have found that the spot market played a comparatively stronger leading role in disseminating information available to the market and therefore said to be more efficient. They further suggest that the results relating to the informational effect on the lead-lag relationship exhibit that though the leading role of the futures market wouldn't strengthen even for major market-wide information releases, the role of the futures market in the matter of price discovery tends to weaken and sometime disappears after the release of major firm-specific announcements.

Bhatia (2007) examines the intraday lead-lag relationship between S&P CNX Nifty futures and S&P CNX Nifty index for the period April, 2005-March, 2006 by employing cointegration and error correction model. The study finds that S&P CNX Nifty futures lead spot index by 10 to 20 minutes suggesting that for a short period of time the prices in the two markets could be out of line, resulting in arbitrage opportunities. Her findings lend support to Thenmozi's (2002) study conducted on NSE.

The existence of lead-lag relationship on selected India stocks has been also studied. Srivasan (2010) Examines lead-lag relationship between NSE spot and futures markets of selected eight individual IT sector stocks of India by using Johansen's Cointegration technique followed by the Vector Error Correction Model (VECM). This study has been conducted for the daily data series from 20$^{th}$ April, 2005 to 15$^{th}$ September, 2008. The study reveals that there is a bidirectional relationship between spot and futures markets in case of five selected IT stocks traded on NSE. This is followed by spot leads to futures and future leads to spot market in case of two and one selected IT stocks respectively.

Zakaria and Shamshuddin (2012) have tested the relationship between index futures price and index spot price on an emerging Malaysian stock exchange by using cointegration and Granger causality regression method. The cointegration tests indicate the existence of long run stable relationship between spot index and future contract index of Malaysian stock market. The Granger causality tests of their study suggests that the information flowed from cash market to future market. In other words, futures market in Malaysia did not play a role of price discovery vehicle spot market. Their findings support to Mukherjee and Mishra (2006) study conducted on NSE in India.

Choudhary and Bajaj (2012) study the relationship between futures and spot prices over the high frequency data of 31 individual securities for the time period of April 2010 to March 2011 traded on NSE. They find that both markets are plying an important role implying that futures (spot) prices may contain useful information about spot (futures) prices. Furthermore, their study finds that futures market is leading the spot market in case of 12 securities whereas 19 securities are being led by the spot market.

Kapoor (2016) examines the price discovery for spot and futures prices in the case of S&P CNX Nifty traded on NSE. It has been found that the Vector Error Correction Model come out with the results of price discovery by revealing that spot prices plays a dominant role in price discovery for S&P CNX Nifty index contracts traded on NSE. It is because the price of spot market tends to discover and assimilate new information faster than futures prices and the spot market in India is more actively traded and is thus, upheld in contrast to the market for futures. In other words, spot market serves as an efficient channel of price discovery. It is therefore, as stated by him, evident that spot market leads future market.

Chiraz (2016) investigates the impact of the futures on the variability of the underlying stock index of French market over the relatively larger sample period starting from 3rd January, 2000 to 31st December, 2015 by using the Markov-switching model. He finds that the futures have a stabilizing effect on the underlying spot market because the futures contain valuable information for modeling and forecasting stock returns. It produces the means for price discovery as a leading indicator in the transmission of new information. Hence, as concluded in his study, the informational value of futures markets contributes to the efficiency and completeness of financial market which leads to the better flow of information into the spot market.

Pradhan (2017) examined the price discovery and causality between the S&P CNX Nifty index spot futures market traded on NSE. He has used two methods, namely auto regressive integrated moving average method and vector error correction method. His study found that there existed a bi-directional causality between index Nifty spot and futures market and the spot market disseminated new information stronger than the futures prices. He also found that the forecast performance of vector error correction method than the auto regressive integrated moving average method.

## 2.2. REVIEWS OF OPTIONS PRICING LITERATURE

The Black-Scholes option pricing model exhibits certain biases on several parameters used in the model. Large number of researches was carried out to test the validity and applicability of this model on the basis of its assumptions and inputs. The following are the brief reviews of empirical developments related to the central theme of this research:

Black-Scholes (1972) found that contracts on high variance securities tend to be underpriced by $22 a contract, on the average and contracts on low variance tend to be overpriced by $55 a contract, on the average by the model but the transaction costs (commission, margin requirement, markup etc.) of trading in option would eliminate the profits. By examining the actual experience of option writers and buyers, they have found that the transaction costs of trading in option market, over the sample period, are much greater than the transaction costs of trading in listed securities. Black-Scholes (1973) empirically examine the accuracy of their own model and they found that "the actual prices, at which options are bought and sold, deviate in certain systematic ways from the values predicted by the formula." Furthermore, they have observed that the option buyers pay prices that are consistently higher than those calculated under the model.

Black (1975) himself was one of the persons who observed stock call option pricing biases in the Black-Scholes option pricing model. He states that "The actual prices on listed options tend to differ in certain systematic ways from the values given the formula." Three important conclusions have been drawn from his study are out-of-the-money options tend to be overpriced, in-the-money options tend to be underpriced and options less than three month to maturity tend to be overpriced.

Latane and Rendleman (1976) examines Black-Scholes model after replacing standard deviation with Weighted Implied standard Deviation on twenty-four individual stocks traded on Chicago Board Option Exchange (CBOE) over a period of October 1973 to June 1974. They have found that the Weighted Implied standard Deviation is generally a better predictor of future variability than standard deviation predictor based on historical data. Hence, model may not fully capture the process determining option prices in the actual market.

Macbeth and Merville (1979) show the efficiency of the BS Model for pricing stock call options traded on Chicago Board of Option Exchange (CBOE) from December 31, 1975 to December 31, 1976. They find that out-of-money options with less than ninety days to expiration are overpriced and in-the-money options with less than ninety days to expiration are underpriced by Black-Scholes model. Further, these effects become more stronger as the time to maturity increases and the degree to which the option is in or out of the money increases. They stated that the extent to which the B-S model underprices in the money options increases with the extent to which the option is in the money and this relationship appears stronger the longer the time to expiration.

Bhattacharya (1980) tests the Black-Scholes model for pricing stock call options over 91 stocks traded on the CBOE under ideal condition by initiating the hedge through buying or selling the call options at the model calculated price and finds surprising result that the model overvalues call ITM options under a maturity of less than three weeks with negative sign while call near-the-money options are overvalued by the model.

Rubinstein (1985) states that B-S model is based on the certain unrealistic assumption such as constant volatility of the underlying assets. He, by using larger data set of 30 stock option contracts traded on CBOE for the period August 23, 1976 to August 31, 1978, is in the favour of binomial process at discrete time interval for the calculation of theoretical price of option contracts.

Whaley (1986) tested the American future option valuation principles on S&P 500 futures option contract data for the period January 28, 1983 to December 30, 1983 by using the Black approximation model for pricing the options. Total 56,986 options transections have been examined to see whether the options are undervalued or overvalued relative to the future option pricing model. The deviations between actual market prices and theoretical model prices are not significant but there is some evidence that the model underprices in-the-money options. It has been found that more than 72 percent out-of-the-money put options are overpriced and thus sold within the trading strategy. During the study period, it has been observed that S&P 500 index rose from 145.30 to 164.93, indicating that writing out-of-the-money put would have been profitable indeed. At-the-money options enjoyed the greatest volume of activity and therefore, probably exercised the lowest bid-ask spread.

Berg, Brevik and Saettem (1996) empirically tested the efficiency of the Black-Scholes model regarding the call to put bias on the Norwegian options market. They found that the majority of mispricing appear in stock call option as compare to put option.

Fortune (1996), in his series of studies for Federal Reserve Bank of Boston, tested the predictability of the B&S model over the S&P 500 stocks traded on CBOE for the period 1980 to 1995. He found systematic and sizable errors in the model and the stock put options are relatively overpriced by the B&S model as compare to the stock call options. Furthermore, according to the B&S model, stock prices are usually consistent with a lognormal distribution but occasional shocks create discrete jumps up or down in the price, hence non-normality observed in the data and CBOE traded S & P 500 does not conform to the normality assumption.

Data not only are the distribution thicker in the middle than the normal distribution but they also show large changes either up or down than the normal distribution and hence, study confirms a departure from normality for the period 1980 to 1995.

The study conducted by Raj and Thurston (1998) to evaluate the performance of Black model at predicting option prices on Nikkei index futures traded on the Singapore International Monetary Exchange (SIMEX) found that the model underprices both call and put options. Overall, the maturity bias and moneyness bias have been found to be monotonic with options in all data categories being underpriced. The model underprices both in-the-money and out-of-money options significantly, but predicts the prices of at-the-money option most efficiently. The maturity bias has been found to be monotonic as all three maturity categories are significantly underpriced. However, he calculated mean error by subtracting actual price from the predicted price.

At the very initial stage of the introduction of derivatives segment in India, Varma (2002) observes that the volatility is severely mispriced under the B&S model and option market moved toward the Black model but has gone only half the way. The market is learning and this is a matter requiring further research using longer time periods. In particular, as found by him, volatility is severally underpriced for both call and put options. He observed that Nifty Futures trade at a discount to the underlying because of the negative cost of carry phenomenon and partly short sale restriction in the cash market. He used discounted value of futures price in Black model on underlying index for the calculation of index option prices. However, options written on underlying stocks traded on NSE have not been tested.

Yakoob (2002) assesses the Black-Scholes model in relation to more complicated model like Absolute Diffusion model and Hull-White Stochastic Volatility model for pricing European options contracts written on S&P 500 Index and S&P 100 Index from January 1, 2001 to December 3, 2001. The calculated prices under the various models are compared to market prices of the options to gauge pricing accuracy. His study finds that the Black-Scholes Model provides far greater accuracy in pricing options than the two other models under consideration. The Hull-White model used in his analysis produces the worst pricing fit among the three models under consideration.

Gencay and Salih (2003) examined the option pricing accuracy of the B-S model on S&P 500 Index traded on the CBOE for the period January 1988 to October 1993 and compared with feedforward network pricing errors. Their study focused on how to eliminate overestimation bias and effect of volatility on mispricing under the B&S model. It has been observed that the B&S model pricing error is high for deeper out-of-the-money option and mispricing increases with increased volatility for call and put. They found that the feedforward Networks largely eliminate the overestimation bias and large positive pricing errors for high volatility levels (volatility levels between 0.25 and 1) observed in B-S model. The feedforward network provides lower bias in terms of the pricing performance relative to the Black-Scholes model.

The applicability and efficiency of the Black-Scholes model are generally tested by several researchers on the model's assumption, namely volatility. Koopman, Jungbacker and Hol (2004) explored the forecasting value of historical volatility (extracted from daily return series), implied volatility (extracted from option pricing) and realized volatility (computed as the sum of squared high frequency returns within a day). Their empirical results found that realized volatility models produced far more accurate volatility forecasts as compared to models based on daily returns.

Kakati (2006) Examines the overall pricing accuracy, call to put bias, Moneyness bias and maturity bias produced under the Black-Scholes model for pricing call and put options contracts written on ten Indian stocks and BSE index SENSEX traded on BSE from Jul 2001 to March 2003. He found that stock put options are overpriced while stock call options are underpriced by the Black-Scholes model using historical volatility and hence, the early exercise feature of American options is not being accounted. Therefore, the magnitude of error for stock call option is comparatively higher than stock put option. The Black-Scholes model has overpriced both BSE index SENSEX call and put options but the magnitude of error for index call option is also found higher than the index put option. It has been observed that the stock call ATM and ITM options are overvalued while OTM options are undervalued by the Black-Scholes model. But stock put ATM, ITM and OTM options are overvalued. For both stock call and put, ITM options are comparatively highly overvalued. The near month and next month stock call options are undervalued while fare month stock options are overvalued by the Black-Scholes model. However, the Black-Scholes model with implied volatility instead of historical volatility shows less pricing error.

McKenzie, Gerace,and Subedar (2007) empirically investigate the efficiency of the Black-Scholes model for pricing ASX200 call options index traded on the Australian Stock Exchange (ASE) for the period February 2003 to July 2007. Their result indicates that the Black-Scholes model is relatively accurate for pricing call options. Comparing the qualitative regression model which provides evidence that the Black-Scholes model is significant in estimating the probability of a European call option being exercised through the calculation of $N(d_2)$.

Comparing the Nifty call option pricing accuracy between Black model and Black-Scholes model, Mitra (2008) also observes, consistent with Verma's research (2002), that 81% of the total observations on Nifty futures, quoted on NSE from October 1, 2005 to September 30, 2006, are traded below the Nifty spot value and hence suffers from the negative cost of carry problem. His study addresses the issue related to mispricing of Nifty call options on account of negative cost of carry phenomenon observed on NSE by replacing Nifty spot price by the discounting value of futures price in the original Black-Scholes model as it is believed that futures prices not only incorporate cost of carry problem but also capture impact of other market sentiment. It is found in his research when the discounting value of future prices compared with the corresponding spot prices that 98% of the total observations are likely to be affected on negative cost carry bias. Therefore, use of discounting value of future price in the place of spot price produces less pricing errors for the calculation of Nifty call options prices but it has not been tested on European style stock options.

Barunikova (2009) evaluates the pricing performance of the Black-Scholes model and neural network model on the European style S&P Index call and put options over the period of 1$^{st}$ Jun, 2006 to 8$^{th}$ Jun, 2007 in Czech Republic. It has been found that the Black-Scholes model shows lower pricing errors as compare to the neural networks for pricing call index options. However, the neural networks improve their performance as the call index option goes long-term and deep in-the-money. His results show that the Black-Scholes model exhibits Index call maturity and moneyness biases. For index put options, both models show higher pricing errors as compare to index call options. This finding is contradicting to Kakati's (2006) finding in the context of Indian derivatives market. Furthermore, regardless the day to expiration the Black-Scholes model underprices the options while the neural networks overprice the options.

Dixit, Yadav and Jain (2009) tested the efficiency of the Black-Scholes model index Nifty traded on NSE in India from June 2001 to June 2007. They found that the B&S model shows higher magnitude of pricing error in pricing index call option as compare to index put option.

Shehgal and Narayanamurthy (2009) examined the efficiency of the Black-Scholes model for pricing call and put options contracts written on S&P CNX Nifty Index traded on NSE from the period 1st January 2004 to 31st December, 2005 using historical and implied volatility. They found that the Black-Scholes model is a good descriptor of S&P CNX Nifty Index option pricing subjective to the trading asymmetry condition (short selling restrictions) prevailing in India. Hence, they have recommended removal of short selling restrictions in India to ensure that derivative pricing is fully efficient. Given the treading symmetry in futures market, spot values are replaced by the futures values for the estimating theoretical value of options. Using the historical and implied volatility, they have Compared the pricing efficiency of the model in both situations in Indian market and found that the Black-Scholes model gives lower pricing error on the basis of historical standard deviation than implied volatility.

The option price under the Black-Scholes model is a function of strike price, spot price, volatility of the underlying asset, risk free rate and the time to maturity. But, as identified by Nagarajan and Malipeddi (2009), market sentiments also play a major role in market and the Black-Scholes option pricing model is independent of market sentiments. They have tested the pricing efficiency under the Black-Scholes Model and skewness & Kurtosis in pricing Indian CNX Nifty index call option considering the effects of market sentiments during the period from April 2002 to December 2008 and found that the market is pricing the call option higher than Black-Scholes price during bullish period compared to that of bearish period even though sentiments are incorporated in the underlying assets which in this case was the Nifty index. They found that the index call options are priced about 1.5 percent more than the Black-Scholes price during bullish period compared to that of bearish period during the period of observation. They stated that Black-Scholes model is comparatively very efficient in pricing Nifty index call options.

The call to put bias has been studied by researchers in different market. Puttonen (1993) studied the efficiency of the B&S model on the Finnish Options Index (FOX) from May 1988 to

December 1990 and found that the B&S model shows higher magnitude of pricing error in pricing index call option as compare to index put option.

Singh and Ahmad (2011) examined the performance efficiency of the Black-Scholes model for pricing S&P CNX Nifty index by implied and time series econometric volatility model. They found that the Black-Scholes model shows maturity and moneyness biases in pricing index options. However, it has been shown in their paper that options prices calculated under the model using implied volatility performed better.

Kala and Pandey (2012) studied a feasibility analysis of the Black-Schole model for pricing stock options using historical volatility traded on NSE in India. The result of analysis found that the Black-Scholes model is more useful in call option pricing than the put option pricing. Furthermore, they have found that the impact of timing is more relevant for pricing stock put option as compare to the pricing stock call options. Hence, according to their suggestion, the traders should be cautious while using the Black-Scholes model for predicting the price of put options in the Indian derivatives market.

Mitra (2012) studies the theoretical prices of Nifty index call options using both Black model and Black-Scholes model and compared with actual prices in the market. Since the beginning of the Nifty index trading in India, Index Nifty suffer from the negative cost of carry effect and sometimes trade below the Nifty spot value. He analyzed 29,724 option quotes from 1$^{st}$ July, 2008 to 30$^{th}$ June, 2011 using both the B-S model and Black model and found, similar to his previous study, that the Black model produces better alternative than the B&S model when Nifty index spot prices have been replaced by the Nifty futures prices (DVFP). From the analysis of error, furthermore, it is verified in his study that the Black model produces less error than that of the B&S model and for that reason use of the Black model is more fitting than that of the B-S model in pricing Nifty index call options traded on NSE. But the applicability of the Black-Scholes model for pricing individual stock option traded on NSE, after replacing spot prices by the discounting value of future prices, has not been conducted under his study.

Ray (2012) finds that inspite of several loopholes in the Black-Scholes model such as simplistic assumptions of constant volatility and a normal distribution function for the underlying asset return, this model still gives very good approximations to the prices of options. The concept behind the Black-Scholes analysis provide the framework for thinking about option pricing. Furthermore, all the researches in options pricing since the Black-Scholes analysis has been done either to extend it or to generalize it. Another reason behind the success of the Black-Scholes model is that the financial world uses it as a standard.

Aboura (2013) tested the applicability of the Black-Scholes model for pricing the European style options written on the CAC 40 index traded on the French option market and observed that the Black-Scholes model undervalued out-the-money calls and overvalued in-the-money calls. He has also compared the pricing accuracy after changing the parsimonious assumption that the security prices follow a constant variance diffusion with log returns normally distributed and found that the jump diffusion model performs better than the stochastic volatility and Hull-White model.

Khan, Gupta and Siraj (2013) suggest modification, in the original Black-Scholes model adding new variable related to the calculation of risk-free interest rate in the context of NSE derivative market in India. The values of stock call and put options are calculated on the basis of assumed and calculated (modified) risk free interest rate. The calculated risk-free interest rate results are changed due to a small correction in the value of risk-free interest rate. This calculated risk free interest rate gives better result in comparison to existing value of risk-free interest rate in the calculation of the value of stock call and put options.

The pricing accuracy of the Black-Scholes model in Indian market is also tested on the individual stock of particular industry. Panduranga (2013a) studies the applicability of the Black-Scholes model in pricing banking sector stock option traded on NSE and found that Black-Scholes model is suitable for pricing banking sector stock options. Results of the paired sample t-test revealed there is no significant difference between expected option prices calculated under the Black-Scholes model and market prices of options, in three out of four cases. It can be inferred that model is relevant for pricing banking sector stock options. However, in one out of four cases, there is a difference expected calculated price and market price of option.

Panduranga (2013b) studied the applicability of the Black-Scholes pricing model for pricing stock options belongs to cement industry relatively for a smaller period of time i.e. one-year Jan. to Dec. 2012. He concluded his result on the basis of the paired sample t-test that there is no significant difference between the expected option calculated under the Black-Scholes model and the market price of the option and hence, the Black-Scholes model is relevant for pricing cement stocks. But he had used very small sample size in his study.

Nagendran and Venkateswar (2014) use more than 95,000 call options to test the validity of the Black-Scholes (BS) model in pricing Indian Stock American style Options traded on NSE, India. They have found that the B-S model is robust in pricing Indian stock call options and option pricing is improved by incorporating implied volatility into the B-S model. The implied volatility has been incorporated to see if there has been an improvement in the predictive ability of the model. It has been found that the newly constituted model improved the predictive ability for 64.23% of the call option prices. They test the model on the American style of option assuming if all arbitrage opportunities for American types option are eliminated, no one will exercise the option early and hence it can be treated like European option as the Black-Scholes model is applicable to the European style option that is exercisable on only expiration day of the option.

Inder (2015) examined the forecast quality of the implied volatility in determining the realized future volatility under the Black-Scholes model. Her study focused on the one-month call options based on CNX Nifty for the time period June 2001 to December 2014. The result indicates that the implied volatility overestimated the future volatility and the degree of biasness increased with increase in time to expiry, whereas the directional efficiency of implied volatility was correctly specified under the model. It has also been also found that the predictive ability of implied volatility to discover the future volatility is not better as compare to the historical volatility in the Indian options market. Her results further revealed that the implied volatility did not have better explanatory power than that of the historical volatility which indicates that Indian options market still needed to mature to enhance the efficiency in price discovery of the underlying through derivatives.

The impact of change in underlying assets prices on the options' moneyness has been also studied by researchers. Mugwagwa, Ramiah and Moosa (2015) find on the Australian Securities

Exchange (ASX) that OTM options have an increased sensitivity to changes in the underlying stock price and that ITM options are less sensitive, particularly call options.

Muthusamy and Vivek (2015) Studied the efficiency of the Black-Scholes model for pricing S&P CNX nifty, Nifty MIDCAP 50, Bank Nifty and CNX IT option for a period of six years from 1st Jan. 2009 to 31st Dec. 2014. The calculated prices are compared to the Market price using paired sample t-test to know whether the calculated and actual prices are similar. Their finding of the study revealed that in most of the contracts the calculated options prices differed from the market values of the options contract during the study period. They suggested that though many studies suggest that B-S-M model is best for estimating European options price, it provides arbitrage opportunity on many occasions for the market participants in Indian derivatives market.

Sharma and Arora (2015) teste the applicability of the Black-Scholes model for pricing ten individual stock option traded on NSE and they found that the most of the model prices are not near to the actual market prices which show the ineffectiveness of the model, therefore model is partially relevant and it can be made effective by taking into consideration all other constraints of the model to make the option pricing more effective.

Singh and Dixit (2016) Change the method of measurement of volatility used in the Black-Scholes model for European style CNX Nifty index call and put options traded on NSE. They have found that the volatility calculated using the intraday data is a much more efficient volatility estimate compared to estimate based on the closing pricing for the CNX Nifty index from 3 January 2011 to 31 December 2012. They have examined the performance of the Black-Scholes model under the both situations and found that the Black-Scholes model shows consistent overpricing with more than 90% call options as overpriced while the same figure for the volatility calculated using the intraday data is 64.12%. In the case of the Black-Scholes model, MAPE for the CNX Nifty call option- ATM, OTM and ITM are found to be 27.2004%, 61.0122% and 7.0644% respectively. Hence, index OTM call option is highly mispriced. Similarly, MAPE for the CNX Nifty put option- ATM, OTM and ITM are found to be 35.1221%, 79.9728% and 8.8085% respectively under the Black-Scholes model. Here, the index OTM put option is highly mispriced as compare to others.

Sudhakar and Srikanth (2016) analyzed the efficiency of the Black-Scholes model for Nifty 50 index call options using regression analysis by regressing market price of Nifty-50 Index options on the theoretical price from January 2008 to December, 2014. The results of the regression analysis highlighted that the value of R-squared was quite larger for at-the-money options, in-the-money options and deep-in-the-money options. Their results of the analysis disclosed that the Black-Scholes performed well in predicting the market price of the index Nifty50 call options except in the case of options which belong to out-of-the-money and deep out-of-the-money categories.

### 2.2.1. Pricing Option with Future Prices in Different Market:

Options prices are also calculated by using the DVFP instead of spot price the B & S model. Usually, Derivatives Traders in options frequently use futures contracts to hedge their positions [Mitra, 2012]. Varma (2002), Mitra (2008 and 2012) have used this concept and found improvement in minimizing pricing errors in Indian derivatives market. There are some other authors who have used also used future prices instead of spot prices in analysing put-call-parity in other markets. Some of them are; Lee and Nayar (1993) tested the efficiency of index options traded on Chicago Board Options Exchange (CBOE) and Chicago Mercantile Exchange (CME) of USA using futures prices and found that violations are much less in frequency and magnitude for PCP. Sternberg (1994) studied the mispricing of call-put-parity using futures prices traded on CME in US market and observed that the options contracts available against futures reduce the mispricing since the options can be priced directly against the underlying futures contract in the US market. Fung and Chan (1994) and Garay, Ordonez and Gonzalez (2003) used futures prices instead of spot prices and their study also found less put-call-parity violation in the U.S. market. Similarly, Fleming, Ostdiek, and Whaley (1996) found in their study that dealers price the S&P 500 index options based on the prevailing S&P 500 futures price in USA. However, Bharadwaj and Wiggins (2001) found violations in using this approach in the US market. Less violations results have been found by Draper and Fung (2002) in the U.K. market, and Fung, Cheng and Chan (1997), Fung and Fung (1997), Fung and Mok (2001) and Lung and Marshall (2002) in the Hong Kong market.

## 2.3. RESEARCH GAP

During the literature review it has been found that the majority of studies in great detail are empirically conducted in the developed market, there are very few studies in developing market. The number of similar studies in Indian derivatives market is even less specially for stock options after the introduction of the European style stock options on NSE on 27th January, 2011.

The majority of researches in the Indian market are conducted on the American style of stock options before 27th January, 2011 because before this period stock options were American style of options traded on NSE which is not as per the assumptions of the Black-Scholes option pricing model. The B&S model assumes that option should be a European style. However, the index NIFTY 50 options traded on NSE are of the European style.

A few researches conducted by Verma (2002) and Mitra (2008 and 2012) have brought modification because CNX Nifty index suffers from the negative cost of carry problem and found improvement in the original Black-Scholes model after replacing the CNX Nifty Index spot price with the Discounting Value of Future Price (DVFP) of CNX Nifty index but they have not experimented on the European style of stock options. It appears based on the reviewed literature that only a few researches have been conducted in the Indian derivatives market replacing the CNX Nifty index spot price by the respective index discounting value of future price in the original Black-Scholes model. However, a study on the replacing stock spot price with the respective stock Discounting Value of Future Price (DVFP) in the original Black-Scholes model for pricing the European style options is missing. In other words, the Black-Scholes model after modification has not been yet empirically tested on the European style stock options as it has been introduced on NSE since 27th January, 2011 to our knowledge. A possible reason might be due to non-availability of the European style of stock options on NSE.

In summary the empirical research concede that the Black-Scholes model produces bias in the calculation of the option prices. Now question is that whether the magnitude of pricing errors for stock and Index options could be minimised. If yes, then how it could be possible. This research makes an attempt to answer this question to some extent. It has been found, while searching answers to these questions, that index Nifty 50 Future prices are traded below their corresponding spot prices because of the negative cost of carry problem. “Mispricing in one instrument influence pricing of other instrument (Mitra, 2012)”. If spot prices are replaced with the corresponding discounting value of future prices in the model, as this is assumed under the cost of carry model that the futures and spot markets are perfectly efficient and hence, there is no lead-lag relationship between futures and spot prices (Shalini Bhatia, 2007), then improvement can be obtained in the original Black-Scholes model used for pricing stock and Index options.

Given the literature gap as mentioned above, it becomes imperative to conduct a comprehensive research on the given model after replacing underlying spot price with their respective discounting value of future price (DVFP) in the original Black-Scholes model in this context. It should be noted that the Black equations are exactly what one would obtain if in the Black Scholes formula stock price (S) is replaced by replaced by $F{*}e^{-rt}$ (Varma, 2002). However, research on the model efficiency for pricing CNX Nifty index options has been also included and conducted. This study accomplishes it by first performing an empirical analysis of the original Black-Scholes model using the stock and CNX Nifty index spot prices and secondly, replacing the stock and CNX Nifty index spot prices with their respective discounting value of future Prices (DVFPs) in the original Black-Scholes model. This research work compares these models’ calculated options prices with the market options prices to gauge which option pricing model produces less pricing errors. Additionally, to make the comparison robust, the performance of the models is evaluated across its subgroups namely maturity biasness & moneyness biasness and call to put biasness of the underlying assets stock and CNX Nifty index traded on the NSE in India.

Numerous papers have empirically examined the relationship between future and spot prices for the various types of assets using different methodologies. The findings from studies are consistent with the findings from other studies while other studies come up with diametrically different findings. The two very informative studies on the lead lag relationship in the Indian market have come up with different views. According to Thenmozhi (2002), futures market leads the spot market while Mukherjee and Mishra’s (2006) study finds that the spot market plays price discovery role and leads over the futures market. Hence, the empirical evidence regarding the existence of lead-lag relationship is mixed, although a majority of studies show that future market has a price discovering role.

In summary empirical investigations conducted by the various researchers across the world in different markets and time periods show that the researchers have conflicting opinions over the efficiency of the Black-Scholes model. A few researchers' studies are favouring the Black-Scholes model for pricing options contracts. At the same time, other researchers' studies are not favouring the Black-Scholes model. The modified/new models have been also proposed by the researchers. However, few studies are partially in the favoure of the Black-Scholes model. The main criticism of the model is based on its assumption of constant volatility of the underlying asset. The researchers' empirical evidence to date is mixed regarding the pricing accuracy produced by the Black-Scholes model in Indian derivatives market, although a majority of studies indicate that the Black-Scholes model produces pricing errors on several occasions and hence, few modifications have been also suggested.

## *CHAPTER III*

# RESEARCH OBJECTIVES AND METHODOLOGY

This research study has been motivated by the pricing errors produced by the Black-Scholes model used for pricing stocks and S&P CNX Nifty index options. It is observed by researchers that that mispricing in one instrument influence pricing of other instrument in financial derivative market (Mitra, 2012). It has been usually observed that the index Nifty 50 future prices are traded below their corresponding spot prices on NSE and hence, to address the negative cost of carry problem, the discounting value of future price has been used in the place of spot price for the calculation of the Nifty 50 index options in India by Varma, (2002), Mitra, (2008 & 2012) and by Black (1976) in USA for commodity. Varma, (2002) and Mitra, (2008 & 2012) used DVFP in the place of spot price to address the negative cost of carry problem in pricing the European style of index Nifty 50 options but it has not been yet analyzed on the European style stock options as it has been introduced on NSE since 27$^{th}$ January, 2011. The primary inputs for the calculation of options prices have been taken from futures market. The discounted values of future prices have been used in the place of spot prices in option pricing model. The primary objective of this research study is to determine the efficiency of the Black & Scholes model, i.e., magnitude of errors, in pricing Nifty fifty stock options and S&P CNX Nifty index options, henceforth, it will be known as Nifty 50, option after addressing the negative cost of carry problem and comparing the accuracy of the same with that of the original Black-Scholes model.

The Mean Error (ME), Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Thiel's U statistic and Mean Absolute Percentage Error (MAPE) have been primarily used for the comparison of pricing accuracy. These values have been calculated with the help of excel.

This chapter drafts research objectives with description based on the above stated research gap. This chapter also reviews the general methodology used and data associated to perform the efficiency of the Black-Scholes model followed by replacing spot price by the DVFP in the model. It includes proposed hypothesis, reasons and explanations behind the objectives and hypotheses, grouping of hypotheses, sampling framework, research design, statistical measures for result comparison for options pricing accuracy. This chapter consists with **ten** sections: **first** section presents objectives of this research. The **second** section proposes research hypothesis. The **third** section describes research methodology. The **fourth** section formulates sample size. The **fifth** section deals with the sources of data collection. The **sixth** section deals with the B&S model and replacement of spot price with the DVFP. The **seventh** explains time to expiry. The **eighth** section deals with the selection and calculation of risk-free rate of return. The **ninth** section deals with the volatility. The **tenth** section is about explains the statistical measures for results comparison.

## 3.1. RESEARCH OBJECTIVES

The Black-Scholes options pricing model exhibits certain biases on several parameters used in the model. This research study has been motivated by the pricing errors produced under the Black-Scholes model. This research deals with the following objectives:

(1) To investigate the pricing errors produced by the Black-Scholes model due to negative cost of carry phenomenon observed in the Indian derivatives market.

(2) To investigate three biases of the option pricing model: Moneyness bias, Maturity bias and Call to Put bias (subgroups under the B&S model & modified B&S model.)

(3) To address the cost of carry bias by replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) in the original Black-Scholes model in the Indian derivatives market.

(4) To show that the model after addressing the cost of carry problem provides better result in comparison to the original Black-Scholes model for pricing options in the Indian derivatives market.

**Description-** It should be noted that objective (2) is the subgroup of option, hence, no separate hypothesis has been formulated.

### 3.2. PROPOSED HYPOTHESIS

The study proposes to test the following hypotheses to meet the objectives of the study-

(a) The prices of individual stock options of companies under Nifty fifty and S&P CNX Nifty index option, calculated under the Black-Scholes model, do not suffer from the cost of carry problem.
(b) There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on reducing the cost of carry problem in the Black-Scholes model.

#### 3.2.1. Interpretation of the Objectives and Hypotheses

The Indian derivatives market suffers from the cost of carry problem and hence due to this when option prices are calculated using spot prices under the B&S model (1973), it produces errors [objective (1) and hypothesis (a)].

To minimize the magnitude of the pricing errors, various authors have tried to addressed the cost of carry problem by replacing underlying spot prices by their corresponding DVFP [objective (3) and Hypothesis (b)]

Major inputs for the development of objectives and hypothesis have been taken from the studies of the following authors:

Varma (2002) states that "It is well known that severe mispricing prevails in India's nascent derivatives market. The mispricing that has been most commented upon is the negative cost of carry phenomenon in which the future trades at a discount to the underlying. Globally, also, it has been observed that futures trade below fair value (though not usually below underlying) in the presence of acute short sale restrictions".

Mitra (2008) finds that "The Black and Scholes option pricing formula exhibits certain biases on several parameters used in the model. Nifty options also suffer from cost of carry bias as future prices of Nifty are usually less than Nifty spot prices plus interest element. Since the inception of Nifty futures trading in India, Nifty futures even traded below the Nifty spot value. These deformities obviously cause difference between the actual prices of Nifty options and the prices calculated using the Black-Scholes formula. Black (1976) tried to address this problem of negative cost of carry by using forward prices in the in the option pricing model instead of spot prices".

Mitra (2012) finds that "Stock index futures sometimes suffer from 'a negative cost-of-carry' bias, as future prices of stock index frequently trade less than their theoretical value that include carrying costs. Since commencement of Nifty future trading in India, Nifty future always traded below the theoretical prices. This distortion of future prices also spills over to option pricing and increase difference between actual price of Nifty options and the prices calculated using the famous Black-Scholes formula".

There are some other authors who have used also used future prices instead of spot prices in analysing put-call-parity in other markets. Some of them are; Lee and Nayar (1993) tested the efficiency of index options traded on Chicago Board Options Exchange (CBOE) and Chicago Mercantile Exchange (CME) of USA using futures prices and found that violations are much less in frequency and magnitude for PCP. Fung and Chan (1994) and Garay, Ordonez and Gonzalez (2003) used futures prices instead of spot prices and their study also found less put-call-parity violation in the U.S. market. However, Bharadwaj and Wiggins (2001) found violations in using this approach in the US market. Less violation Same results have been found by Draper and Fung (2002) in the U.K. market, and Fung, Cheng and Chan (1997), Fung and Fung (1997), Fung and Mok (2001) and Lung and Marshall (2002) in the Hong Kong market.

The research objectives and hypotheses formulated in section 3.1 and 3.2 are based on the above stated reasons and explanations.  Above authors views can be summarised in the following ways; options prices calculated under the B & S model using underlying spot prices, produces pricing error due to cost of carry problem. The cost of carry problem or bias, here, is taken as negative. To address this cost of carry problem, the DVFP is used instead of the underlying spot price. Hence, the cost of carry has not been tested separately [Varma, 2002].

The pricing efficiency of the models have been evaluated for call and put options written on stocks and Nifty 50 index traded on NSE. The above stated hypotheses have been mainly grouped in to the following three parts and extended to meet the stated objectives of the study separately for stock call, index Nifty 50 call, stock put and index Nifty 50 put option:

**3.2.2. Group (a)** [for objectives (1) and (2)]

**Hypothesis for Stock Call Options:**

$H_{01}$: The prices of individual stock call options of companies under Nifty 50, calculated under the Black-Scholes model, do not suffer from the pricing errors, i.e., there is no significant difference between the mean values of the stock call options closing price and calculated price under the B&S model.

**Hypothesis for Index Call Options:**

$H_{02}$: The prices of S&P CNX Nifty index call options, calculated under the Black-Scholes model, do not suffer from the pricing errors. i.e., there is no significant difference between the mean values of the S&P CNX Nifty index Call options closing price and calculated price under the B&S model.

**Hypothesis for Stock Put Options:**

$H_{03}$: The prices of individual stock put options of companies under Nifty fifty, calculated under the Black-Scholes model, do not suffer from the pricing errors. i.e., there is no significant difference between the mean values of the stock put options closing price and calculated price under the B&S model.

**Hypothesis for Index Put Options:**

$H_{04}$: The prices of S&P CNX Nifty index put options, calculated under the Black-Scholes model, do not suffer from the pricing errors. i.e., there is no significant difference between the mean values of the S&P CNX Nifty index put options closing price and calculated price under the B&S model.

### 3.2.3. Group (b) [for objectives (2) and (3)]

**Hypothesis for Stock Call Options:**

$H_{05}$: There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on the prices of individual stock call options in the Black-Scholes model. i.e., there is no significant difference between the mean values of the stock call options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

**Hypothesis for Index Call Options:**

$H_{06}$: There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on the prices of S&P CNX Nifty index call options in the Black-Scholes model. i.e., there is no significant difference between the mean values of the S&P CNX Nifty index call options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

**Hypothesis for Stock Put Options:**

$H_{07}$: There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on the prices of individual stock put options in the Black-Scholes model. i.e., there is no significant difference between the mean values of the stock put options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

**Hypothesis for Index Put Options:**

$H_{08}$: There is no impact of replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) on the prices of S&P CNX Nifty index put options in the Black-Scholes model. i.e., there is no significant difference between the mean values of the S&P CNX Nifty index put options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

**3.2.4. Group (C)** [for objective (4)]

**Hypothesis for Stock Call Options:**

$H_{09}$: The model after addressing the cost of carry problem does not provide better result in comparison to the original Black-Scholes model for pricing stock call options in Indian market. i.e., there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock call options in the Indian derivatives market.

**Hypothesis for Index Call Options:**

$H_{010}$: The model after addressing the cost of carry problem does not provide better result in comparison to the original Black-Scholes model for pricing S&P CNX Nifty index call options in Indian market. i.e., there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing Index Nifty 50 call options in the Indian derivatives market.

**Hypothesis for Stock Put Options:**

$H_{011}$: The model after addressing the cost of carry problem does not provide better result in comparison to the original Black-Scholes model for pricing stock put options in Indian market. i.e., there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock put options in the Indian derivatives market.

**Hypothesis for Index Put Options:**

$H_{012}$: The model after addressing the cost of carry problem does not provide better result in comparison to the original Black-Scholes model for pricing index Nifty50 put options in Indian market. i.e., there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing S&P CNX Nifty index put options in the Indian derivatives market.

### 3.3. RESEARCH METHODOLOGY

The price of individual stocks options and index Nifty 50 options have been calculated under the Black-Scholes model without bringing any modification in its variables and assumptions. Hence, this research first aims to determine the efficiency of the Black-Scholes model for pricing the Indian stocks options and index Nifty 50 options traded on NSE. The research methodologies used in this researcher are based on descriptive type of research. The descriptive research investigates phenomenon in natural setting and involves measurement, analysis, comparison and interpretation. Varma (2002) and Mitra (2008 & 2012) found that the index Nifty 50 suffers from the negative cost of carry problem and in the index option pricing they have replaced index Nifty 50 spot prices by their corresponding DVFP to address the negative cost of carry problem. Here, an attempt has been made to apply the same concept on the stock as well as index Nifty 50 option traded on NSE in India and to suggest which model exhibit comparatively lower pricing errors.

A visual inspection has been made regarding how many times stock and index futures prices are traded lower than their corresponding spot prices. The futures prices then have been discounted and again compared with spot prices. Thus, before analysis and interpretation of options pricing accuracy produced under the Black-Scholes model, the underlying individual stocks future and index Nifty 50 future prices and their corresponding spot prices have been compared to identify the negative cost of carry problem. Describing the negative cost of carry problem, it has been identified that how many times individual stock future and index Nifty 50 future prices are being traded below their corresponding spots prices. The underlying asset’s future prices have been discounted on the prevailing risk-free interest rate to address the negative cost of carry problem found in the Indian stock market. If the Black-Scholes model produces errors in pricing stocks and index options, can these pricing errors be minimized. For this purpose, the stocks and index Nifty 50 spot prices used as the important variables in the Black-Scholes model have been replaced in the modified Black-Scholes model by their corresponding Discounting Value of Future Prices (DVFPs).

### 3.3.1. RESEARCH DESIGN

A detailed blueprint has been prepared under the research design which guides this research to achieve its stated objectives. Hence, this research work consistently goes through the following three stages:

Stage 1. Error matrices of the B&S model for call and put options using spot price.

Stage 2. Error matrices of the B&S model after replacing Sport price (S) by the discounted value of Future price ($Fe^{-(r-y)t}$).

Stage 3. Comparison of pricing errors between the B&S Model and modified B&S model.

In stage second, the spot price has been replaced by the corresponding discounting value in the original B&S model, hence it is referred as the modified B&S model. It may be noted that the mispricing has been also examined across different subgroups formed by the moneyness & maturity and call to put bias of an option (objective 2) in stage first and second. It would enable research to identify whether the Black-Scholes model based on the spot price performs poorly only for certain cases of moneyness, maturity and call to put bias or it would be inferior to the Black-Scholes model based on the DVFP (modified Black-Scholes model). It may be also noted that the results of moneyness bias are examined in a way that convey the meaning rather than the ratio moneyness [Singh and Dixit, 2016)]. It may be also noted that a single error matrix has been prepared in each stage on entire sample of twenty-two companies for four years. In other words, error matrix for individual company and year wise has not been prepared.

### 3.3.2. SAMPLING FRAMEWORK

The magnitude options pricing errors have been empirically evaluated for both stock and index traded on NSE in India. Hence, this research depends heavily for data on the spot, future and option prices of stocks and index. For this research the number of qualified stocks of companies are selected from the list of Nifty 50 stocks which consists of 50 actively traded stocks of companies. Here, the stock of the company is the underlying asset for option.

Secondly, the magnitude options pricing errors have been also empirically evaluated for index options. Here, the equity index Nifty 50 of NSE has been selected for the study as it is one of the most actively traded derivative index contracts in the world. Hence, the index Nifty 50 option has the index as the underlying asset. The Nifty 50 is a diversified 50 stock index accounting for 12 sectors of Indian economy. This index represents about 62.9% of the free float market capitalization of the stocks listed on NSE as on 31st March, 2017 and this index is also ideal for derivative trading among the traders and investors.

Data have been framed by applying the following criteria:

**3.3.3. Instrument Types Data:** There are four types of instruments have been selected in this research to meet the stated objectives-

(a) OPTSTK i.e. options on stock
(b) FUTSTK i.e. Futures on stocks
(c) OPTIDX i.e. Options on Index
(d) FUTIDX i.e. Futures on Index.

**3.3.4. Underlying Assets Data:** Indian Security in equity segment selected from the list of Nifty 50 companies for instruments OPTSTK & FUTSTK and stock index Nifty 50 (old name S&P CNX Nifty) for instruments OPTIDX & FUTIDX.

**3.3.5. Option Types:** European Style of call European and put European. The model pricing efficiency is also exhibited through its different subgroups. The subgroups of options are OTM, ATM, and ITM (Moneyness) and Near Month, Next Month and Far Month (Maturity) including call to put bias. The conditions for OTM, ATM and ITM have been defined in section 1 [Table 1]. The models efficiency is exhibited by ME, MAE, MSE, RMSE, Theil U statistics and MAPE which are explained in section 3.11.

**3.3.6. Spot Prices Data:** The Stocks spot closing prices and index Nifty 50 spot closing prices traded on NSE have been considered in this research during the study period.

**3.3.7. Futures Prices Data:** The Stocks future and index Nifty 50 future closing prices traded on NSE have been considered in this research during the study period.

**3.3.8. Options Prices Data:** The Stocks options and index Nifty 50 options closing prices traded on NSE have been considered in this research during the study period.

The trading of qualified stocks of the companies must be traded in the both markets i.e., in option market and future market because the Discounting Value of Future Price (DVFP) has been used in the place of spot price for the calculation of option price in the model.

While sorting and matching the data, the options and futures contracts with the same maturity have been selected.

**3.3.9. Period of Study:** The data cover a sample period of four year from 1$^{st}$ April, 2012 to 31$^{st}$ March, 2016 for this research.

**3.3.10. Minimum Number of Options Contracts:** The companies for the study are qualified if their option contracts trading is in the minimum 200 number of contracts for each call and put option, accessed on 1$^{st}$ April, 2012 and once a company qualify, it will remain in study period unless until its trading has been suspended. In other words, options with number of contracts less than 200 are excluded from the sample.

**3.3.11. Expiration of Contracts:** Options and futures contracts traded for only near month, next month and far month are considered.

Hence, the total 22 companies have been qualified for stock options from the list of 50 companies (Appendix 1) taken from the Nifty 50 based on the above-mentioned criteria. List of qualified companies has been given in Appendix 2.

## 3.4. SAMPLE SIZE

Equity options and equity index Nifty 50 options written over the underlying equity of the companies and equity index Nifty 50 respectively have been used in this research for the empirical evaluation of magnitude of the pricing errors. This study investigates 78,069 options (call and put option) written on underlying stocks of 22 companies, which are taken from the list Nifty 50 stock and 5,656 options (call and put options) written on underlying index Nifty 50 (Total 83,725 observations), for a period of 4 years, dated from April 1, 2012 to March 31, 2016 as stated in the following table-

Table 2.1: No. of observations for stocks and Index Nifty50 options

| Year | No. of observations for call options | No. of observations for put options | Total No. of observation | Underlying |
|---|---|---|---|---|
| 1st Apr, 2012– 31st Mar, 2016 | 40,653 | 37,416 | 78,069 | Stocks |
| 1st Apr, 2012– 31st Mar. 2016 | 2,824 | 2,832 | 5,656 | Index Nifty 50 |
| Total | 43,477 | 40,248 | 83,725 | Stocks and Index Nifty50 |

Source: Compiled by Researcher on the Basis of Analysis

To make the study representative of whole market a leading index Nifty 50 (earlier known as S&P CNX Nifty) and total 22 stocks of individual companies (taken from Nifty 50 individual stocks of companies) listed on NSE, India, if their option contracts trading is in the minimum 200 number of contracts, accessed on 1st April, 2012, have been chosen on the basis of above-mentioned criteria to conduct this study. Hence, the total 83,725 observations (78,069 stock options and 5,656 Index Nifty 50 options) have been qualified for this research as stated in the table. However, total 44,064 number of observations (written on stock and Nifty50) had been earlier proposed. For this purpose, sample consists of closing prices of 83,725 options (observations), written on underlying stocks of 22 companies and Index Nifty 50, for the time period ranging from April 1, 20012 to March 31, 2016, have been collected from the website of exchange www.nseindia.com. This research does not increase the period of study beyond four years because the number of observations would be too huge to handle. Similarly, the secondary data related to the date, time, contract month, European option type, strike price and closing price have been taken from the same website and for the same period. The 91day T. Bill yield has been considered as the risk-free rate of interest taken from RBI website www.rbi.org.in for the respective period under the study. The spot prices of stocks have been replaced by their corresponding discounted value future prices for the calculation of option prices. Hence, the stocks, on which future and option both trading are available, have been qualified for study.

## 3.5. SOURCE OF DATA COLLECTION

(a) Types of Data- Secondary data have been collected and used for the purpose of the calculation of the theoretical predicted premium prices as well as for the standard deviation of the stock option.

(b) Sources of data- The primary sources of data regarding time to maturity, contract month, option types, strike price, closing prices and options closing prices are, for the purpose of this study have been taken from the NSE website www.nseindia.com (accessed From April 1, 20012 to March 31, 2016). The risk-free interest rate used in this analysis is the 91 days T-bills rate taken from the RBI website www.rbi.org.in (accessed From April 1, 20012 to March 31, 2016).

(c) Options and Futures Prices: Options and Futures prices in this research are the market closing prices which are obtained from www.nseindia.com. The calculated option price means price calculated under the model.

Other parameters required for estimating theoretical call option prices with the Black-Scholes and the modified Black-Scholes models are obtained as follows-

## 3.6. BLACK-SCHOLES MODEL AND REPLACEMENT OF SPOT PRICE

### 3.6.1. Black-Scholes Model

The Black-Scholes call and put options pricing model used in this research are given as:

$$c = SN(d_1) - Xe^{-rt}N(d_2)$$

$$p = Xe^{-rt}N(-d_2) - SN(-d_1)$$

The variables and assumptions of the model have been discussed in detail in chapter 1, section [1.9].

**3.6.2. Cost of Carry:** The future prices of stock and index should be higher than their corresponding spot prices because of the interest rate element under the cost of carry model. Based on the COC model the spot and future act as substitute [(Bhatia, (2007) and Lin and Stevenson, (1999)] and hence, they can be substituted. The future prices, in this research have been discounted on risk free rate of interest with dividend yield (Appendix4 and 5). The discounting Value of Future Price has been calculated from the following cost of carry equation [Vohra and Bagri, (2007), pp. 87]:

$$F_0 = S_0 e^{(r-y)t}$$

Hence, Spot price will be

$$S_0 = F_0 e^{(r-y)t} \qquad [3.1]$$

The cost of carry has been discussed in detail in chapter 1, section [1.10]. Here, the dividend (y), as an income received on the underlying assets is presented in yield rather than a known cash income. This means that the dividend is known when expressed in percentage of the asset's price at the time when dividend is paid. This DVFP has been used in the Black-Schole model instead of spot price to address the negative cost of carry problem.

### 3.6.3. Replacing Spot price by DVFP in Black-Scholes model

The spot price ($S_0$) of the stock and index has been replaced by their corresponding Discounting Value of Future Price (DVFP) as it is used by Black (1976) in pricing commodity options, Varma (2002) and Mitra (2008 & 2012) in pricing index Nifty 50 traded on NSE. The formula for the prices of European stock call and put options are as follows:

$$C = F_0\, e^{-rt}.N\,(d_1) - X.e^{-rt}N\,(d_2)$$

$$P = X.e^{-rt}N\,(-d_2) - F_0\, e^{-rt}.N\,(-d_1)$$

All other parameters of Black-Scholes (1973) are kept unchanged and the futures prices have the same lognormal property as the Black-Scholes model assumed [Hull, (2007), pp. 354]. It may be noted that the Black equations [Eq. 1.7 and 1.8] are exactly what one would obtain if we used the Black Scholes formula with the stock price (S) replaced by $F*e^{-rt}$ (Varma, 2002).

Below the details of how the other inputs, including method used for measuring the magnitude of pricing errors, have been used in this research:

## 3.7. TIME TO EXPIRY

Time to expiry is used in the formula as $e^{-rt}$, where 't' is time left for the option and future to expire. Whether to use calendar days to expiry or business days to expiry is a debatable issue in finance. The use of calendar days leads to a big overstatement of the weekend's volatility. On the other hand, trading day's leads to understatement of the weekend's volatility as no trading takes place on holidays. Volatility on holidays  Banks, generally, calculate interest on the calendar days, irrespective of the number of intervening holidays during the period. Hence, the calendar days have been taken here (Devanadhen, 2011 and Jin, 2011). Time to expiry is annualized by dividing the number of days left for the option to expire by the total number of calendar days (365 days) in a year. It may be noted that there are three contracts available for both options and futures trading with one month, two months and three months to maturity at any point of time with different strike prices based on decided increments. On each trading day one option on any given strike price has been selected. The contracts are matured on the last Thursday of the expiry month and hence, contracts have a maximum of three months expiration cycle. A new contract for both options and futures is introduced on the next trading day following the expiry of near month.

## 3.8. RISK-FREE RATE RETURN

The risk-free rate is an important concept in finance. According to Investopedia, "it is the theoretical rate of return of an investment with zero risk". The risk-free rate represents the interest an investor expects from the risk-free investment over a specified period of time.

Treasury bills (T. bills) are considered nearly free of default because they are full backed by the governments. T-bills are particularly paid at their par values and do not have any interest rate payments. Therefore, it has no association with interest rate risk. It is used by several researchers

Ackert and Tian (2000), Sharma, (2012), and Mohanti (2015) as a proxy for the risk-free rate of return. The 91-day T. Bills, 182-day T. Bills and 364-day T. Bills are issued by RBI in Indian. The 91-day T-Bills are issued on weekly auction basis in the market.

The continuous compounded risk-free interest rate is used under the Black-Scholes model for pricing options contracts. Hence, yield on the 91-day T-bills issued by the government of India through Reserve Bank of India (RBI) is taken in this research as a proxy for the risk-free rate of return (Appendix 3). The implicit yield-to-maturity at cut-off price of the 91-days T. Bills is weekly published by RBI and the same has been considered. The 91-day T-Bills yield is calculated through the following steps:

1. The implicit yield-to-maturity at cut-off price (simple annualized rate) is taken from the Reserve Bank of India (RBI) for each stated sample period which is calculated by applying the following formula:

   $$r_y = \frac{F - P}{P} \times \frac{365}{m}$$

   Where,

   $r_y$ is the rate of interest

   $F$ is the face value

   $P$ is the cut-off price (or price issue)

   $m$ is the time to maturity of the bills. (Sharma, 2012)

2. The simple yield then has been converted into continuously compounded rate as the continuously compounded risk-free rate of interest is used under the Black-Scholes model. The following natural log function has been used:

   $$r = ln\left(1 + r_y\right)$$

   Where,

   $r$ is the continuously compounded risk-free rate of interest

   $ln$ is the natural logarithm

   $r_y$ is the risk-free rate of interest.

This continuous compounded risk-free rate of interest is calculated for each day matching the expiration dates of both T-Bills and options contracts.

### 3.9. VOLATILITY

The volatility using closing prices is used in the Black-Scholes model. The volatility of a stock is a measure of the uncertainty on the returns provided by the security. The volatility under the Black-Scholes Model is measured by calculating the standard deviation of the return provided by security, when the return is expressed using continuous compounding. However, stock prices are usually observed and recorded in fixed intervals like daily, weekly or monthly and calculating 'n' day standard deviation ($\sigma$) of returns, the volatility of the security can be found. The historical volatility under this research has been calculated by considering the qualified stocks and Nifty50 index prices movement for each period between April 2012 and March 2013, April 2013 and March 2014, April 2014 and March 15 and April 2015 and March 2016 (Appendix 6). For the computation of stocks and index annual volatility, first daily return of the stocks and index has been calculated by the following formula, using the logarithmic difference of the closing prices (Quigley and Ramsey, 2008 and Kumar, Das and Reza, 2013):

$$r(t) = ln\left(\frac{P_t}{P_{t-1}}\right)$$

Where,

$r(t)$ is the log return of an asset,

$r(t)$ is the asset price at time t and

$P_{t-1}$ is the asset price at the previous step in time

Then daily standard deviation has been converted in to annual volatility for each selected stocks and index by using the following formula [Hull, (2007), pp. 310]:

Volatility per annum = volatility per trading day × √number of trading days per annum.

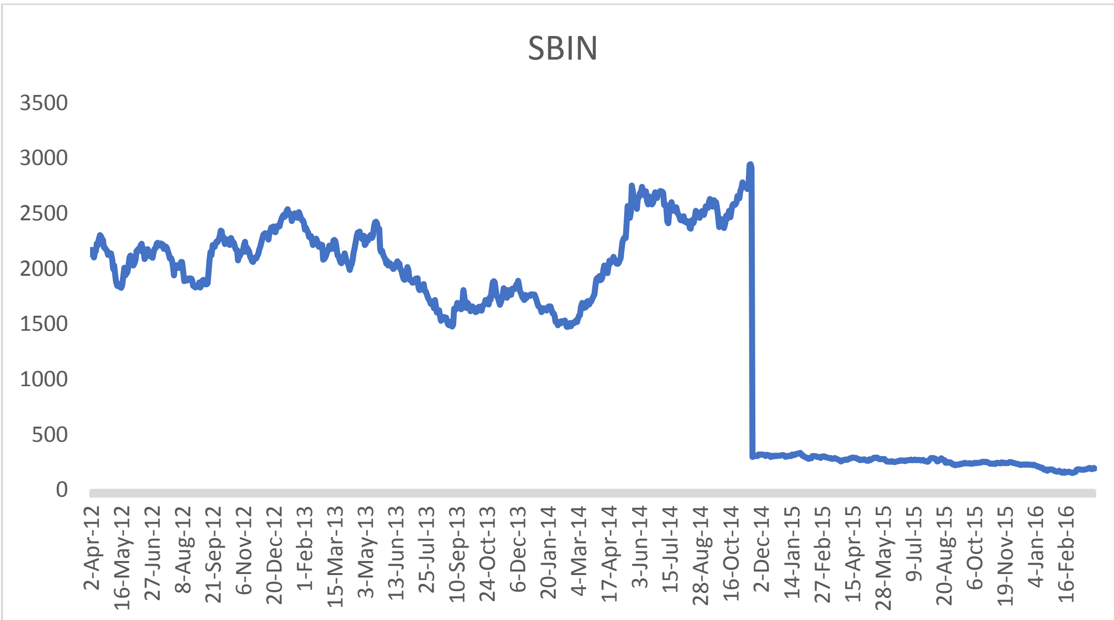
However, volatility of asset prices during trading and holidays will not remain the same. Since no trading in spot and derivatives markets takes place on holiday, volatility on these days is zero. French and Roll (1986), in his study found that volatility is higher on trading days only, and the effect of volatility on non-trading days is usually minimal. Hence, here in this research study, the standard deviation is measured on returns of the trading days only and ignoring any effect due to intervening holidays. It may be noted that under the COC model the volatility of the futures price is the same as the volatility of the underlying asset [Hull, (2007), pp. 355], hence separate volatility for futures have not been used.

The standard deviation calculated on the basis of historical price is affected by the stock splits or issue of bonus shares, consequently the same stock prices have to be adjusted for during the calculation of standard deviation. During the study, it has been identified that SBI has exercised stock splits on 20$^{th}$ November, 2014. Hence, the share has been quoting on an ex-split basis from November 20, 2014. The share price of Rs. 2910.5 on 19$^{th}$ November, 2014 has decreased to Rs. 297.1 on the next working day of 20$^{th}$ November, 2014 because SBI has gone for split the face value of its shares from Rs. 10 to Re. 1 per share, i.e. a share of face value Rs 10 is split into 10 shares of face value Rs 1 each. In this case, if the volatility σ, without adjustment, were calculated, it would be 2.3094 and it will be a wrong calculation of volatility. Hence, the stock prices are adjusted in the proportionate to stock/bonus/demerger shares (Nagendran, 2008). Similarly, stock splits/bonus/demerger have been exercised by AXISBANK (on 28$^{th}$ July, 2014), ICICIBANK (4$^{th}$ Dec., 2014), IDFC (5$^{th}$ Oct., 2015), INFY (on 2$^{nd}$ Dec. 2014 and on 15$^{th}$ Jun. 2015), L T (11$^{th}$ Jul. 2013), SBIN (20$^{th}$ Nov., 2014). SBIN stock prices chart is given below for visual inspection and rest of the charts of stocks prices are given in appendix 10. Chart 3.1 A is without adjustment while chart 3.1 B is with adjustment-

Chart 3.1 A

SHARE PRICES OF SBIN (without Adjustment)

FROM 2.4.2012 TO 31.3.2016



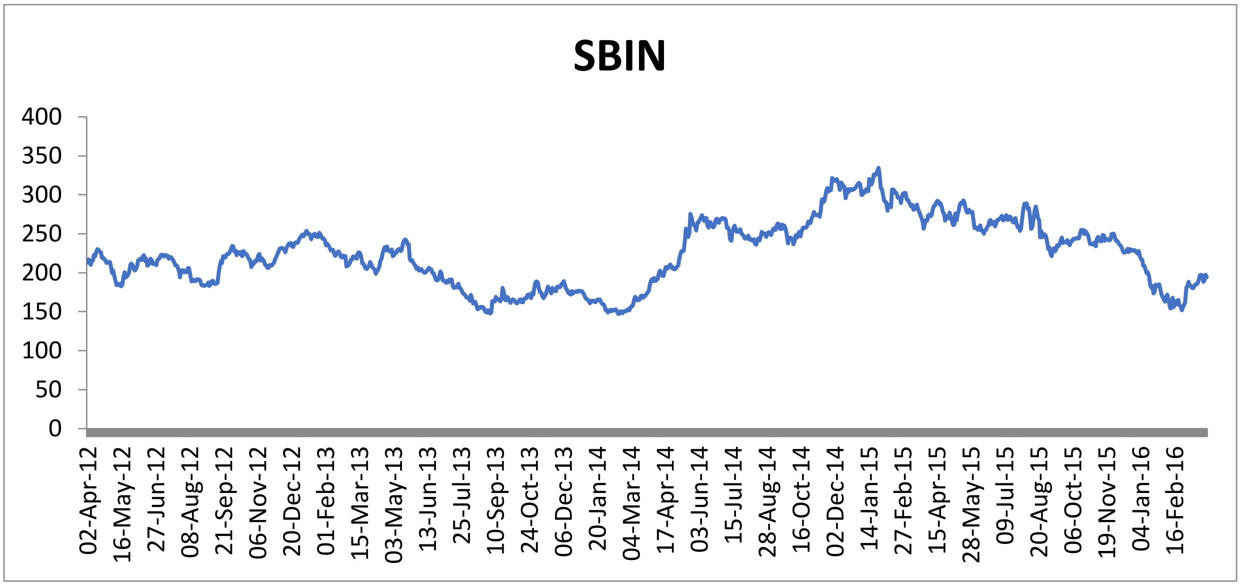

*Source: Compiled and Developed by Researcher from NSE*

It can be observed from the chart that the SBIN share price of Rs. 2,910.5 on 19th November, 2014 has decreased to Rs. 297.1 on the next working day of 20th November, 2014. The reason being the SBIN went for a stock-split.

Chart 3.1 B

SHARE PRICES OF SBIN (with Adjustment)

FROM 2.4.2012 TO 31.3.2016




*Source: Compiled and Developed by Researcher from NSE*

The SBIN stock prices are adjusted in the proportionate of the stock-split as shown in chart 3.1B. Similarly, the charts for all stocks have been developed to identify such actions of companies which drastically affect the stock prices. These charts are shown in appendix 10.

## 3.10. STATISTICAL MEASURES FOR RESULTS COMPARISON

It is now possible after gathering all the required data to calculate options prices by using both the Black-Scholes model and the model after replacing the spot price (S) by the discounted value of future price ($F.e^{-rt}$) in the original Black-Scholes Model. The various forecast statistics used by researchers are the Mean Error (ME), Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Thiel's U statistic and Mean Absolute Percentage Error (MAPE). These methods are suggested by Cook (2006). These forecast evaluation statistics have been used to know the magnitude of the produced errors and to compare model produced errors. These values have been calculated with the help of excel. However, the Mean Error (ME) is considered as the most basic and powerful of all forecast statistics hence the call to put bias has been decided on this basis. The easiest way to measure the pricing accuracy of both models is to compare the calculated prices of options with the market closing prices. The differences between actual and computed values are the magnitude of errors. The model that produces lowest error can be considered as a better model. It may be noted that stage third makes comparison between the models hence, if overall improvement is exhibited by the modified model then the performance of its subgroups will be compared. This research uses following common method of evaluating the performance of the option pricing models:

### 3.10.1. Mean Error (ME)

Mean error is the average of all errors in a data set. This a very common and simple method used for evaluating the relative performance of models. It can be computed by adding all error values and dividing total error by the number of observations-

$$ME = \frac{1}{n}\sum_{i=1}^{n}(y_i - f_1)$$

Where,

$y_i$ is the actual value

$f_i$ is the forecasted value and $n$ is the number of total observations.

A lower ME is considered better than a higher one. However, the positive and negative values cancel each other out in this method. A low value of the ME may conceal forecasting accuracy due to the offsetting effect of large positive and negative forecast errors and make this measure unacceptable. Options prices calculated under a model suffer from overpricing or underpricing error. In this research, regarding a model's efficiency, a positive ME value obtained from subtracting model price from the market price (Market Price > Model Price) indicates that concerned model underprices options while regarding a model's efficiency, a negative ME value obtained from subtracting model price from the market price (Market Price < Model Price) indicates that concerned model overprices options. It should be noted that the market price is treated as the actual price in the calculation of ME.

The following statistical measures are also commonly used to gauge the relative prediction error of the option pricing models:

### 3.10.2. Mean Absolute Error (MAE)

The mean absolute error value is the average absolute error value. The closer this value is to zero, the better is the forecast. The neutralization of positive errors by negative errors can be avoided in this measure. MAE is computed using the formula-

$$MAE = \frac{1}{n}\left(\sum_{i=1}^{n}|y_i - f_i|\right)$$

Where,

$y_i$ is the actual value
$f_i$ is the forecasted value and
$n$ is the number of total observations.

The concept of MAE is simpler and more interpretable than other methods. Hence, it is considered as a more natural measure average error. It does not require use of square root or square. The Inter-comparisons of average model-performanceerror should be based on MAE (Willmott and Matsuura, 2005). when it is being compared to RMSE. But one problem associated with MAE is that the relative size of error is not always obvious.

### 3.10.3. Mean Squared Error (MSE)

Mean squared error iscomputed as the average of the squared error values. This is the commonly used error indicator in statistical fitting procedures. As compare to the mean absolute error value, this measure is very sensitive to large outlier as it places more penalties on large errors than mean absolute error. MSE is computed using the following formula-

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - f_i)^2$$

Where,

$y_i$ is the actual value
$f_i$ is the forecasted value and
$n$ is the number of total observations.

The MSE is always non-negative and the value closer to zero is better.

**3.10.4. Root Mean Squared Error (RMSE)**

It is the square root of mean squared error and conceptually similar to the widely used statistic called- Standard Deviation. This method is frequently used for measuring the differences between values predicted by a model and the value observed. RMSE is calculated with the help of residuals which are the difference between the actual values and predicted values. It is the square root of the average of squared errors and hence its value is always non-negative. Hence, squaring the residuals, averaging the squares and taking the square root gives the value of RMSE.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - f_i)^2}$$

Where,

$y_i$ is the actual value
$f_i$ is the forecasted value and
$n$ is the number of total observations.

RMSE is commonly used to verify the experimental results. Here, the errors are squared, before they are averaged, consequently researchers use RMSE which gives a relatively high weight to large errors. It should be noted that the ME, MAE and MAPE methods are based on the mean error and sometimes these methods may understate the impact of big but infrequent error. Hence researchers use RMSE which adjusts large rare error. A lower RMSE is considered better than a higher one.

### 3.10.5. Thiel's U statistic

Henri Theil (1961) developed for measuring the degree to which one time series particularly differs from another. Theil's U statistic, stands for unbiased statistics, is computed as under-

$$U = \frac{\sqrt{\left[\frac{1}{n}\sum_{i=1}^{n}(y_i - f_i)^2\right]}}{\left[\sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i)^2} + \sqrt{\frac{1}{n}\sum_{i=1}^{n}(f_i)^2}\right]}$$

Where,

$y_i$ is the actual value

$f_i$ is the forecasted value and

$n$ is the number of total observations.

It measures the forecast accuracy. Here the two times series in question are (a) the actual value of options ($y_n$) and (b) the value of option predicted by the models ($f_n$). The Theil's U statistics value must be between 0 and 1. The value closer to zero indicates great forecasting accuracy and indicates a good fit, whereas, value greater than 1 indicates that the technique is actually worse. In comparing the two models- the Black-Scholes and the modified Black model, the model that produces lower U statistic, may be considered better than the other. Methods' pricing accuracy has been tested by using the Theil's U statistic by Kakati (2014) and Japanlan (2013).

### 3.10.6. Mean Absolute Percentage Error (MAPE)

The Mean Absolute Percentage Error (MAPE) measures the prediction accuracy of a forecasting method in percentage term. This method is also known as the Mean Absolute Percentage Deviation (MAPD). The MAPE is defined as follows:

$$MAPE = \left(\frac{1}{n}\sum_{i=1}^{n}\frac{|y_i - f_i|}{|y_i|}\right) \times 100$$

Where,

$y_i$ is the actual value

$f_i$ is the forecasted value and

$n$ is the number of total observations.

The MAPE is scale sensitive and used when the researchers work with large-volume data. The two time series data must be identical in size when researchers measure the accuracy of models. Many researchers focus primarily on the MAPE when assessing forecast accuracy of a model because comparing accuracy in percentage term is easy to interpret. Secondly, as mentioned above, one problem associated with MAE is that the relative size of error is not always obvious and hence, the mean absolute error in percentage term deals with this type of problem. However, this method cannot be used if there are zero values which sometimes happens with low-value data.

The paired sample t-test has been also used to obtain the p-value under the SPSS version 21 to support hypotheses as a secondary tool. If p-value is found greater than 0.05 then null hypothesis is accepted and if p-value is found less than 0.05 then the null hypothesis is rejected.

The above mentioned six statistical tools have their own advantages and disadvantages in assessing models' accuracy performance. Hence, a combination of methods, including but certainly not limited to ME, MAE and RMSE are often required to assess models' accuracy performances.

The research objectives have been formulated on the basis of research gap with description followed by research methodology used to achieve the stated objectives scientifically. The proposed hypothesis, grouping of hypotheses, sampling framework, research design, and statistical measures for result comparison for options pricing accuracy have been also discussed. The formulated objectives have been discussed and achieved based on the hypothesis with supported data analysis and interpretation in the next chapter.

# *CHAPTER IV*

# DATA ANALYSIS AND INTERPRETATION

## INTRODUCTION

This chapter calculates and discusses the magnitude of pricing error produced under the Black-Scholes model using both spot prices and discounting value of future prices. Researchers have found that the B & S model exhibits pricing error when option price is calculated using the spot price due to cost of carry problem (bias). Some researchers have addressed this cost of carry problem by using discounting value of future price (DVFP) instead of spot price in the B & S model and hence, they have minimized magnitude of pricing error. This chapter calculates and discusses the magnitude of pricing errors in three stages for stock call, index call, stock put and index put including OTM, ATM, ITM, Near Month, Next Month, Far Month and call to put bias. But before these calculation and discussion, a visual inspection has been made regarding how many times stock and index futures prices are traded lower than their corresponding spot prices. The futures prices then have been discounted and again compared with spot prices. These discounted values of futures prices have been used instead of the spot prices to address the negative cost of carry problem.

This chapter consists with **eight** sections: **first** section makes Comparison between underlying's future and spot prices. The **second** section tests normality assumption of the model. The **third** section describes error matrices of the B&S model using spot price (stage $1^{st}$). The **fourth** section describes error matrices of the B&S model after replacing spot price by the discounting value of future price (stage $2^{nd}$). The **fifth** section makes comparison between B&S model and modified B&S model to identify improvement. The **sixth** section shows SPSS output for stage $1^{st}$. The **seventh** shows SPSS output for stage $2^{nd}$. The **eighth** section shows SPSS output for stage $3^{rd}$.

## 4.1. COMPARISON BETWEEN UNDERLYINGS' FUTURE AND SPOT PRICES

### 4.1.1. Comparison between stocks' future and spot prices for Stock Call Options:

The NSE stock future and spot prices have been compared in table 4.1 for stock call options to see whether the future prices are greater than their corresponding spot prices.

Table 4.1: Comparison between stocks' future and spot prices for stock call options

| Underlying Assets | Future prices less than spot prices | Future prices greater than spot prices | Total No. of Observations |
|---|---|---|---|
| AXISBANK | 355 | 1,378 | 1,733 |
| BHARTIARTL | 198 | 1,574 | 1,772 |
| BHEL | 1037 | 712 | 1,749 |
| CAIRN | 360 | 1,291 | 1,651 |
| DLF | 323 | 1,510 | 1,833 |
| HDFC | 246 | 1,477 | 1,723 |
| HDFCBANK | 140 | 1,530 | 1,670 |
| HINDALCO | 146 | 1,673 | 1,819 |
| HINDUNILVR | 256 | 1,489 | 1,745 |
| ICICIBANK | 314 | 1,693 | 2,007 |
| IDFC | 284 | 1,585 | 1,869 |
| INFY | 374 | 1,687 | 2,061 |
| ITC | 172 | 1,705 | 1,877 |
| JPASSOCIAT | 276 | 1,534 | 1,810 |
| LT | 226 | 1,661 | 1,887 |
| M&M | 243 | 1,307 | 1,550 |
| RELIANCE | 134 | 1,963 | 2,097 |
| RELINFRA | 221 | 1,450 | 1,671 |
| SBIN | 353 | 1,797 | 2,150 |
| TATAMOTORS | 248 | 1,822 | 2,070 |
| TATASTEEL | 402 | 1,610 | 2,012 |
| TCS | 326 | 1,571 | 1,897 |
| Total No. of observation for stock call options | 6,634 | 3,4019 | 40,653 |

Source: Compiled by Researcher on the Basis of Analysis

It has been found, as stated in table 4.1, that the total 6,634 stock future prices out of total 40,653 observations have been quoted lower than their corresponding stock spot prices. In other words, 16.32% of the total observations, the stock future prices have been traded below their corresponding stock spot prices.

The stocks' future prices have been discounted and compared to their corresponding stocks' spot prices for addressing negative cost of carry problem for stock call options in table 4.2.

Table 4.2: Comparison between stocks' DVFP and spot prices for stock call options

| Underlying Assets | DVFP less than spot prices | DVFP greater than spot prices | Total No. of Observations |
|---|---|---|---|
| AXISBANK | 839 | 894 | 1,733 |
| BHARTIARTL | 814 | 958 | 1,772 |
| BHEL | 1,424 | 325 | 1,749 |
| CAIRN | 666 | 985 | 1,651 |
| DLF | 945 | 888 | 1,833 |
| HDFC | 637 | 1,086 | 1,723 |
| HDFCBANK | 528 | 1,142 | 1,670 |
| HINDALCO | 558 | 1,261 | 1,819 |
| HINDUNILVR | 796 | 949 | 1,745 |
| ICICIBANK | 759 | 1,248 | 2,007 |
| IDFC | 514 | 1,355 | 1,869 |
| INFY | 1,015 | 1,046 | 2,061 |
| ITC | 548 | 1,329 | 1,877 |
| JPASSOCIAT | 667 | 1,143 | 1,810 |
| LT | 820 | 1,067 | 1,887 |
| M&M | 624 | 926 | 1,550 |
| RELIANCE | 611 | 1,486 | 2,097 |
| RELINFRA | 510 | 1,161 | 1,671 |
| SBIN | 1,133 | 1,017 | 2,150 |
| TATAMOTORS | 1,018 | 1,052 | 2,070 |

| | | | |
|---|---|---|---|
| TATASTEEL | 648 | 1,364 | 2,012 |
| TCS | 1,063 | 834 | 1,897 |
| Sum | 17,137 | 23,516 | 40,653 |
| Source: Compiled by Researcher on the Basis of Analysis | | | |

When the stocks' future prices have been discounted, then 17,137 out of total 40,653 observations are found lower than their corresponding spot prices (table 4.2). In other words, 42.15% of the total observations, the stocks' DVFP have been traded below their corresponding stock spot prices. Hence, comparing the discounting value of the futures prices of stocks with their corresponding spot prices, a visual inspection reveals that 42.15% of the total observations for stock call options are likely to be affected by the negative cost of carry problem.

**4.1.2. Comparison between index Nifty 50 future and spot prices for index Nifty 50 call options:**

The options pricing models have been also tested for the equity index Nifty 50 call options. The NSE equity index Nifty 50 future and spot prices have been compared in table 4.3 for index Nifty 50 call options to see whether the future prices are greater than their corresponding spot prices.

| Table 4.3: Comparison between index Nifty 50's future and spot prices for index Nifty 50 call options | | | |
|---|---|---|---|
| Underlying Assets | Future prices less than spot prices | Future prices greater than spot prices | Total No. of Observations |
| Equity Index Nifty 50 | 124 | 2,700 | 2,824 |
| Source: Compiled by Researcher on the Basis of Analysis | | | |

It has been found that the total 124 equity index Nifty 50 future prices out of total 2,824 observations have been quoted lower than their corresponding Nifty 50's spot prices. In other words, 4.39% of the total observations, the Nifty 50 stock future prices have been traded below their corresponding Nifty 50 spot prices (Table 4.3).

The equity index Nifty 50 future prices have been discounted and compared to their corresponding Nifty 50 spot prices for addressing negative cost of carry problem for index call options in table 4.4.

| Table 4.4: Comparison between index Nifty 50 DVFP and spot prices for index Nifty 50 call options | | | |
|---|---|---|---|
| Underlying Assets | DVFP less than spot prices | DVFP greater than spot prices | Total No. of Observations |
| Equity Index Nifty 50 | 1,446 | 1,378 | 2,824 |
| Source: Compiled by Researcher on the Basis of Analysis | | | |

When the equity index Nifty 50 future prices have been discounted, then 1,446 out of total 2,824 observations are found lower than their corresponding spot prices (table 4.4). In other words, 51.20% of the total observations, the Nifty 50's DVFP have been traded below their corresponding Nifty 50 spot prices. Hence, comparing the discounting value of the futures prices of index nifty 50 with their corresponding spot prices, A visual inspection reveals that 51.20% of the total observations for index Nifty 50 call options are likely to be affected by the negative cost of carry problem.

### 4.1.3. Comparison between stocks' future and spot prices for stock put options:

The NSE stock future and spot prices have been compared in table 4.5 for stock put options to see whether the future prices are greater than their corresponding spot prices.

Table 4.5: Comparison between stocks future and spot prices for stock put options

| Underlying Assets | Future prices less than spot prices | Future prices greater than spot prices | Total No. of Observations |
|---|---|---|---|
| AXISBANK | 341 | 1,307 | 1,648 |
| BHARTIARTL | 183 | 1,443 | 1,626 |
| BHEL | 979 | 673 | 1,652 |
| CAIRN | 340 | 1,199 | 1,539 |
| DLF | 300 | 1,419 | 1,719 |
| HDFC | 232 | 1,338 | 1,570 |
| HDFCBANK | 135 | 1,365 | 1,500 |
| HINDALCO | 143 | 1,601 | 1,744 |
| HINDUNILVR | 217 | 1,402 | 1,619 |
| ICICIBANK | 307 | 1,527 | 1,834 |
| IDFC | 240 | 1,383 | 1,623 |
| INFY | 355 | 1,565 | 1,920 |
| ITC | 155 | 1,558 | 1,713 |
| JPASSOCIAT | 259 | 1,371 | 1,630 |
| LT | 215 | 1,580 | 1,795 |
| M&M | 224 | 1,233 | 1,457 |
| RELIANCE | 129 | 1,713 | 1,842 |
| RELINFRA | 211 | 1,360 | 1,571 |
| SBIN | 338 | 1,634 | 1,972 |
| TATAMOTORS | 242 | 1,638 | 1,880 |
| TATASTEEL | 349 | 1,437 | 1,786 |
| TCS | 312 | 1,464 | 1,776 |
| Total No. of observation for stock call options | 6,206 | 31,210 | 37,416 |

Source: Compiled by Researcher on the Basis of Analysis

It has been found, as stated in table 4.5, that the total 6,206 stock future prices out of total 37,416 observations have been quoted lower than their corresponding stock spot prices. In other words, 16.59% of the total observations, the stock future prices have been traded below their corresponding stock spot prices.

The stocks future prices have been discounted and compared to their corresponding stocks spot prices for addressing negative cost of carry problem for stock put options in table 4.6.

Table 4.6: Comparison between stocks' DVFP and spot prices for stock put options

| Underlying Assets | DVFP less than spot prices | DVFP greater than spot prices | Total No. of Observations |
|---|---|---|---|
| AXISBANK | 785 | 863 | 1,648 |
| BHARTIARTL | 728 | 898 | 1,626 |
| BHEL | 1,336 | 316 | 1,652 |
| CAIRN | 627 | 912 | 1,539 |
| DLF | 876 | 843 | 1,719 |
| HDFC | 586 | 984 | 1,570 |
| HDFCBANK | 475 | 1,025 | 1,500 |
| HINDALCO | 533 | 1,211 | 1,744 |
| HINDUNILVR | 715 | 904 | 1,619 |
| ICICIBANK | 720 | 1,114 | 1,834 |
| IDFC | 434 | 1,189 | 1,623 |
| INFY | 938 | 982 | 1,920 |
| ITC | 501 | 1,212 | 1,713 |
| JPASSOCIAT | 584 | 1,046 | 1,630 |
| LT | 765 | 1,030 | 1,795 |
| M&M | 584 | 873 | 1,457 |
| RELIANCE | 551 | 1,291 | 1,842 |
| RELINFRA | 477 | 1,094 | 1,571 |
| SBIN | 1,023 | 949 | 1,972 |
| TATAMOTORS | 904 | 976 | 1,880 |

| | | | |
|---|---|---|---|
| TATASTEEL | 572 | 1,214 | 1,786 |
| TCS | 999 | 777 | 1,776 |
| Sum | 15,713 | 21,703 | 37,416 |
| Source: Compiled by Researcher on the Basis of Analysis | | | |

When the stocks future prices have been discounted, then 15,713 out of total 37,416 observations are found lower than their corresponding spot prices (table 4.6). In other words, 41.95% of the total observations, the stocks DVFP have been traded below their corresponding stock spot prices. Hence, comparing the discounting value of the futures prices of stocks with their corresponding spot prices, A visual inspection reveals that 41.99% of the total observations for stock put options are likely to be affected by the negative cost of carry problem.

### 4.1.4 Comparison between index Nifty 50 future and spot prices for index Nifty 50 put options:

The options pricing models have been also tested for the equity index Nifty 50 call and put options. The NSE equity index Nifty 50 future and spot prices have been compared in table 4.7 for index Nifty 50 put options to see whether the future prices are greater than their corresponding spot prices.

| Table 4.7: Comparison between index Nifty 50's future and spot prices for index Nifty 50 call options | | | |
|---|---|---|---|
| Underlying Assets | Future prices less than spot prices | Future prices greater than spot prices | Total No. of Observations |
| Equity Index Nifty 50 | 125 | 2,707 | 2,832 |
| Source: Compiled by Researcher on the Basis of Analysis | | | |

It has been found that the total 125 equity index Nifty 50 future prices out of total 2,832 observations have been quoted lower than their corresponding Nifty 50 spot prices. In other words, 4.41% of the total observations, the Nifty 50's future prices have been traded below their corresponding Nifty 50 spot prices (Table 4.7).

The equity index Nifty 50 future prices have been discounted and compared to their corresponding Nifty 50 spot prices for addressing negative cost of carry problem for index Nifty 50 put options in table 4.8.

| Table 4.8: Comparison between index Nifty 50 DVFP and spot prices for index Nifty 50 put options | | | |
|---|---|---|---|
| Underlying Assets | DVFP less than spot prices | DVFP greater than spot prices | Total No. of Observations |
| Equity Index Nifty 50 | 1,450 | 1,382 | 2,832 |
| Source: Compiled by Researcher on the Basis of Analysis | | | |

When the equity index Nifty 50 future prices have been discounted, then 1,446 out of total 2,824 observations are found lower than their corresponding spot prices (table 4.8). In other words, 51.20% of the total observations, the Nifty 50 DVFP have been traded below their corresponding Nifty 50 spot prices. Hence, comparing the discounting value of the futures prices of index Nifty 50 with their corresponding spot prices, A visual inspection reveals that 51.20% of the total observations for index Nifty 50 put options are likely to be affected by the negative cost of carry problem.

A visual inspection reveals that 42.15% of the total observations for stock call options, 51.20% of the total observations for index Nifty 50 call options, 41.95% of the total observations for stock put options and 51.20% of the total observations for index Nifty 50 put options are likely to be affected by the negative cost of carry problem and hence, this bias is bound to influence options pricing. These findings are consistent with results from Mitra (2008 & 2012) for the index Nifty 50.

## 4.2. TEST OF NORMALITY

The B&S model is based on seven assumptions and testing of its all assumption will divert the main objectives of this research. One of the main assumptions of the B & S model is that stock returns follow log normal distribution. Hence, this important condition is tested empirically in this research. The daily log-returns for all twenty-two companies and index Nifty 50 are calculated using the formula ln ($S_t$ / $S_{t-1}$). Then the distribution of log-returns is tested to check whether they satisfy the normal distribution criteria. The normal distribution can be tested by many methods. Histograms are easy testing tools for testing the normality of a distribution. The mean-based statistics like mean, standard deviation, skewness and kurtosis are also commonly used as the normality testing tools by researchers.

Mean-based statistics have been used to test normality. The Mean-based statistics depend on four measures namely the mean (to know the centre), the standard deviation (to know the spread), the coefficient of skewness (to know the symmetry), and the coefficient of kurtosis (to know the heavy or thin tails). Histograms have also been used for identifying the normality of a distribution.

Histograms are generated and mean-based statistical values of the mean, standard deviation, skewness and Kurtosis have been calculated to check for the normality of the distribution of the log-returns of all the twenty-two companies and index Nifty 50. The values of mean-based statistics are presented in the table 4.9-

Table 4.9: Mean-based statistics for Log-Returns of stocks and Index Nifty 50

| S. No. | Underlying | Mean | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|---|---|
| 1 | AXIS BANK | 0.0007 | 0.0222 | 0.5511 | 5.5135 |
| 2 | BHARTIARTLE | 0.0000 | 0.0193 | 0.1819 | 1.1664 |
| 3 | BHEL | -0.0008 | 0.0262 | -0.2622 | 3.3731 |
| 4 | CAIRN | -0.0008 | 0.0204 | -0.4552 | 3.3922 |
| 5 | DLF | -0.0004 | 0.0309 | -0.0353 | 2.0446 |
| 6 | HDFC | 0.0005 | 0.0175 | 0.0622 | 1.5831 |
| 7 | HDFC BANK | 0.0007 | 0.0139 | 0.1388 | 3.1339 |
| 8 | HINDALCO | -0.0004 | 0.0254 | 0.1293 | 1.0731 |
| 9 | HINDUNILVRE | 0.0008 | 0.0155 | 0.7264 | 3.8628 |
| 10 | ICICIBANK | 0.0003 | 0.0199 | 0.2656 | 1.700 |
| 11 | IDFC | 0.0001 | 0.0235 | -0.3882 | 4.6227 |

| | | | | | |
|---|---|---|---|---|---|
| 12 | INFY | 0.0009 | 0.0151 | 0.3724 | 5.9054 |
| 13 | ITC | 0.0004 | 0.0158 | -0.3570 | 3.6711 |
| 14 | JPASSOCIATE | -0.0025 | 0.0380 | -0.4870 | 3.8074 |
| 15 | LT | 0.0003 | 0.0191 | 0.0679 | 1.3885 |
| 16 | M&M | 0.0005 | 0.0170 | 0.0490 | 0.6301 |
| 17 | Reliance | 0.0003 | 0.0161 | -0.1371 | 1.8030 |
| 18 | RELINFRA | -0.0001 | 0.0278 | -0.1232 | 2.8049 |
| 19 | SBIN | -0.0001 | 0.0204 | 0.3061 | 2.6359 |
| 20 | TATASTEEL | -0.0004 | 0.0232 | 0.0378 | 2.5869 |
| 21 | TATAMOTORS | 0.0003 | 0.0227 | -0.0151 | 1.7087 |
| 22 | TCS | 0.0008 | 0.0152 | -0.1238 | 3.9011 |
| 23 | Index Nifty 50 | 0.0003 | 0.0098 | -0.3273 | 2.4761 |
| Source: Compiled by Researcher on the Basis of Analysis | | | | | |

The above table show that the mean returns are almost zero in all cases and standard deviations are around 0.0 to 0.0309. That indicates the logarithmic returns of the stock of the companies are more or less normally distributed.

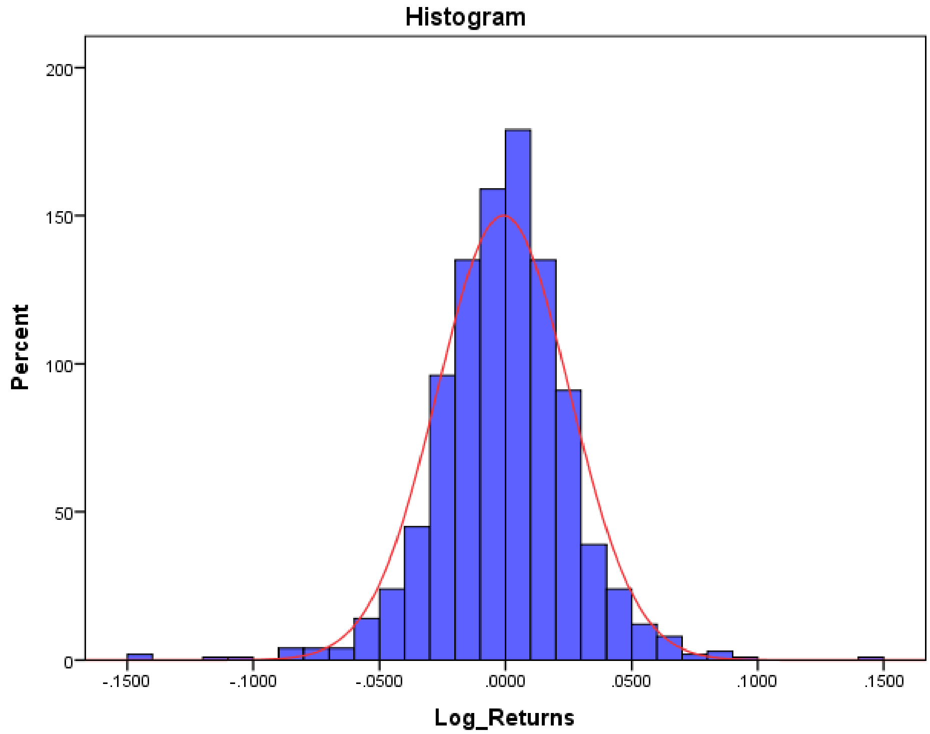
The skewness figures are slightly high for some cases like AXISBANK; 0.5511, CAIRN; -0.4552, HINDUNILVRE; 0.7264, IDFC; -0.3882, ITC; -0.3570, JPASSOCIATE; -0.4870, SBIN; 0.3061 These deviations may be because of some outliers in the data. Hence, it may be inferred that though, there are asymmetry in the distribution they are low.

The kurtosis figures are slightly high for some companies like AXIS BANK; 5.5135, BHEL; 3.3731, CAIRN; 3.3922, HDFC; 3.1339, HINDUNILVRE; 3.8628, IDFC; 4.6227, INFY; 5.9054, ITC; 3.6711, LT; 3.8074, TCS; 3.9011 which show slightly peakedness in the histogram. For a normal distribution the value of kurtosis should be three. Most, 7 out of 23 companies have shown the value of kurtosis little bit more than three except AXISBANK, IDFC and INFY. As far as location of the symmetry of the distributions are concerned, they satisfy the norms of a normal distribution. This is evident from the corresponding histograms shown below-

Chart 4.1

Distribution of Log Returns

BHEL

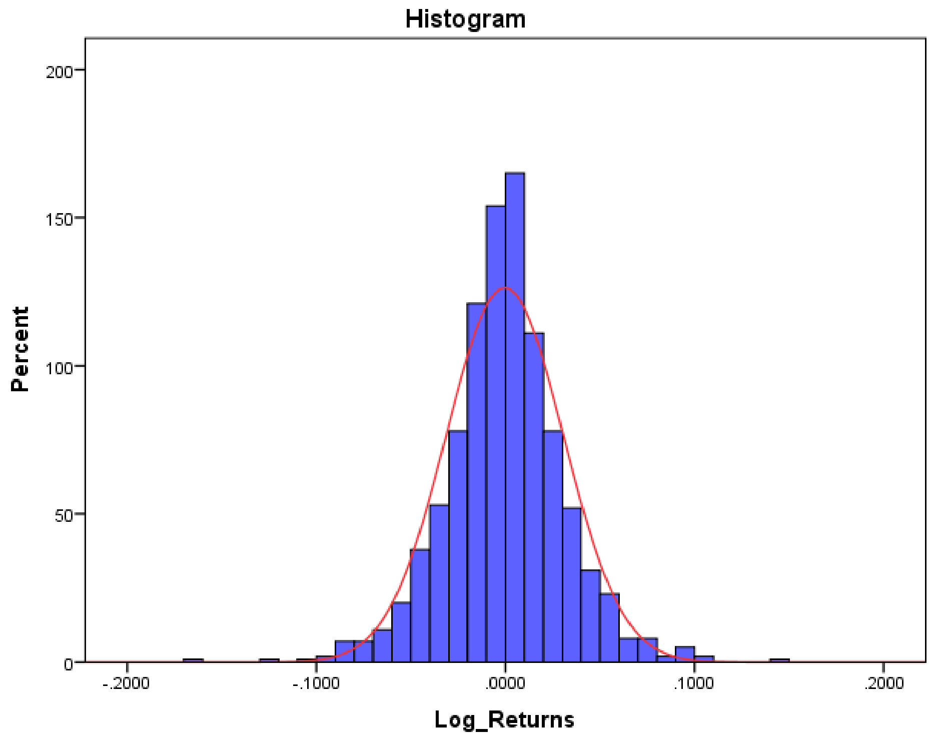



*Source: Compiled and Developed by Researcher from NSE*

Chart 4.2

Distribution of Log Returns

DLF




*Source: Compiled and Developed by Researcher from NSE*

The log normal assumptions of the model are mostly care taken but peakedness of the distribution is found. However, the mean of log-returns for all companies and index Nifty 50 is zero. Hence, Except the kurtosis all other tests point the log-returns are normally distributed. The corresponding histograms of all selected twenty-two companies and index Nifty 50 are given in Appendix 8.

## EFFICIENCY OF BLACK-SCHOLES MODEL USING SPOT PRICE AND DVFP

The empirical analysis starts with stage 1$^{st}$ where the pricing efficiency of the Black-Scholes model for call and put options written on stocks and index has been tested using underlying spot price. In stage 2$^{nd}$, the pricing efficiency of the Black-Scholes model has been tested using DVFP instead of spot price of the underlying assets while stage 3rd makes comparison between the models to show which model exhibits less pricing errors.

**STAGE FIRST**

### 4.3. ERROR MATRICES OF THE B&S MODEL USING SPOT PRICE

**In stage 1st**, the pricing accuracy of the Black-Scholes model for call and put options written on stocks and index have been tested using spot price.

#### 4.3.1. For Stock call options under the Black-Scholes model

Table 4.10 describes the entire samples pricing errors exhibited under the Black-Scholes model when the stock call options prices have been calculated by using stock spot prices. The magnitude of pricing error has been calculated by using the ME, MAE, MSE, RMSE, Theil U statistics and MAPE for stock call options. The theoretical prices (premium) of stock call options, here, have been calculated under the Black-Scholes model by using the stock spot prices. The calculated prices using the stock spot prices under the Black-Scholes model are compared with their corresponding stock call market prices to gauge the pricing errors. The difference between the actual price (market price) and model calculated price is known as pricing error.

| Table 4.10: Entire pricing errors metrics under the B&S model for stock call options | |
|---|---|
| Parameters | Value |
| Mean Error (ME) | -2.6325 |
| Mean Absolute Error (MAE) | 7.0509 |
| Mean Squared Error (MSE) | 525.5003 |
| Root Mean Squared Error (RMSE) | 22.9238 |
| Thiel’s U statistic | 0.1588 |
| Mean Absolute Percentage Error (MAPE) | 41.0784 |
| *Source: Compiled by Researcher on the Basis of Analysis* | |

The results shown in Table 4.10 are the outcome for the objective 1 and Hypothesis $H_{01}$. The value of ME is -2.6325. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of -2.6325 given in table 4.49. Consequently, it is more likely to reject the null hypothesis for stock call options.Hence, there is a significant difference between the mean values of the stock call options closing price and calculated price under the B&S model.

The overpriced or underpriced options under the Black-Scholes model are exhibited by ME. The Black-Scholes model considerably overprices stock call option with a ME of -2.6325 as found in table 4.10. The results of entire samples pricing errors produced under the Black-Scholes model have been shown in above table where the MAE, MSE, RMSE, Theil's U statistic and MAPE are found 7.0509, 525.5003, 22.9238, 0.1588 and 41.0784 respectively. It is, hence, evident that model produces pricing errors and overall stock call options are overpriced by the original Black-Scholes model during the study period of this research.

Further, the moneyness bias, as a subgroup, is mentioned in table 4.11

Table 4.11: Subgroup measures of moneyness bias for stock call options under the B&S model

| Moneyness | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
|---|---|---|---|---|---|---|---|
| Out-of-the-Money | 22571 | -6.0873 | 9.8263 | 1301.6082 | 36.0778 | 0.5811 | 95.1157 |
| At-the-Money | 34 | -2.0261 | 2.5845 | 17.6680 | 4.2033 | 0.1321 | 27.3324 |
| In-the-Money | 18048 | -5.3775 | 9.6175 | 892.1892 | 29.8695 | 0.1458 | 21.0751 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.11 are the outcome for the objective 2 for stock call options moneyness bias. Table 4.11 illustrates the results of subgroup measures of moneyness bias for each category such as OTM, ATM and ITM for stock call options under the original Black-

Scholes model. The negative ME has been produced by the Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock call options are overpriced with a ME of -6.0873, -2.0261 and -5.3775, respectively. Hence, it is evident that the original Black-Scholes model consistently overprices across all categories of moneyness. The OTM options have been highly overpriced with the ME of -6.0873. The ATM options, however, show comparatively lower overpricing as compare to other categories which is -2.0261. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 9.8263, 1301.6082, 36.0778, 0.5811 and 95.1157, respectively for OTM options. The same corresponding to ATM options are 2.5845, 17.6680, 4.2033, 0.1321 and 27.3324. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 9.6175, 892.1892, 29.8695, 0.1458 and 21.0751 respectively for ITM options.

The maturity bias, as a subgroup, is depicted in table 4.12

Table 4.12: Subgroup measures of maturity bias for stock call options under the B&S model

| Maturity | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
|---|---|---|---|---|---|---|---|
| Near Month | 18910 | -3.0254 | 6.4623 | 502.5480 | 22.4176 | 0.1589 | 66.4776 |
| Next Month | 19013 | -7.7576 | 11.8452 | 1,529.0032 | 39.1025 | 0.2674 | 55.0248 |
| Far Month | 2730 | -10.9202 | 17.5966 | 2,530.1501 | 50.3006 | 0.3321 | 82.3704 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.12 are the outcome for the objective 2 for stock call options maturity bias. Table 4.12 illustrates the maturity biasness for the near month, next month and far month expiration stock call options contracts whose prices are calculated under the Black-Scholes model using the stock spot prices. Pricing errors calculated on the basis all parameters state that mispricing increases as maturity increases. The ME for the near month, next month and far month stock call options contracts are -3.0254, -7.7576 and -10.9202, respectively. The values of mean errors show that the options prices calculated under the Black Scholes model using the stock spot prices for stock call options consistently overprices across all maturity. On the basis of mean error, the stock call near month options contracts are overpriced with a lowest mean error of -3.0254.

The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 6.4623, 502.5480, 22.4176, 0.1589 and 66.4776, respectively for near month options. The same corresponding to next month options are 11.8452, 1529.0032, 39.1025, 0.2674 and 55.0248. The values of MAE, MSE, RMSE, Thiel's U statistic, and MAPE are found 17.5966, 2530.1501, 50.3006, 0.3321, and 82.3704, respectively for far month options. Hence, the magnitude of mispricing increases as maturity increases in pricing stock call option under the Black-Scholes model.

During the study period, a significant difference has been found between the mean values of the stock call options closing price and calculated price under the B&S model. The theoretical prices of stock call options have been calculated under the Black-Scholes model by using the stock spot prices. It has been found that the Black-Scholes model considerably overprices stock call option with a ME of -2.6325 when it is calculated using spot price of the stock.

The subgroup measures of moneyness bias have been found for each category such as OTM, ATM and ITM for stock call options under the original Black-Scholes model. The original Black-Scholes model consistently overprices across all categories of moneyness.

The maturity biasness for the near month, next month and far month expiration stock call options contracts have been found whose prices are calculated under the Black-Scholes model using the stock spot prices. The magnitude of mispricing increases as maturity increases in pricing stock call option under the Black-Scholes model.

### 4.3.2. For Index Call Options under the Black-Scholes model

Table 4.13 describes the entire samples pricing errors exhibited under the Black-Scholes model when the index call options prices have been calculated by using index spot prices. The magnitude of pricing error has been calculated by using the ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for index call options. The theoretical prices (premium) of index call options, here, have been calculated under the Black-Scholes model by using the index spot prices. The calculated prices using the index spot prices under the Black-Scholes model are compared with their corresponding index call market prices to gauge the pricing errors. The difference between the actual price (market price) and model calculated price is known as pricing error.

| Table 4.13: Entire pricing errors metrics under the B&S model for index S&P CNX Nifty call options | |
|---|---|
| Parameters | Value |
| Mean Error (ME) | -3.408 |
| Mean Absolute Error (MAE) | 17.7109 |
| Mean Squared Error (MSE) | 881.8559 |
| Root Mean Squared Error (RMSE) | 29.696 |
| Thiel's U statistic | 0.023 |
| Mean Absolute Percentage Error (MAPE) | 38.2434 |
| *Source: Compiled by Researcher on the Basis of Analysis* | |

The results shown in Table 4.13 are the outcome for the objective 1 and Hypothesis $H_{02}$. The value of ME is -3.408. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of -3.408 given in table 4.50. Consequently, it is more likely to reject the null hypothesis for index call options. Hence, there is a significant difference between the mean values of the index call options closing price and calculated price under the B&S model.

The overpriced or underpriced options under the Black-Scholes model are exhibited by ME. The Black-Scholes model considerably overprices index call option with a ME of -3.408 as found in table 4.13. The results of entire samples pricing errors produced under the Black-Scholes model have been shown in above table where the MAE, MSE, RMSE, Theil U statistics and MAPE are found 17.7109, 881.8559, 29.696, 0.023 and 38.2434, respectively. It is, hence, evident that model produces pricing errors and overall index call options are overpriced by the original Black-Scholes model during the study period of this research.

Further, the moneyness bias, as a subgroup, is mentioned in table 4.14

Table 4.14: Subgroup measures of moneyness bias for index S&P CNX Nifty Call options under the B&S model

| Moneyness | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
|---|---|---|---|---|---|---|---|
| Out-of-the-Money | 1599 | -0.6918 | 14.127 | 572.4621 | 23.9262 | 0.1563 | 64.016 |
| In-the-Money | 1225 | -6.9533 | 22.389 | 1285.7096 | 35.8567 | 0.0184 | 4.6021 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.14 are the outcome for the objective 2 for index call options moneyness bias. Table 4.14 illustrates the results of subgroup measures of moneyness bias for OTM and ITM index call options under the original Black-Scholes model. The data for ATM index options are not found during the study period. The negative ME has been produced by the original Black-Scholes model in the category OTM and ITM index call options. The OTM and ITM index call options both are overpriced with a ME of -0.6918 and -6.9533, respectively. Hence, it is evident that the original Black-Scholes model also consistently overprices across all categories of given moneyness. However, the OTM options have been overpriced with a lowest ME of-0.6918 while ITM options are overpriced with a highest ME of -6.9533. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 14.127, 572.4621, 23.9262, 0.1563 and 64.016, respectively for OTM options. Notably, the same corresponding to the ITM options are 22.389, 1285.7096, 35.8567, 0.0184 and 4.6021.

The maturity bias, as a subgroup, is depicted in table 4.15

| Table 4.15: Subgroup measures of maturity bias for index S&P CNX Nifty Call options under the B&S model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Maturity | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
| Near Month | 860 | -3.3974 | 9.8592 | 368.876 | 19.2061 | 0.0118 | 29.6516 |
| Next Month | 985 | -2.2385 | 18.5804 | 1041.6331 | 32.2743 | 0.0287 | 39.3436 |
| Far Month | 979 | -4.594 | 23.7334 | 1171.7255 | 34.2305 | 0.0316 | 44.6839 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | |

The results shown in Table 4.15 are the outcome for the objective 2 for index call options maturity bias. Table 4.15 illustrates the maturity biasness for the near month, next month and far month expiration index call options contracts whose prices are calculated under the Black-Scholes model using the index spot prices. The ME for the near month, next month and far month index call options contracts are -3.3974, -2.2385 and -4.594, respectively. The values of mean errors show that the options prices calculated under the Black Scholes model using the index spot prices for index call options consistently underprices across all maturity. On the basis of mean error, the index call next month options contracts are underpriced with a lowest mean error of -2.2385 while far month options contracts are underpriced with a highest mean error of -4.594. Hence, the magnitude of mispricing increases as maturity increases in pricing index call option under the Black-Scholes model. The same corresponding to next month options are-2.2385, 18.5804, 1041.6331, 32.2743, 0.0287 and 39.3436. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found-4.594, 23.7334, 1171.7255, 34.2305, 0.0316 and 44.6839, respectively for far month options.

It has been found that there is a significant difference between the mean values of the index call options closing price and calculated price under the B&S model. The results of entire samples pricing errors produced under the Black-Scholes model shows that the model considerably overprices index call option with a ME of -3.408. The original Black-Scholes model also consistently overprices across all categories of given moneyness and maturity. The magnitude of mispricing increases as maturity increases in pricing index call option under the Black-Scholes model.

### 4.3.3. For Stock Put options under the Black-Scholes model

Table 4.16 describes the entire samples pricing errors exhibited under the Black-Scholes model when the stock put options prices have been calculated by using stock spot prices. The magnitude of pricing error has been calculated by using the ME, MAE, MSE, RMSE, Theil U statistics and MAPE for stock put options. The theoretical prices (premium) of stock put options, here, have been calculated under the Black-Scholes model by using the stock spot prices. The calculated prices using the stock spot prices under the Black-Scholes model are compared with their corresponding stock put market prices to gauge the pricing errors. The difference between the actual price (market price) and model calculated price is known as pricing error.

Table 4.16: Entire pricing errors metrics under the B&S model for stock Put options

| Parameters | Value |
|---|---|
| Mean Error (ME) | -1.5727 |
| Mean Absolute Error (MAE) | 6.6594 |
| Mean Squared Error (MSE) | 530.7265 |
| Root Mean Squared Error (RMSE) | 23.0375 |
| Thiel’s U statistic | 0.1954 |
| MAPE | 71.7882 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.16 are the outcome for the objective 1 and Hypothesis $H_{03}$. The value of ME is -1.5727. The P-value of SPSS output of Paired samples t-test is found less than

0.05 with the same ME of -1.5727 given in table 4.51. Consequently, it is more likely to reject the null hypothesis for stock put options. Hence, there is a significant difference between the mean values of the stock put options closing price and calculated price under the B&S model.

The overpriced or underpriced options under the Black-Scholes model are exhibited by ME. The Black-Scholes model considerably overprices stock put option with a ME of -1.5727as found in table 4.16. The results of entire samples pricing errors produced under the Black-Scholes model have been shown in above table where the MAE, MSE, Theil's statistic and MAPE are found 6.6594, 530.7265, 23.0375, 0.1954 and 71.7882, respectively. It is, hence, evident that model produces pricing errors and overall stock put options are overpriced by the original Black-Scholes model during the study period of this research.

Further, the moneyness bias, as a subgroup, is mentioned in table 4.17

| Table 4.17: Subgroup measures of moneyness bias for stock put options under the B&S model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Moneyness | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
| Out-of-the-Money | 13,809 | -3.1240 | 7.7120 | 502.9189 | 22.4259 | 0.1232 | 72.2351 |
| At-the-Money | 30 | -0.7167 | 1.4869 | 8.0650 | 2.8399 | 0.1676 | 25.493 |
| In-the-Money | 23,577 | -0.6651 | 6.0495 | 547.6784 | 23.4025 | 0.4586 | 71.5854 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | |

The results shown in Table 4.17 are the outcome for the objective 2 for stock put options moneyness bias. Table 4.17 illustrates the results of subgroup measures of moneyness bias for each category such as OTM, ATM and ITM for stock put options under the original Black-Scholes model. The negative ME has been produced by the Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock put options are overpriced with a ME of -3.1240, -0.7167 and -0.6651, respectively. Hence, it is evident that the original Black-Scholes model consistently overprices across all categories of moneyness. The OTM options have been highly overpriced with the ME of -3.1240. The ITM options, however, show comparatively lower overpricing as compare to other categories which is -0.6651. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 7.7120, 502.9189, 22.4259,0.1232 and 72.2351, respectively for OTM options. The same corresponding to ATM options are 1.4869, 8.065, 2.8399, 0.1676 and 25.493. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 6.0495, 547.6784, 23.4025, and 71.5824, respectively for ITM options.

The maturity bias, as a subgroup, is depicted in table 4.18

Table 4.18: Subgroup measures of maturity bias for stock put options under the B&S model

| Maturity | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
|---|---|---|---|---|---|---|---|
| Near Month | 18,879 | -0.6323 | 4.6920 | 356.9053 | 18.8919 | 0.1795 | 92.7206 |
| Next Month | 17,184 | -2.4779 | 8.2616 | 654.8014 | 25.5891 | 0.1979 | 49.788 |
| Far Month | 1,353 | -3.1964 | 13.7634 | 1380.2961 | 37.1523 | 0.2853 | 59.1285 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.18 are the outcome for the objective 2 for stock put options maturity bias. Table 4.18 illustrates the maturity biasness for the near month, next month and far month expiration stock put options contracts whose prices are calculated under the Black-Scholes model using the stock spot prices. The ME for the near month, next month and far month stock put options contracts are -0.6323, -2.4779 and -3.1964, respectively. The values of mean errors show that the options prices calculated under the Black Scholes model using the stock spot prices for stock put options consistently overprices across all maturity. On the basis of mean error, the stock put near month options contracts are overpriced with a lowest mean error of -0.6323 while far month options contracts are overpriced with a highest mean error of -3.1964. Hence, the magnitude of mispricing increases as maturity increases in pricing stock put option under the Black-Scholes model. The same corresponding to next month options are 8.2616, 654.8014, 25.5891, 0.1979 and 49.788. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 13.7634, 1380.2961, 37.1523, 0.2853 and 59.1225, respectively for far month options.

**Stock Call to Put bias under the Black-Scholes model**

The stock call to put bias under the Black-Scholes model has been investigated from the entire pricing errors metrices established for stock call and put options as presented in table4.10 and table 4.16 respectively where the stock call option has been overpriced by the mean error of -2.6325 and the same corresponding to put option is -1.5727. The statement, hence, drawn from the respective tables provides evidence that the B&S model shows higher magnitude of errors in pricing of stock call as compare to pricing put options. This Finding is in line with Kakati (2006) report.

During the study period it has been found that there is a significant difference between the mean values of the stock put options closing price and calculated price under the B&S model. The Black-Scholes model considerably overprices stock put option with a ME of -1.5727. The model also overprices across all categories of moneyness. The values of mean errors show that the options prices calculated under the Black Scholes model using the stock spot prices for stock put options consistently overprices across all maturity.

During the study period regarding the stock call to put bias under the Black-Scholes model, it has been found that the B&S model shows higher magnitude of errors in pricing of stock call as compare to pricing put options.

**4.3.4. For Index Put Options under the Black-Scholes model**

Table 4.19 describes the entire samples pricing errors exhibited under the Black-Scholes model when the index put options prices have been calculated by using index spot prices. The magnitude of pricing error has been calculated by using the ME, MAE, MSE, RMSE, Theil's statistic and MAPE for index put options. The theoretical prices (premium) of index put options, here, have been calculated under the Black-Scholes model by using the index spot prices. The calculated prices using the index spot prices under the Black-Scholes model are compared with their corresponding index put market prices to gauge the pricing errors. The difference between the actual price (market price) and model calculated price is known as pricing error.

| Table 4.19: Entire pricing errors metrics under the B&S model for index S&P CNX Nifty Put options | |
|---|---|
| Parameters | Value |
| Mean Error (ME) | 7.2097 |
| Mean Absolute Error (MAE) | 14.4822 |
| Mean Squared Error (MSE) | 781.6228 |
| Root Mean Squared Error (RMSE) | 26.9472 |
| Thiel’s U statistic | 0.0175 |
| Mean absolute Percentage Error (MAPE) | 60.7176 |
| *Source: Compiled by Researcher on the Basis of Analysis* | |

The results shown in Table 4.19 are the outcome for the objective 1 and Hypothesis $H_{04}$. The value of ME is 7.2097. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of 7.2097 given in table 4.52. Consequently, it is more likely to reject the null hypothesis for index put options. Hence, there is a significant difference between the mean values of the S&P CNX Nifty index put options closing price and calculated price under the B&S model.

The overpriced or underpriced options under the Black-Scholes model are exhibited by ME. The Black-Scholes model considerably underprices index put options with a ME of 7.2097 as found in table 4.19. The results of entire samples pricing errors produced under the Black-Scholes model have been shown in above table where the MAE, MSE, RMSE, Theil’s U statistic and MAPE are found 14.4822, 781.6228, 26.9472, 0.0175 and 60.7176, respectively. It is, hence, evident that model produces pricing errors and overall index put options are underpriced by the original Black-Scholes model during the study period of this research.

Further, the moneyness bias, as a subgroup, is mentioned in table 4.20

| Table 4.20: Subgroup measures of moneyness bias for index S&P CNX Nifty put options under the B&S model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Moneyness | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
| Out-of-the-Money | 853 | 3.5522 | 27.2383 | 1855.0714 | 43.0705 | 0.0148 | 3.2636 |
| In-the-Money | 1979 | 8.7861 | 8.984 | 318.9388 | 17.8589 | 0.3208 | 85.4818 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | |

The results shown in Table 4.20 are the outcome for the objective 2 for the index put options moneyness bias.

Table 4.20 illustrates the results of subgroup measures of moneyness bias for OTM and ITM index put options under the original Black-Scholes model. The data for ATM index options are not found during the study period. The positive ME has been produced by the original Black-Scholes model in the category OTM and ITM index put options. The OTM and ITM index put options both are underpriced with a ME of3.5522 and 8.7861, respectively. Hence, it is evident that the original Black-Scholes model also consistently underprices across all categories of given moneyness. However, The OTM options have been underpriced with a lowest ME of3.5522 while ITM options are underpriced with a highest ME of8.7861. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 27.2383, 1855.0714, 43.0705, 0.0148 and 3.2636, respectively for OTM options. Notably, the same corresponding to the ITM are 8.984, 318.9388, 17.8589 and 0.3208.

The maturity bias, as a subgroup, is depicted in table 4.21

| Table 4.21: Subgroup measures of maturity bias for index S&P CNX Nifty Put options under the B&S model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Maturity | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
| Near Month | 862 | -0.4468 | 10.1183 | 548.6898 | 23.4241 | 0.0118 | 52.9429 |
| Next Month | 986 | 5.5088 | 13.6019 | 694.4377 | 26.3522 | 0.0155 | 60.7178 |
| Far Month | 984 | 15.6212 | 19.1872 | 1073.0382 | 32.7573 | 0.0324 | 67.5283 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | |

The results shown in Table 4.21 are the outcome for the objective 2 for the index put options maturity bias. Table 4.21 illustrates the maturity biasness for the near month, next month and far month expiration index put options contracts whose prices are calculated under the Black-Scholes model using the index spot prices. The ME for the near month, next month and far month index put options contracts are -0.4468, 5.5088 and 15.6212, respectively. On the basis of mean error, the index put next month options contracts are overpriced with a lowest mean error of -0.4468 while far month options contracts are underpriced with a highest mean error of 15.6212.

The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 10.1183, 548.6898, 23.4241, 0.0118 and 52.9429, respectively for near month options. The same corresponding to next month options are 13.6019, 694.4377, 26.3522, 0.0155 and 60.7178. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found19.1872, 1073.0382, 32.7573, 0.0324 and 67.5283, respectively for far month options.

**Index Call to Put bias under the Black-Scholes model**

The index S&P CNX Nifty call to put bias under the Black-Scholes model has been investigated from the entire pricing errors metrices established for index S&P CNX Nifty call and put options as presented in table 4.13 and table 4.19 respectively where the S&P CNX Nifty call option has been overpriced by the mean error of -3.408 and the same corresponding to put option which has been underpriced, is 7.2097. The statement, hence, drawn from the respective tables provides evidence that the magnitude of errors for pricing Index Nifty50 put options is relatively higher under the Black-Scholes model.

During the study period, a significant difference has been found between the mean values of the S&P CNX Nifty index put options closing price and calculated price under the B&S model. It has been found that the model produces pricing errors for index put option and overall index put options are underpriced with the mean error of 7.2097 by the original Black-Scholes model during the study period of this research. It is evident that the original Black-Scholes model also consistently underprices across all categories of given moneyness. similarly, the next month and far month expiration index put options contracts whose prices are calculated under the Black-Scholes model using the index spot prices are underpriced while the near month contracts are overpriced by the model.

During the study period regarding the index call to put bias under the Black-Scholes model, it has been found that the magnitude of errors for pricing Index Nifty 50 put options is relatively higher under the Black-Scholes model.

**STAGE SECOND**

### 4.4. ERROR MATRICS OF THE B&S MODEL AFTER REPLACING SPOT PRICE BY THE DISCOUNTING VALUE OF FUTURE PRICE ($Fe^{-rt}$)

In stage 2nd, an empirical analysis of the Black-Scholes model after bringing modification has been conducted by replacing Sport price (S) by the discounted value of Future price ($Fe^{-rt}$) for call and put options written on stocks and index have been tested.

#### 4.4.1. For Stock call options under the modified Black-Scholes model

Table 4.22 describes the entire samples pricing errors exhibited under the Black-Scholes model when the stock call options prices have been calculated by using their respective DVFP in the place of stock spot prices. The magnitude of pricing error has been calculated by using the ME, MAE, MSE, RMSE, Theil's U statistics and MAPE for stock call options. The theoretical prices (premium) of stock call options, here, have been calculated under the Black-Scholes model by using the DVFP in the place of stock spot prices. The calculated prices using the DVFP in the place of stock spot prices under the Black-Scholes model are compared with their corresponding stock call market prices to gauge the pricing errors. The difference between the actual price (market price) and model calculated price is known as pricing error.

| Table 4.22: Entire pricing errors metrics under the modified B&S model for stock call options | |
|---|---|
| Parameters | Value |
| Mean Error (ME) | -2.3028 |
| Mean Absolute Error (MAE) | 6.7857 |
| Mean Squared Error (MSE) | 503.2098 |
| Root Mean Squared Error (RMSE) | 22.4323 |
| Thiel's U statistic | 0.1561 |
| MAPE | 39.7136 |
| *Source: Compiled by Researcher on the Basis of Analysis* | |

The results shown in Table 4.22 are the outcome for the objective 3 and Hypothesis $H_{05}$. The value of ME is -2.3028. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of -2.3028 given in table 4.53. Consequently, it is more likely to reject the null hypothesis for stock call options. Hence, there is a significant difference between the mean values of the stock call options closing price and calculated price under the B&S model using DVFP.

The overpriced or underpriced options under the modified Black-Scholes model are exhibited by ME. The Black-Scholes model considerably overprices stock call option with a ME of -2.3028 as found in table 4.22. The results of entire samples pricing errors produced under the Black-Scholes model have been shown in above table where the MAE, MSE, RMSE, Theil's statistic and MAPE are found 6.7857,503.2098, 22.4323, 0.1561 and 39.7136, respectively. It is, hence, evident that the modified Black-Scholes model also produces pricing errors and overall stock call options are also overpriced by the modified Black-Scholes model during the study period of this research.

Further, the moneyness bias calculated using DVFP, as a subgroup, is mentioned in table 4.23

Table 4.23: Subgroup measures of moneyness bias for stock call options under the modified B&S model

| Moneyness | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
|---|---|---|---|---|---|---|---|
| Out-of-the-Money | 22571 | -5.9201 | 9.7388 | 1278.7444 | 35.7595 | 0.5807 | 93.8468 |
| At-the-Money | 34 | -2.0522 | 2.5432 | 19.5879 | 4.4258 | 0.1380 | 26.0767 |
| In-the-Money | 18048 | -4.8459 | 9.1108 | 858.7979 | 29.3052 | 0.1437 | 19.8459 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.23 are the outcome for the objective 2 for stock call options moneyness bias calculated on the basis of DVFP. Table 4.23 illustrates the results of subgroup measures of moneyness bias for each category such as OTM, ATM and ITM for stock call options under the modified Black-Scholes model. The negative ME has been produced by the modified Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock call options are overpriced with a ME of -5.9201, -2.0522 and -4.8459, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of moneyness. The OTM options have been highly overpriced with the ME of -5.9201. The ATM options, however, show comparatively lower overpricing as compare to other categories which is -2.0522. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 9.7388, 1278.7443, 35.7595, 0.5807 and 93.8468 respectively for OTM options. The same corresponding to ATM options are 2.5432, 19.5879, 4.4258, 0.138 and 26.0767. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 9.1108, 858.7979, 29.3052,0.1437and 19.8459, respectively for ITM options.

The maturity bias calculated using DVFP, as a subgroup, is depicted in table 4.24.

| Table 4.24: Subgroup measures of maturity bias for stock call options under the modified B&S model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Maturity | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
| Near Month | 18910 | -2.8774 | 6.1973 | 489.7981 | 22.1314 | 0.1573 | 65.5060 |
| Next Month | 19013 | -7.3341 | 11.5332 | 1488.7538 | 38.5843 | 0.2652 | 53.4824 |
| Far Month | 2730 | -9.9988 | 17.5313 | 2489.0224 | 49.8901 | 0.3326 | 81.2100 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | |

The results shown in Table 4.24 are the outcome for the objective 2 for stock call options maturity bias calculated on the basis of DVFP. Table 4.24 illustrates the maturity biasness for the near month, next month and far month expiration stock call options contracts whose prices are calculated under the modified Black-Scholes model using the discounting value of futures price. Pricing errors calculated on the basis all parameters state that mispricing increases as maturity increases. The ME for the near month, next month and far month stock call options contracts are -2.8774, -7.3341and -9.9988, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the discounting value of futures price for stock call options also consistently overprices across all maturity. This also confirms the literature of Raj and Thurston (1998) that the all three maturity categories are significantly underpriced under the Black Scholes model. On the basis of mean error, the stock call near month options contracts are underpriced with a lowest mean error of -2.8774 while far month options contracts are underpriced with a highest mean error of -9.9988. Hence, the magnitude of mispricing increases as maturity increases in pricing stock call option under the Black-Scholes model.

The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 6.1973, 489.7981, 22.1314,0.1573 and 65.506, respectively for near month options. The same corresponding to next month options are11.5332, 1488.7538, 38.5843,0.2652 and 53.4824. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 17.5313, 2489.0224, 49.8901, 0.3326 and 81.21, respectively for far month options.

During the period of this research, a significant difference has been found between the mean values of the stock call options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model also produces pricing errors and overall stock call options are also overpriced by the modified Black-Scholes model when DVFP is used during the study period of this research. The modified Black-Scholes model considerably overprices stock call option with a ME of -2.3028.

The negative ME has been produced by the modified Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock call options are overpriced with a ME of -5.9201, -2.0522 and -4.8459, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of moneyness.

Pricing errors calculated on the basis all parameters state that mispricing increases as maturity increases under the modified B&S model. The ME for the near month, next month and far month stock call options contracts are -2.8774, -7.3341and -9.9988, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the discounting value of futures price for stock call options also consistently overprices across all maturity.

**4.4.2. For Index Call Options under the modified Black-Scholes model**

Table 4.25 describes the entire samples pricing errors exhibited under the Black-Scholes model when the index call options prices have been calculated by using their respective DVFP in the place of index spot prices. The magnitude of pricing error has been calculated by using the ME, MAE, MSE, RMSE and Theil U statistics for index call options. The theoretical prices (premium) of index call options, here, have been calculated under the Black-Scholes model by using the DVFP in the place of index spot prices. The calculated prices using the DVFP in the place of index spot prices under the Black-Scholes model are compared with their corresponding index call market prices to gauge the pricing errors. The difference between the actual price (market price) and model calculated price is known as pricing error.

| Table 4.25: Entire pricing errors metrics under the modified B&S model for index S&P CNX Nifty call options | |
|---|---|
| Parameters | Value |
| Mean Error (ME) | -2.7506 |
| Mean Absolute Error (MAE) | 15.7003 |
| Mean Squared Error (MSE) | 745.3993 |
| Root Mean Squared Error (RMSE) | 27.302 |
| Thiel's U statistic | 0.0211 |
| Mean Absolute Percentage Error (MAPE) | 36.6763 |
| *Source: Compiled by Researcher on the Basis of Analysis* | |

The results shown in Table 4.25 are the outcome for the objective 3 and Hypothesis $H_{06}$. The value of ME is -2.7506. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of -2.7506 given in table 4.54. Consequently, it is more likely to reject the null hypothesis for index call options. Hence, there is a significant difference between the mean values of the S&P CNX Nifty index call options closing price and calculated price under the B&S model using DVFP.

The overpriced or underpriced options under the modified Black-Scholes model are exhibited by ME. The Black-Scholes model considerably overprices index call option with a ME of -2.7506 as found in table 4.25. The results of entire samples pricing errors produced under the Black-Scholes model have been shown in above table where the MAE, MSE, RMSE, Theil's U statistic and MAPE are found 15.7003, 745.3993, 27.302, 0.0211, and 36.6763, respectively. It is, hence, evident that model produces pricing errors and overall index call options are overpriced by the modified Black-Scholes model during the study period of this research.

Further, the moneyness bias calculated using DVFP, as a subgroup, is mentioned in table 4.26

| Table 4.26: Subgroup measures of moneyness bias for index S&P CNX Nifty Call options under the modified B&S model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Moneyness | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
| Out-of-the-Money | 1,599 | -0.1964 | 13.5372 | 541.3012 | 23.2659 | 0.1529 | 61.8401 |
| In-the-Money | 1,225 | -6.0846 | 18.5238 | 1011.8098 | 31.8089 | 0.0163 | 3.8298 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | |

The results shown in Table 4.26 are the outcome for the objective 2 for index call options moneyness bias calculated on the basis of DVFP. Table 4.26 illustrates the results of subgroup measures of moneyness bias for OTM and ITM index call options under the modified Black-Scholes model. The data for ATM index options are not found during the study period. The negative ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index call options. The OTM and ITM index call options both are overpriced with a ME of -0.1964 and -6.0846, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of given moneyness. The OTM options have been overpriced with a lowest ME of -0.1964. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 13.5372, 541.3012, 23.2659, 0.1529 and 61.8401, respectively for OTM options. Notably, the same corresponding to the ITM options are 18.5238, 1011.8098, 31.8089, 0.0163 and 3.8298.

The maturity bias calculated using DVFP, as a subgroup, is depicted in table 4.27

Table 4.27: Subgroup measures of maturity bias for index S&P CNX Nifty Call options under the modified B&S model

| Maturity | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
|---|---|---|---|---|---|---|---|
| Near Month | 860 | -4.0651 | 8.1419 | 297.3351 | 17.2434 | 0.0106 | 29.9827 |
| Next Month | 985 | -1.9345 | 16.6114 | 856.2548 | 29.2618 | 0.026 | 37.8676 |
| Far Month | 979 | -2.417 | 21.4234 | 1027.4654 | 32.0541 | 0.0296 | 41.3578 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.27 are the outcome for the objective 2 for index call options maturity bias calculated on the basis of DVFP. Table 4.27 illustrates the maturity biasness for the near month, next month and far month expiration index call options contracts whose prices are calculated under the modified Black-Scholes model using the index spot prices. The ME for the near month, next month and far month index call options contracts are -4.0651, -1.9345 and -2.417, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using discounting value of futures price for index call options consistently overprices across all maturity. This confirms the literature of Raj and Thurston (1998) that the all three maturity categories are significantly underpriced under the modified Black Scholes model. On the basis of mean error, the index call next month options contracts are underpriced with a lowest mean error of -1.9345 while near month options contracts are underpriced with a highest mean error of -4.0651. Hence, the magnitude of mispricing increases as maturity increases in pricing index call option under the Black-Scholes model.

The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 8.1419, 297.3351, 17.2434, 0.0106 and 29.9827, respectively for near month options. The same corresponding to next month options are 16.6114, 856.2548, 29.2618, 0.026 and 37.8676. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 21.4234, 1027.4654, 32.0 541, 0.0296 and 41.3578, respectively for far month options.

During this research period, a significant difference has been found between the mean values of the S&P CNX Nifty index call options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably overprices index call option with a ME of -2.7506. The negative ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index call options. The OTM and ITM index call options both are overpriced with a ME of -0.1964 and -6.0846, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of given moneyness.

The ME for the near month, next month and far month index call options contracts are -4.0651, -1.9345 and -2.417, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using discounting value of futures price for index call options consistently underprices across all maturity.

### 4.4.3. For Stock Put Options Under the Modified Black-Scholes Model

Table 4.28 describes the entire samples pricing errors exhibited under the Black-Scholes model when the stock put options prices have been calculated by using their respective DVFP in the place of stock spot prices. The magnitude of pricing error has been calculated by using the ME, MAE, MSE, RMSE, Theil U statistics and MAPE for stock put options. The theoretical prices(premium) of stock put options, here, have been calculated under the Black-Scholes model by using the DVFP in the place of stock spot prices. The calculated prices using the DVFP in the place of stock spot prices under the Black-Scholes model are compared with their corresponding stock put market prices to gauge the pricing errors. The difference between the actual price (market price) and model calculated price is known as pricing error.

| Table 4.28: Entire pricing errors metrics under the modified B&S model for stock Put options | |
|---|---|
| Parameters | Value |
| Mean Error (ME) | -1.7469 |
| Mean Absolute Error (MAE) | 6.5250 |
| Mean Squared Error (MSE) | 541.0015 |
| Root Mean Squared Error (RMSE) | 23.2594 |
| Thiel's U statistic | 0.1966 |
| MAPE | 72.1027 |
| *Source: Compiled by Researcher on the Basis of Analysis* | |

The results shown in Table 4.28 are the outcome for the objective 3 and Hypothesis $H_{07}$. The value of ME is -1.7469. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of -1.7469 given in table 4.55. Consequently, it is more likely to reject the null hypothesis for stock put options. Hence, there is a significant difference between the mean values of the stock put options closing price and calculated price under the B&S model using DVFP.

The overpriced or underpriced options under the modified Black-Scholes model are exhibited by ME. The modified Black-Scholes model considerably overprices stock put option with a ME of -1.7469 as found in table 4.28. The results of entire samples pricing errors produced under modified the Black-Scholes model have been shown in above table where the MAE, MSE, RMSE, Theil's U statistic and MAPE are found 6.5250, 541.0015, 23.2594, 0.1966 and 72.1027, respectively. It is, hence, evident that model produces pricing errors and overall stock put options are also overpriced by the modified Black-Scholes model during the study period of this research.

Further, the moneyness bias calculated using DVFP, as a subgroup, is mentioned in table 4.29

Table 4.29: Subgroup measures of moneyness bias for stock put options under the modified B&S model

| Moneyness | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
|---|---|---|---|---|---|---|---|
| Out-of-the-Money | 13,809 | -3.3020 | 7.4300 | 510.5025 | 22.5943 | 0.1238 | 73.1223 |
| At-the-Money | 30 | -0.6960 | 1.5808 | 8.9876 | 2.9979 | 0.1766 | 25.5494 |
| In-the-Money | 23,577 | -0.8374 | 6.0012 | 559.5417 | 23.6546 | 0.4588 | 71.5647 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.29 are the outcome for the objective 2 for stock put options moneyness bias calculated on the basis of DVFP. Table 4.29 illustrates the results of subgroup measures of moneyness bias for each category such as OTM, ATM and ITM for stock put options under the modified Black-Scholes model. The negative ME has been produced by the Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock put options are overpriced with a ME of -3.3020, -0.6960, and -0.8374, respectively. Hence, it is evident that the original Black-Scholes model consistently overprices across all categories of moneyness. The OTM options have been highly overpriced with the ME of -5.2865. The ATM options, however, show comparatively lower overpricing as compare to other categories which is -0.696. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 7.4300, 510.5025,22.5943,0.1238 and 73.1223, respectively for OTM options. The same corresponding to ATM options are 1.5808, 8.9876, 2.9979, 0.1766 and 25.5494. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 6.0012, 559.5417, 23.6546,0.4588 and 71.5647, respectively for ITM options.

The maturity bias calculated using DVFP, as a subgroup, is depicted in table 4.30

Table 4.30: Subgroup measures of maturity bias for stock Put options under the modified B&S model

| Maturity | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
|---|---|---|---|---|---|---|---|
| Near Month | 18,879 | -0.6426 | 4.5835 | 359.3114 | 18.9555 | 0.1799 | 93.4477 |
| Next Month | 17,184 | -2.7822 | 8.1192 | 672.4033 | 25.9307 | 0.1995 | 49.7414 |
| Far Month | 1,353 | -4.0052 | 13.3677 | 1407.3130 | 37.5142 | 0.2847 | 58.2677 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.30 are the outcome for the objective 2 for stock put options maturity bias calculated on the basis of DVFP. Table 4.30 illustrates the maturity biasness for the near month, next month and far month expiration stock put options contracts whose prices are calculated under the modified Black-Scholes model using the DVFP. The ME for the near month, next month and far month stock put options contracts are -0.6426, -2.7822and -4.0052, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the stock DVFP for stock put options consistently overprices across all maturity. On the basis of mean error, the stock put near month options contracts are overpriced with a lowest mean error of -0.6426 while far month options contracts are overpriced with a highest mean error of -4.0052. Hence, the magnitude of mispricing increases as maturity increases in pricing stock put option under the Black-Scholes model.

The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 4.5835, 359.3114, 18.9555,0.1799 and 93.4477, respectively for near month options. The same corresponding to next month options are 8.1192, 672.4033, 25.9307,0.1995 and 49.7414. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 13.3677, 1407.3130, 37.5142,0.2847 and 58.2677, respectively for far month options.

**Stock Call to Put bias under the modified Black-Scholes model**

The stock call to put bias under the modified Black-Scholes model has been investigated from the entire pricing errors metrices established for stock call and put options as presented in table 4.22 and table 4.28, respectively where the stock call option has been overpriced by the mean error of -2.3028 and the same corresponding to put option is -1.7469. The statement, hence, drawn from the respective tables provides evidence that the modified B&S model shows higher magnitude of errors in pricing of stock call as compare to pricing put options.

During this research period, a significant difference has been found between the mean values of the stock put options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably overprices stock put option with a ME of -1.7469. It is, hence, evident that model produces pricing errors and overall stock put options are also overpriced by the modified Black-Scholes model during the study period of this research.

The OTM, ATM and ITM stock put options are overpriced with a ME of -3.3020, -0.6960, and -0.8374, respectively. Hence, it is evident that the original Black-Scholes model consistently overprices across all categories of moneyness. However, The OTM options have been highly overpriced with the ME of -5.2865.

The ME for the near month, next month and far month stock put options contracts are -0.6426, -2.7822 and -4.0052, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the stock DVFP for stock put options consistently overprices across all maturity. the magnitude of mispricing increases as maturity increases in pricing stock put option under the Black-Scholes model.

During the study period regarding the stock call to put bias under the modified B&S model, it has been found that the modified Black-Scholes model shows higher magnitude of errors in pricing of stock call as compare to pricing put options.

### 4.4.4. For Index Put Options Under the Modified Black-Scholes Model

Table 4.31 describes the entire samples pricing errors exhibited under the Black-Scholes model when the index put options prices have been calculated by using their respective DVFP in the place of index spot prices. The magnitude of pricing error has been calculated by using the ME, MAE, MSE, RMSE, Theil's statistic and MAPE for index put options. The theoretical prices (premium) of index put options, here, have been calculated under the Black-Scholes model by using the DVFP in the place of index spot prices. The calculated prices using the DVFP in the place of index spot prices under the Black-Scholes model are compared with their corresponding index put market prices to gauge the pricing errors. The difference between the actual price (market price) and model calculated price is known as pricing error.

| Table 4.31: Entire pricing errors metrics under the modified B&S model for index S&P CNX Nifty Put options | |
|---|---|
| Parameters | Value |
| Mean Error (ME) | 7.2881 |
| Mean Absolute Error (MAE) | 12.8289 |
| Mean Squared Error (MSE) | 704.2579 |
| Root Mean Squared Error (RMSE) | 27.9575 |
| Thiel's U statistic | 0.0166 |
| Mean Absolute Percentage Error (MAPE) | 60.3975 |
| *Source: Compiled by Researcher on the Basis of Analysis* | |

The results shown in Table 4.31 are the outcome for the objective 3 and Hypothesis $H_{08}$. The value of ME is 7.2881. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of 7.2881 given in table 4.56. Consequently, it is more likely to reject the null hypothesis for the S&P CNX Nifty index put options. Hence, there is a significant difference between the mean values of the index put options closing price and calculated price under the B&S model using DVFP.

The overpriced or underpriced options under the modified Black-Scholes model are exhibited by ME. The modified Black-Scholes model considerably underprices index put option with a ME of

7.2881 as found in table 4.31. The results of entire samples pricing errors produced under the modified Black-Scholes model have been shown in above table where the MAE, MSE, RMSE, Theil's U statistic and MAPE are found 12.8289, 12.8289, 704.2579, 27.9575, 0.0166 and 60.3975, respectively. It is, hence, evident that model produces pricing errors and overall index put options are underpriced by the modified Black-Scholes model during the study period of this research.

Further, the moneyness bias calculated using DVFP, as a subgroup, is mentioned in table 4.32

| Table 4.32: Subgroup measures of moneyness bias for index S&P CNX Nifty Put options under the modified B&S model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Moneyness | No. of Observations | ME | MAE | MSE | RMSE | Theil's U statistic | MAPE |
| Out-of-the-Money | 853 | 3.0606 | 21.675 | 1570.627 | 39.6311 | 0.0136 | 2.7025 |
| In-the-Money | 1979 | 8.807 | 9.016 | 330.8304 | 18.1887 | 0.3286 | 85.2655 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | |

The results shown in Table 4.32 are the outcome for the objective 2 for index put options moneyness bias calculated on the basis of DVFP. Table 4.32 illustrates the results of subgroup measures of moneyness bias for OTM and ITM index put options under the original Black-Scholes model. The data for ATM index options are not found during the study period. The positive ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index put options. The OTM and ITM index put options both are underpriced with a ME of 3.0606 and 8.807, respectively. Hence, it is evident that the modified Black-Scholes model also consistently underprices across all categories of given moneyness. However, The OTM options have been underpriced with a lowest ME of3.0606 while ITM options are underpriced with a highest ME of 8.807. The values of MAE, MSE, RMSE, Theil's U statistic and MAPE are found 21.675, 1570.627, 39.6311, 0.0136 and 2.7025, respectively for OTM options. Notably, the same corresponding to the ITM are 9.016, 330.8304, 18.1887, 0.3286 and 85.2655.

The maturity bias calculated using DVFP, as a subgroup, is depicted in table 4.33.

| Table 4.33: Subgroup measures of maturity bias for index S&P CNX Nifty Put options under the modified B&S model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Maturity | No. of Observations | ME | MAE | MSE | RMSE | Thiel's U statistic | MAPE |
| Near Month | 862 | -0.2645 | 8.2492 | 487.2018 | 22.0726 | 0.0111 | 52.6837 |
| Next Month | 986 | 5.1989 | 11.3083 | 610.4479 | 24.7072 | 0.0145 | 60.3566 |
| Far Month | 984 | 15.3879 | 18.3645 | 988.4031 | 31.4389 | 0.031 | 67.1958 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | |

The results shown in Table 4.33 are the outcome for the objective 2 for index put options maturity bias calculated on the basis of DVFP. Table 4.33 illustrates the maturity biasness for the near month, next month and far month expiration index put options contracts whose prices are calculated under the modified Black-Scholes model using the DVFP. The ME for the near month, next month and far month index put options contracts are -0.2645, 5.1989 and 15.3879, respectively. On the basis of mean error, the index put next month options contracts are overpriced with a lowest mean error of-0.2645 while far month options contracts are underpriced with a highest mean error of15.3879.

The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 8.2492, 487.2018, 22.0726, 0.0111 and 52.6837, respectively for near month options. The same corresponding to next month options are 11.3083, 610.4479, 24.7072, 0.0145 and 60.3566. The values of MAE, MSE, RMSE, Thiel's U statistic and MAPE are found 18.3645, 988.4031, 31.4389, 0.031 and 67.1958, respectively for far month options.

**Index Call to Put bias under the modified Black-Scholes model**

Index S&P CNX Nifty call to put bias under the modified Black-Scholes model has been investigated from the entire pricing errors metrices established for index call and put options as presented in table 4.25 and table 4.31 respectively where the index call option has been overpriced by the mean error of -2.7506 and the same corresponding to put option is 7.0762. hence, Index Nifty 50 call is overpriced while put option is underpriced by the modified B&S model. The statement, hence, drawn from the respective tables provides evidence that the magnitude of error for pricing Index Nifty 50 put options is relatively higher under the modified B&S model.

During this research period, a significant difference has been found between the mean values of the index put options closing price and calculated price under the B&S model using DVFP.

The modified Black-Scholes model considerably underprices index put option with a ME of 7.0762. Hence, model produces pricing errors and overall stock put options are underpriced by the modified Black-Scholes model during the study period.

The positive ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index put options. The OTM and ITM index put options both are underpriced with a ME of 3.0606 and 8.807, respectively.

The ME for the near month, next month and far month index put options contracts are -0.2645, 5.1989 and 15.3879, respectively. On the basis of mean error, the index put next month options contracts are overpriced with a lowest mean error of -0.2645 while far month options contracts are underpriced with a highest mean error of 15.3879.

During the study period regarding the index call to put bias under the modified B&S model, it has been found that the magnitude of error for pricing Index Nifty 50 put options is relatively higher under the modified B&S model.

**STAGE THIRD**

## 4.5. COMPARISON OF PRICING ERRORS BETWEEN THE B&S MODEL AND MODIFIED B&S MODEL

Stage 3rd makes comparison between the models to show which model exhibits less pricing errors.

### 4.5.1. For Stock call options under the Black-Scholes model and modified Black-Scholes model

It has been found while evaluating the performance of the Black-Scholes model for pricing stock call options in stage 1st, ($H_{01}$), that there is a significant difference between the mean values of the stock call options closing price and calculated price under the B&S mode.

Similarly, it has been also found while evaluating the performance of the modified Black-Scholes model where the spot prices of underlying have been replaced by their corresponding discounting values of futures prices in stage 2nd, ($H_{05}$), that there is a significant difference between the mean values of the stock call options closing price and calculated price after replacing spot price by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

The original Black-Scholes and modified Black-Scholes models, hence, both show the significant differences in their mean values in pricing stock call options ($H_{01}$ and $H_{05}$). This section empirically compares the pricing errors produced under the both models to show which model produces lower pricing errors in pricing stock call options and the same can be considered as a better model.

The calculated theoretical prices of stock call options under the Black-Scholes model and modified Black-Scholes model have been compared to show which model exhibits less pricing errors. This research uses ME, MAE, MSE, RMSE, Theil's statistic and MAPE methods of evaluating the performance of the option pricing models. The calculated results of the error metric for the entire sample have been shown in table 4.34, as a comparative study. Further, the moneyness bias and maturity bias, as a subgroup, have been also comparatively studied in their respective tables. The results of moneyness bias such as stock call OTM, ATM and ITM options contracts are presented in table 4.35, table 4.36 and table 4.37, respectively. Similarly, the results of maturity bias such as near month, next month and far month options contracts are presented in table 4.38, table 4.39 and table 4.40, respectively. The model that produces lowest error can be considered as a better model.

A statistical comparison of the mispricing magnitudes of the both cases has been conducted. Table 4.34 compares the entire samples pricing errors exhibited under the Black-Scholes model when the stock call options prices errors have been separately calculated by using stock spot prices and DVFP. The magnitude of pricing error has been compared by using the ME, MAE, MSE, RMSE, Theil U statistics and MAPE for stock call options. The compared pricing errors have been used to encompass which model produces lower pricing errors in pricing stock call options and the same can be considered as a better model.

Table 4.34: Entire pricing errors comparison between the B&S model and modified B&S model for stock call options

| Parameters | Original B&S Model | Modified B&S Model | Improvement |
|---|---|---|---|
| ME | -2.6325 | -2.3028 | (-) 0.3297 |
| MAE | 7.0509 | 6.7857 | 0.2652 |
| MSE | 525.5003 | 503.2098 | 22.2905 |
| RMSE | 22.9238 | 22.4323 | 0.4915 |
| Thiel's U statistic | 0.1588 | 0.1561 | 0.0027 |
| MAPE | 41.0784 | 39.7136 | 1.3648 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.34 are the outcome for the objective 4 and Hypothesis $H_{09}$. The value of ME is (-) 0.3322. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of 0.3297 given in table 4.57. Consequently, it is more likely to reject the null hypothesis for stock call options. Hence, there is a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock call options in the Indian derivatives market. It may be noted that both models overprice stock call option.

The overall results on the performance of the Black-Scholes model based on the spot price and DVFP are provided in table 4.34. The number of observations in each case is 40,653. The result shown earlier in table4.10and table4.22are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for the Black-Scholes model based on the spot price are -2.6325, 7.0509, 525.5003, 22.9238, 0.1588 and 41.0784, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -2.3028, 6.7857, 503.2098, 22.4323, 0.1561 and 39.7136 as exhibited in third column. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing stock call options are (-)0.3322, 0.2652, 22.2905, 0.4915, 0.0027 and 1.3648, respectively. It should be noted that overall stock call options are overpriced under the both cases with the mean errors of -2.6325 and -2.3028 but overpricing is improved by (-) 0.3322 if it is priced using the DVFP instead of spot price. The comparative Improvements have been exhibited on the all above mentioned parameters. Hence, the results provided in table 4.34 depict further evidence of the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing stock call options in the Indian derivatives market.

Further, the moneyness bias improvement for OTM options, as a subgroup, is compared in table 4.35

| Table 4.35: Subgroup comparison of moneyness bias between the B&S model and modified B&S model for stock call OTM options | | | |
|---|---|---|---|
| Parameters | Original B&S Model | Modified B&S Model | Improvement |
| ME | -6.0873 | -5.9201 | (-) 0.1672 |
| MAE | 9.8263 | 9.7388 | 0.0875 |
| MSE | 1301.6082 | 1278.7444 | 22.8638 |
| RMSE | 36.0778 | 35.7595 | 0.3183 |
| Thiel's U statistic | 0.5811 | 0.5807 | 0.0004 |
| MAPE | 95.1157 | 93.8468 | 1.2689 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | |

The results shown in Table 4.35 are the outcome for the objective 2 for stock call OTM options moneyness bias. Further, for a robust comparison, the magnitude of mispricing has been also examined through table 4.35 across subgroup of options formed by moneyness with regard to OTM for the stock call options. The number of observations in each case is 22,571. The results shown earlier in table 4.11and table 4.23, second row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for OTM options with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for the Black-Scholes model based on the spot price are-6.0873, 9.8263, 1301.6082, 36.0778, 0.5811 and 95.1157 , respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are-5.9201, 9.7388, 1278.7444, 35.7595, 0.5807 and 93.8468, as exhibited in third column of table 4.35. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE and Theil's U statistic for pricing OTM stock call options are (-) 0.1672, 0.0875, 22.8638, 0.3183, 0.0004 and 1.2689, respectively. It may be noted that OTM stock call options are also overpriced under the both cases with the mean errors of -6.0873 and -5.9201 but overpricing is improved by (-)0.1672 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the results provided in table 4.35 depict further evidence of the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM stock call options in the Indian derivatives market.

The moneyness bias improvement for ATM options, as a subgroup, is compared in table 4.36-

Table 4.36: Subgroup comparison of moneyness bias between the B&S model and modified

| Parameters | Original B&S Model | Modified B&S Model | Improvement |
|---|---|---|---|
| ME | -2.0261 | -2.0522 | (-) 0.0261 |
| MAE | 2.5845 | 2.5432 | 0.0413 |
| MSE | 17.6680 | 19.5879 | -1.9199 |
| RMSE | 4.2033 | 4.4258 | -0.2225 |
| Thiel's U statistic | 0.1321 | 0.1380 | -0.0059 |
| MAPE | 27.3324 | 26.0767 | 1.2557 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.36 are the outcome for the objective 2 for stock call ATM options moneyness bias. The performance of moneyness with regard to ATM stock call options is provided in table 4.36. The number of observations in each case is 34 which is comparatively very low because the options traded on ATM are very rare to obtain. The results shown earlier in table 4.11 and table 4.23, third row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for ATM options with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for the Black-Scholes model based on the spot price are -2.0261, 2.5845, 17.6680, 4.2033, 0.1321 and 27.3324, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -2.0522, 2.5432, 19.5879, 4.4258, 0.1380 and 26.0767 , as exhibited in third column of table 4.36. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE and Theil's u statistic for pricing ATM stock call options are -0.0261, 0.0413, -1.9199, -0.2225, -0.0059 and 1.2557, respectively. It may be noted that ATM stock call options are also overpriced under the both cases with the mean errors of -2.0261 and -2.0522 but the magnitude of overpricing is higher by -0.0261 if it is priced using the DVFP instead of spot price. The comparative Improvements have not been found on the all above mentioned parameters except MAE. Hence, the results provided in table 4.36 depict further that the Black-Scholes model based on the spot price produces lower pricing error for pricing ATM stock call options in the Indian derivatives market.

The moneyness bias improvement for ITM options, as a subgroup, is compared in table 4.37-

Table 4.37: Subgroup comparison of moneyness bias between the B&S model and modified B&S model for stock call ITM options

| Parameters | Original B&S Model | Modified B&S Model | Improvement |
|---|---|---|---|
| ME | -5.3775 | -4.8459 | (-) 0.5316 |
| MAE | 9.6175 | 9.1108 | 0.5067 |
| MSE | 892.1892 | 858.7979 | 33.3913 |
| RMSE | 29.8695 | 29.3052 | 0.5643 |
| Thiel's U statistic | 0.1458 | 0.1437 | 0.0021 |
| MAPE | 21.0751 | 19.8459 | 1.2292 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.37 are the outcome for the objective 2 for stock ITM call options moneyness bias. Table 4.37 illustrates the moneyness with regard to ITM stock call options. The number of observations in each case is 18,048. The results shown earlier in table 4.11 and table 4.23, third row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for ITM options with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for the Black-Scholes model based on the spot price are -5.3775, 9.6175, 892.1892, 29.8695, 0.1458 and 21.0751, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -4.8459, 9.1108, 858.7979, 29.3052, 0.1437 and 19.8459, as exhibited in third column of table 4.37. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing ITM stock call options are (-) 0.5316, 0.5067, 33.3913, 0.5643, 0.0021 and 1.2292, respectively. It may be noted that ITM stock call options are also overpriced under the both cases with the mean errors of -5.3775 and -4.8459 but overpricing is improved by (-) 0.5316 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the results provided in table 4.37 depict further evidence of the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM stock call options in the Indian derivatives market.

Further, the maturity bias improvement for the near month options, as a subgroup, is compared in table 4.38-

Table 4.38: Subgroup comparison of maturity bias between the B&S model and modified B&S model for stock call near month options

| Parameters | Original B&S Model | Modified B&S Model | Improvement |
|---|---|---|---|
| ME | -3.0254 | -2.8774 | (-) 0.1480 |
| MAE | 6.4623 | 6.1973 | 0.2650 |
| MSE | 502.5480 | 489.7981 | 12.7499 |
| RMSE | 22.4176 | 22.1314 | 0.2862 |
| Thiel's U statistic | 0.1589 | 0.1573 | 0.0016 |
| MAPE | 66.4776 | 65.506 | 0.9716 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in table 4.38 are the outcome for the objective 2 for stock call near month options moneyness bias. Further, the results of the near month subgroup of stock call options are shown in table 4.38. The number of observations in each case is 18,910. The results shown earlier in table 4.12 and table 4.24, first row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for the near month stock call options with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for the Black-Scholes model based on the spot price are -3.0254, 6.4623, 502.5480, 22.4176, 0.1589 and 66.4776, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -2.8774, 6.1973, 489.7981, 22.1314, 0.1573 and 65.506, As exhibited in third column of table 4.38. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the near month stock call options are (-) 0.1480, 0.2650, 12.7499, 0.2862, 0.0016 and 0.9716, respectively. It may be noted that the near month stock call options are also overpriced under the both cases with the mean errors of -3.0254 and -2.8774 but overpricing is improved by (-) 0.1480 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, it can be observed from the table 4.38 that the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the near month stock call options in the Indian derivatives market.

The maturity bias improvement for the next month options, as a subgroup, is compared in table 4.39-

| Table 4.39: Subgroup comparison of maturity bias between the B&S model and modified B&S model for stock call next month options | | | |
|---|---|---|---|
| Parameters | Original B&S Model | Modified B&S Model | Improvement |
| ME | -7.7576 | -7.3341 | (-) 0.4235 |
| MAE | 11.8452 | 11.5332 | 0.3120 |
| MSE | 1529.0032 | 1488.7538 | 40.2494 |
| RMSE | 39.1025 | 38.5843 | 0.5182 |
| Thiel's U statistic | 0.2674 | 0.2652 | 0.0022 |
| MAPE | 55.0248 | 53.4824 | 1.5424 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | |

The results shown in Table 4.39 are the outcome for the objective 2 for stock call next month options moneyness bias. The results of the next month subgroup of stock call options are shown in table 4.39. The number of observations in each case is 19,013. The results shown earlier in table 4.12 and table 4.24, second row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for the next month stock call options with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for the Black-Scholes model based on the spot price are -7.7576, 11.8452, 1529.0032, 39.1025, 0.2674 and 55.0248, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -7.3341, 11.5332, 1488.7538, 38.5843, 0.2652 and 53.4824, as exhibited in third column of table 4.39. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the next month stock call options are (-) 0.4235, 0.3120, 40.2494, 0.5182, 0.0022 and 1.5424, respectively. It may be noted that the next month stock call options are also overpriced under the both cases with the mean errors of -7.7576 and -7.3341 but overpricing is improved by (-) 0.4235 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, it can be observed from the table 4.39 that the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month stock call options in the Indian derivatives market.

The maturity bias improvement for the far month options, as a subgroup, is compared in table 4.40-

Table 4.40: Subgroup comparison of maturity bias between the B&S model and modified B&S model for stock call far month options

| Parameters | Original B&S Model | Modified B&S Model | Improvement |
|---|---|---|---|
| ME | -10.9202 | -9.9988 | (-) 0.9214 |
| MAE | 17.5966 | 17.5313 | 0.0653 |
| MSE | 2530.1501 | 2489.0224 | 41.1277 |
| RMSE | 50.3006 | 49.8901 | 0.4105 |
| Thiel's U statistic | 0.3321 | 0.3326 | -0.0005 |
| MAPE | 82.3704 | 81.21 | 1.1604 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.40 are the outcome for the objective 2 for stock call far month options moneyness bias. The results of the far month subgroup of stock call options are shown in table 4.40. The number of observations in each case is 2,730. The result shown earlier in table 4.12 and table 4.24, third row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for the far month stock call options with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for the Black-Scholes model based on the spot price are -10.9202, 17.5966, 2530.1501, 50.3006, 0.3177 and 82.3704, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -9.9988, 17.5313, 2489.0224, 49.8901, 0.3326 and 81.21, as exhibited in third column of table 4.40. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month stock call options are (-) 0.9214, 0.0653, 41.1277, 0.4105, -0.0005 and 1.1604, respectively but the value of Theil's u statistic does not support. The comparative Improvements has not been found. Hence, it can be observed from the table 4.40 that the performance of the Black-Scholes model based on the DVFP is not superior to that of the Black-Scholes model based on the spot price for pricing the far month stock call options in the Indian derivatives market.

During the study period of this research, a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock call options has been found with the ME value of (-) 0.3322. The overall stock call options are overpriced under the both cases with the mean errors of -2.6325 and -2.3028 but overpricing is improved by (-) 0.3322 if it is priced using the DVFP instead of spot price. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing stock call options are (-) 0.3322, 0.2652, 22.2905, 0.4915, 0.0027 and 1.3648, respectively. The comparative Improvements have been exhibited on the all the used parameters. Hence, the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing stock call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE and Theil's U statistic for pricing OTM stock call options are (-) 0.1672, 0.0875, 22.8638, 0.3183, 0.0004 and 1.2689, respectively. It may be noted that OTM stock call options are also overpriced under the both cases with the mean errors of -6.0873 and -5.9201 but overpricing is improved by (-) 0.1672 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters. The improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM stock call options in the Indian derivatives market.

ATM stock call options are also overpriced under the both cases with the mean errors of -2.0261 and -2.0522 but the magnitude of overpricing is higher by -0.0261 if it is priced using the DVFP instead of spot price. The comparative Improvements have not been found for stock call ATM options. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing ATM stock call options in the Indian derivatives market.

ITM stock call options are also overpriced under the both cases with the mean errors of -5.3775 and -4.8459 but overpricing is improved by (-) 0.5316 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM stock call options in the Indian derivatives market.

The near month stock call options are also overpriced under the both cases with the mean errors of -3.0254 and -2.8774 but overpricing is improved by (-) 0.1480 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. The performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the near month stock call options in the Indian derivatives market.

The next month stock call options are also overpriced under the both cases with the mean errors of -7.7576 and -7.3341 but overpricing is improved by (-) 0.4235 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month stock call options in the Indian derivatives market.

For far month stock call, the overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month stock call options are (-) 0.9214, 0.0653, 41.1277, 0.4105, -0.0005 and 1.1604, respectively but the value of Theil's u statistic does not support. The comparative Improvements has not been found. Hence, the performance of the Black-Scholes model based on the DVFP is not superior to that of the Black-Scholes model based on the spot price for pricing the far month stock call options in the Indian derivatives market.

**4.5.2. For Index Nifty 50 call options under the Black-Scholes model and modified Black-Scholes model**

It has been found while evaluating the performance of the Black-Scholes model for pricing index Nifty 50call options in stage 1st, ($H_{02}$), that there is a significant difference between the mean values of the index Nifty 50 call options closing price and calculated price under the B&S model.

Similarly, it has been also found while evaluating the performance of the modified Black-Scholes model where the spot prices of underlying have been replaced by their corresponding discounting values of futures prices in stage 2nd, ($H_{06}$), that there is a significant difference between the mean values of the index Nifty 50 call options closing price and calculated price after replacing spot price by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

The original Black-Scholes and modified Black-Scholes models, hence, both show the significant differences in their mean values in pricing index Nifty 50 call options ($H_{02}$ and $H_{06}$). This section empirically compares the pricing errors produced under the both models to show which model produces lower pricing errors in pricing index Nifty 50 call options and the same can be considered as a better model.

The calculated theoretical prices of index Nifty 50 call options under the Black-Scholes model and modified black-Scholes model have been compared to show which model exhibits less pricing errors. This research uses ME, MAE, MSE, RMSE, Theil's U statistics and MAPE method of evaluating the performance of the option pricing models. The calculated results of the error metric for the entire sample have been shown in table4.41, as a comparative study. Further, the moneyness bias and maturity bias, as a subgroup, have been also mentioned in their respective tables. The results of moneyness bias such as index call OTM and ITM options contracts are presented in table 4.42 and table 4.43, respectively. The index call ATM data have not been found during this research period. Similarly, the results of maturity bias such as Near Month, Next Month and Far Month options contracts are presented in table 4.44, table 4.45 and table 4.46, respectively. The model that produces lowest error can be considered as a better model.

A statistical comparison of the mispricing magnitudes of the both cases has been conducted. Table 4.41 compares the entire samples pricing errors exhibited under the Black-Scholes model when the index call options prices errors have been separately calculated by using index spot prices and DVFP. The magnitude of pricing error has been compared by using the ME, MAE, MSE, RMSE and Theil's U statistics for index call options. The compared pricing errors have been used to encompass which model produces lower pricing errors in pricing index call options and the same can be considered as a better model.

| Table 4.41: Entire pricing errors comparison between the B&S model and modified B&S model for index Nifty 50 call options | | | |
|---|---|---|---|
| Parameters | Original B&S Model | Modified B&S Model | Improvement |
| ME | -3.4080 | -2.7506 | (-) 0.6574 |
| MAE | 17.7109 | 15.7003 | 2.0106 |
| MSE | 881.8559 | 745.3993 | 136.4566 |
| RMSE | 29.6960 | 27.3020 | 2.3940 |
| Thiel's U statistic | 0.0230 | 0.0211 | 0.0019 |
| MAPE | 38.2434 | 36.6763 | 1.5671 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | |

The results shown in Table 4.41 are the outcome for the objective 4 and Hypothesis $H_{10}$. The value of ME is (-) 0.6574. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of 0.6574 given in table 4.58. Consequently, it is more likely to reject the null hypothesis for index call options. Hence, there is a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing index Nifty 50 call options in the Indian derivatives market. It may be noted that both models overprice index call option.

The overall results on the performance of the Black-Scholes model based on the spot price and DVFP are provided in table 4.41. The number of observations in each case is 2,824 The result shown earlier in table 4.13 and table 4.25 are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors with regard to ME, MAE, MSE, RMSE. Theil's U statistics and MAPE for the Black-Scholes model based on the spot price are -3.4080, 17.7109, 881.8559, 29.6960, 0.0230 and 38.2434, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -2.7506, 15.7003, 745.3993, 27.3020, 0.0211 and 36.6763 as exhibited in third column of table 4.41. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistics and MAPE for pricing index call options are (-) 0.6574, 2.0106, 136.4566, 2.3940, 0.0019 and 1.5671, respectively. It should be noted that overall index call options are overpriced under the both cases with the mean errors of -3.4080 and -2.7506 but overpricing is improved by (-) 0.6574 if it is priced using the DVFP instead of spot price. The comparative Improvements have been exhibited on the all above mentioned parameters. Hence, the results provided in table 4.41 depict further evidence of the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing index call options in the Indian derivatives market.

Further, the moneyness bias improvement for OTM options, as a subgroup, is compared in table 4.42-

| Table 4.42: Subgroup comparison of moneyness bias between the B&S model and modified B&S model for index Nifty 50 call OTM options | | | |
|---|---|---|---|
| Parameters | Original B&S Model | Modified B&S Model | Improvement |
| ME | -0.6918 | -0.1964 | (-) 0.4954 |
| MAE | 14.1270 | 13.5372 | 0.5898 |
| MSE | 572.4621 | 541.3012 | 31.1609 |
| RMSE | 23.9262 | 23.2659 | 0.6603 |
| Thiel's U statistic | 0.1563 | 0.1529 | 0.0034 |
| MAPE | 64.016 | 61.8401 | 2.1759 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | |

The results shown in Table 4.42 are the outcome for the objective 2 for index call OTM options moneyness bias. Further, for a robust comparison, the magnitude of mispricing has been also examined through table 4.42 across subgroup of options formed by moneyness with regard to OTM for the index call options. The number of observations in each case is 1,599. The results shown earlier in table 4.14 and table 4.26, second row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for OTM options with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for the Black-Scholes model based on the spot price are -0.6918, 14.1270, 572.4621, 23.9262, 0.1563 and 64.016, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -0.1964, 13.5372, 541.3012, 23.2659, 0.1529 and 61.8401, as exhibited in third column of table 4.42. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing OTM index call options are (-) 0.4954, 0.5898, 31.1609, 0.6603, 0.0034 and 2.1759, respectively. It should be noted that OTM index call options are also overpriced under the both cases with the mean errors of -0.6918 and -0.1964 but overpricing is improved by (-) 0.4954 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the results provided in table 4.42 depict further evidence of the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM index call options in the Indian derivatives market.

The moneyness bias improvement for ITM options, as a subgroup, is compared in table 4.43-

Table 4.43: Subgroup comparison of moneyness bias between the B&S model and modified B&S model for index Nifty 50 call ITM options

| Parameters | Original B&S Model | Modified B&S Model | Improvement |
|---|---|---|---|
| ME | -6.9533 | -6.0846 | (-) 0.8687 |
| MAE | 22.3890 | 18.5238 | 3.8652 |
| MSE | 1285.7096 | 1011.8098 | 273.8998 |
| RMSE | 35.8567 | 31.8089 | 4.0478 |
| Thiel's U statistic | 0.0184 | 0.0163 | 0.0021 |
| MAPE | 4.6021 | 3.8298 | 0.7721 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.43 are the outcome for the objective 2 for index call ITM options moneyness bias. Table 4.43 illustrates the moneyness with regard to ITM index call options. The number of observations in each case is 1,225. The results shown earlier in table 4.14 and table 4.26, third row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for ITM options with regard to ME, MAE, MSE, RMSE and Theil's U statistic for the Black-Scholes model based on the spot price are -6.9533, 22.3890, 1285.7096, 35.8567, 0.0184 and 4.6021, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -6.0846, 18.5238, 1011.8098, 31.8089, 0.0163 and 3.8298, As exhibited in third column of table 4.43. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing ITM index call options are (-) 0.8687, 3.8652, 273.8998, 4.0478, 0.0021 and 0.7721, respectively. It should be noted that ITM index call options are also overpriced under the both cases with the mean errors of -6.9533 and -6.0846 but overpricing is improved by (-) 0.8687 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the results provided in table 4.43 depict further evidence of the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM index call options in the Indian derivatives market.

Further, the maturity bias improvement for the near month options, as a subgroup, is compared in table 4.44-

Table 4.44: Subgroup comparison of maturity bias between the B&S model and modified B&S model for index Nifty 50 call near month options

| Parameters | Original B&S Model | Modified B&S Model | Improvement |
|---|---|---|---|
| ME | -3.3974 | -4.0651 | -0.8276 |
| MAE | 9.8592 | 8.1419 | 1.7173 |
| MSE | 368.8760 | 297.3351 | 71.5409 |
| RMSE | 19.2061 | 17.2434 | 1.9627 |
| Thiel's U statistic | 0.0118 | 0.0106 | 0.0012 |
| MAPE | 29.6516 | 29.9827 | -0.3311 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.44 are the outcome for the objective 2 for index call near month options moneyness bias. Further, the results of the near month subgroup of index call options are shown in table 4.44. The number of observations in each case is 860. The results shown earlier in table 4.15 and table 4.27, first row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for the near month index call options with regard to

ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for the Black-Scholes model based on the spot price are -3.3974, 9.8592, 368.8760, 19.2061, 0.0118 and 29.6516, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -4.0651, 8.1419, 297.3351, 17.2434, 0.0106 and 29.9827, as exhibited in third column of table 4.44. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the near month index call options are -0.8276, 1.7173, 71.5409, 1.9627, 0.0012 and -0.3311, respectively. It may be noted that the near month index call options are also overpriced under the both cases with the mean errors of -3.3974 and -4.0651 but overpricing is not improved if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters except ME and Theil's U statistic. Hence, the results provided in table 4.44 depict further that the Black-Scholes model based on the spot price produces lower pricing error for pricing near month index call options in the Indian derivatives market.

Further, the maturity bias improvement for the next month options, as a subgroup, is compared in table 4.45-

Table 4.45: Subgroup comparison of maturity bias between the B&S model and modified B&S model for index Nifty 50 call next month options

| Parameters | Original B&S Model | Modified B&S Model | Improvement |
|---|---|---|---|
| ME | -2.2385 | -1.9345 | (-) 0.3040 |
| MAE | 18.5804 | 16.6114 | 1.9690 |
| MSE | 1041.6331 | 856.2548 | 185.3783 |
| RMSE | 32.2743 | 29.2618 | 3.0125 |
| Thiel's U statistic | 0.0287 | 0.0260 | 0.0027 |
| MAPE | 39.3436 | 37.8676 | 1.476 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in Table 4.45 are the outcome for the objective 2 for index call next month options moneyness bias.

The results of the next month subgroup of index call options is shown in table 4.45. The number of observations in each case is 985. The result shown earlier in table 4.15 and table 4.27, second row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for the next month index call options with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for the Black-Scholes model based on the spot price are -2.2385, 18.5804, 1041.6331, 32.2743, 0.0287 and 39.3436, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -1.9345, 16.6114, 856.2548, 29.2618, 0.0260 and 37.8676, as exhibited in third column of table 4.45. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the next month index call options are (-) 0.3040, 1.9690, 185.3783, 3.0125, 0.0027 and 1.476, respectively. It may be noted that the next month index call options are also overpriced under the both cases with the mean errors of -2.2385 and -1.9345 but overpricing is improved by (-) 0.3040 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, it can be observed from the table 4.45 that the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month index call options in the Indian derivatives market.

Further, the maturity bias improvement for the far month options, as a subgroup, is compared in table 4.46-

| Table 4.46: Subgroup comparison of maturity bias between the B&S model and modified B&S model for index Nifty 50 call far month options | | | |
|---|---|---|---|
| Parameters | Original B&S Model | Modified B&S Model | Improvement |
| ME | -4.5940 | -2.4170 | (-) 2.1770 |
| MAE | 23.7334 | 21.4234 | 2.3100 |
| MSE | 1171.7255 | 1027.4654 | 144.2601 |
| RMSE | 34.2305 | 32.0541 | 2.1764 |
| Thiel's U statistic | 0.0316 | 0.0296 | 0.0020 |
| MAPE | 44.6839 | 41.3578 | 3.3261 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | |

The results shown in Table 4.46 are the outcome for the objective 2 for index call far month options moneyness bias. The results of the far month subgroup of index call options are shown in table 4.46. The number of observations in each case is 979.The result shown earlier in table 4.15 and table 4.27, third row, are here compared to gauge the pricing accuracy under the both cases. The magnitude of pricing errors for the far month index call options with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for the Black-Scholes model based on the spot price are -4.5940, 23.7334, 1171.7255, 34.2305, 0.0316 and 44.6839, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -2.4170, 21.4234, 1027.4654, 32.0541, 0.0296 and 41.3578, As exhibited in third column of table 4.46. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month index call options are (-) 2.1770, 2.3100, 144.2601, 2.1764, 0.0020 and 3.3261, respectively. It may be noted that the far month index call options are also overpriced under the both cases with the mean errors of -4.5940and-2.4170 but overpricing is improved by (-) 2.1770 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, it can be observed from the table 4.46 that the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the far month index call options in the Indian derivatives market.

During this research period the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing index Nifty 50 call options differs with a ME value of (-) 0.6574. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistics and MAPE for pricing index call options are (-) 0.6574, 2.0106, 136.4566, 2.3940, 0.0019 and 1.5671, respectively. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing OTM index call options are (-) 0.4954, 0.5898, 31.1609, 0.6603, 0.0034 and 2.1759, respectively. It may be noted that OTM index call options are also overpriced under the both cases with the mean errors of-0.6918 and -0.1964 but overpricing is improved by (-) 0.4954 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing ITM index call options are (-) 0.8687, 3.8652, 273.8998, 4.0478, 0.0021 and 0.7721, respectively. It may be noted that ITM index call options are also overpriced under the both cases with the mean errors of -6.9533 and -6.0846 but overpricing is improved by (-) 0.8687 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the near month index call options are -0.8276, 1.7173, 71.5409, 1.9627, 0.0012 and -0.3311, respectively. It may be noted that the near month index call options are also overpriced under the both cases with the mean errors of-3.3974 and -4.0651 but overpricing is not improved if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters except ME and Theil's U statistic. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing near month index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the next month index call options are (-) 0.3040, 1.9690, 185.3783, 3.0125, 0.0027 and 1.476, respectively. It may be noted that the next month index call options are also overpriced under the both cases with the mean errors of -2.2385 and -1.9345 but overpricing is improved by (-) 0.3040 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month index call options in the Indian derivatives market.

For the far month index option, overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month index call options are (-) 2.1770, 2.3100, 144.2601, 2.1764, 0.0020 and 3.3261, respectively. It may be noted that the far month index call options are also overpriced under the both cases with the mean errors of -4.5940 and -2.4170 but overpricing is improved by (-) 2.1770 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the far month index call options in the Indian derivatives market.

### 4.5.3. For Stock put options under the Black-Scholes model and modified Black-Scholes model

It has been found while evaluating the performance of the Black-Scholes model for pricing stock put options in stage 1st, ($H_{03}$), that there is a significant difference between the mean values of the stock put options closing price and calculated price under the B&S model.

Similarly, it has been also found while evaluating the performance of the modified Black-Scholes model where the spot prices of underlying have been replaced by their corresponding discounting values of futures prices in stage 2nd, ($H_{07}$), that there is a significant difference between the mean values of the stock put options closing price and calculated price after replacing spot price by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

The original Black-Scholes and modified Black-Scholes models, hence, both show the significant differences in their mean values in pricing stock put options ($H_{03}$ and $H_{07}$). This section empirically compares the pricing errors produced under the both models to show which model produces lower pricing errors in pricing stock put options and the same can be considered as a better model.

The calculated theoretical prices of stock put options under the Black-Scholes model and modified black-Scholes model have been compared to show which model exhibits less pricing errors. This research uses ME, MAE, MSE, RMSE, Theil's U statistic and MAPE method of evaluating the performance of the option pricing models. The compared pricing errors have been used to encompass which model produces lower pricing errors in pricing stock put options and the same can be considered as a better model. The calculated results of the error metric for the entire sample have been shown in table 4.47, as a comparative study-

| Table 4.47: Entire pricing errors comparison between the B&S model and modified B&S model for stock put options | | | |
|---|---|---|---|
| Parameters | Original B&S Model | Modified B&S Model | Improvement |
| ME | -1.5727 | -1.7469 | - 0.1742 |
| MAE | 6.6594 | 6.5250 | 0.1344 |
| MSE | 530.7265 | 541.0015 | -10.2750 |
| RMSE | 23.0375 | 23.2594 | -0.2219 |
| Thiel's U statistic | 0.1954 | 0.1966 | -0.0012 |
| MAPE | 71.7882 | 72.1027 | -0.3145 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | |

The results shown in Table 4.47 are the outcome for the objective 4 and Hypothesis $H_{11}$. The value of ME is - 0.1742. The P-value of SPSS output of Paired samples t-test is found less than 0.05 with the same ME of 0.1742 given in table 4.59. Consequently, it is more likely to reject the null hypothesis for stock put options. Hence, there is a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock put options in the Indian derivatives market. Here, the modified B&S model exhibits lager mean error. It may be noted that both models overprice stock put option.

The overall results on the performance of the Black-Scholes model based on the spot price and DVFP are provided in table 4.47. The number of observations in each case is 37,416. The magnitude of pricing errors with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for the Black-Scholes model based on the spot price are -1.5727, 6.6594, 530.7265, 23.0375, 0.1954 and 71.7882, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are -1.7469, 6.5250, 541.0015, 23.2594, 0.1966 and 72.1027 as exhibited in third column. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found.

The overall improvements with regard to ME, MSE, RMSE, Theil's U statistic and MAPE for pricing stock put options have not been found except MAE if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters except MAE. The results provided in table 4.47 depict that the Black-Scholes model based on the spot price produces overall lower pricing error for pricing stock put options in the Indian derivatives market. In other words, modification is not suitable for pricing stock put option. Hence, the improvements regarding its subgroups have not been discussed further.

During the study period of this research, the overall improvements with regard to ME, MSE, RMSE, Theil's U statistic and MAPE for pricing stock put options have not been found except MAE if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters except MAE. The Black-Scholes model based on the spot price produces overall lower pricing error for pricing stock put options in the Indian derivatives market. In other words, modification is not suitable for pricing stock put option. Hence, the improvements regarding its subgroups have not been discussed further.

**4.5.4. For Index Nifty 50 put options under the Black-Scholes model and modified Black-Scholes model**

It has been found while evaluating the performance of the Black-Scholes model for pricing index Nifty 50 put options in stage 1$^{st}$, ($H_{04}$), that there is a significant difference between the mean values of the index Nifty 50 put options closing price and calculated price under the B&S model.

Similarly, it has been also found while evaluating the performance of the modified Black-Scholes model where the spot prices of underlying have been replaced by their corresponding discounting values of futures prices in stage 2$^{nd}$, ($H_{08}$), that there is a significant difference between the mean values of the index Nifty 50 put options closing price and calculated price after replacing spot price by the discounted value of the future price ($F.e^{-rt}$) in the B&S model.

The original Black-Scholes and modified Black-Scholes models, hence, both show the significant differences in their mean values in pricing index Nifty 50 put options ($H_{04}$ and $H_{08}$). This section empirically compares the pricing errors produced under the both models to show which model produces lower pricing errors in pricing index Nifty 50 put options and the same can be considered as a better model. The results have been compared in table 4.48-

| Table 4.48: Entire pricing errors comparison between the B&S model and modified B&S model for index Nifty 50 call options. | | | |
|---|---|---|---|
| Parameters | Original B&S Model | Modified B&S Model | Improvement |
| ME | 7.2097 | 7.2881 | -0.0784 |
| MAE | 14.4822 | 12.8289 | 1.6533 |
| MSE | 781.6228 | 704.2579 | 77.3649 |
| RMSE | 26.9472 | 27.9575 | -1.0104 |
| Thiel's U statistic | 0.0175 | 0.0166 | 0.0009 |
| MAPE | 60.7176 | 60.3975 | 0.3201 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | |

The results shown in Table 4.48 are the outcome for the objective 4 and Hypothesis $H_{12}$. The value of ME is -0.0784. The P-value of SPSS output of Paired samples t-test is found greater than 0.05 with the same ME of 0.0784 given in table 4.60. Consequently, it is more likely to accept the null hypothesis for index put options. Hence, there is no significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing S&P CNX Nifty index put options in the Indian derivatives market. Here, the modified B&S model exhibits lager mean error by -0.0784. It may be noted that both models undervalue index put option.

The overall results on the performance of the Black-Scholes model based on the spot price and DVFP are provided in table 4.48. The number of observations in each case is 2,832. The magnitude of pricing errors with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for the Black-Scholes model based on the spot price are 7.2097, 14.4822, 781.6228, 26.9472, 0.0175 and 60.7176, respectively as exhibited in second column and the same corresponding to the Black-Scholes model based on the DVFP are 7.2881, 12.8289, 704.2579, 27.9575, 0.0166 and 60.3975 as exhibited in third column. The difference between the errors produced under the Black-Scholes model based on the spot price and DVFP mentioned in the fourth column is considered as an improvement, if any found.

The overall improvements with regard to ME and RMSE for pricing index put options have not been found if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters. The results provided in table 4.48 depict that the Black-Scholes model based on the spot price produces overall lower pricing error for pricing index put options in the Indian derivatives market. In other words, modification is not suitable for pricing index put option. Hence, the improvements regarding its subgroups have not been discussed further.

During the study period of this research, the overall improvements with regard to ME and RMSE for pricing index put options have not been found if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters. The Black-Scholes model based on the spot price produces overall lower pricing error for pricing index put options in the Indian derivatives market. In other words, modification is not suitable for pricing index put option. Hence, the improvements regarding its subgroups have not been discussed further.

**SPSS Output**

The theoretical prices of stocks and index options have been calculated under the Black-Scholes model using spot price of the underlying asset in stage 1st. The theoretical prices of the same underlying assets options have been calculated under the Black-Scholes model using DVFP of the underlying asset to address the negative cost of carry problem in stage 2$^{nd}$ (modified). The stage 3$^{rd}$ makes comparison between the models (stage 1$^{st}$ and stage 2$^{nd}$) to show which model exhibits less pricing errors. It may be noted that the error metrics have been calculated on the entire sample which consist with twenty-two companies. These twenty-two selected companies are from thirteen different sectors such as Bank & Finance, Telecommunication, Electrical

Equipment, Oil Exploration, Construction, Aluminium, Computer Software, Cigarettes, Diversified, Automobiles, Engineering, Refineries, Steel. In this section, an attempt has been also made to obtain the p-value to support hypotheses.

## 4.6. SPSS OUTPUT FOR STAGE FIRST

**Error Matrices of the Black& Scholes (B&S) model for Call and Put Options using spot price**

### 4.6.1. For Stock call options under the Black-Scholes model using spot price

The paired sample t-test has been conducted to obtain the p-value between the market closing prices of option contracts and the calculated prices under the Black Scholes model for stock call options. The results of paired samples test between stock call closing price and B&S model price are shown in table 4.49-

Table 4.49: Paired samples test for stock call options under the B&S model

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | Closing price and B&S Model price | -2.6325 | 22.7724 | 0.1129 | -2.8539 | -2.4111 | -23.3082 | 40652 | 0.000 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in table 4.49 are the outcome for the Hypothesis $H_{01}$. The P-value of SPSS output of Paired samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the mean values of the stock call options closing price and calculated price under the B&S model. It may be noted that the value of standard deviation is relatively high and it is found in almost each stage. It might be because of the pricing errors of twenty-two stocks for four years have been pulled together then their respective single error has been calculated on the entire sample. These twenty-two selected stocks are from thirteen different sectors.

### 4.6.2. For Index Call Options under the Black-Scholes model

The paired sample t-test has been conducted to obtain the p-value between the index S&P CNX Nifty call closing price and index S&P CNX Nifty call calculated price under B&S model and presented in table 4.50.

Table 4.50: Paired samples test for index S&P CNX Nifty call options under the B&S model

| | | Paired Differences | | | | | t | Df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| Pair 1 | Closing Price and B&S Model Price | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval Lower | 95% Confidence Interval Upper | | | |
| | | -3.408 | 29.5051 | 0.5552 | -4.4966 | -2.3193 | -6.1381 | 2823 | 0.000 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in table 4.50 are the outcome for the Hypothesis $H_{02}$. The P-value of SPSS output of Paired samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the mean values of the S&P CNX Nifty Index Call options closing price and calculated price under the B&S Model.

### 4.6.3. For Stock Put options under the Black-Scholes model

The paired sample t-test has been conducted to obtain the p-value between the stock put closing price and stock put calculated price under B&S model and presented in table 4.51-

| Table 4.51: Paired samples test for stock put options under the B&S model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | T | Df | Sig. (2-tailed) |
| Pair 1 | Closing Price and B&S model Price | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| | | -1.5726 | 22.9841 | 0.1188 | -1.8055 | -1.3397 | -13.2353 | 37415 | 0.000 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | | | |

The results shown in table 4.51 are the outcome for the Hypothesis $H_{03}$. The P-value of SPSS output of paired samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the Mean values of the Stock Put options closing price and calculated price under the B&S Model.

### 4.6.4. For Index Put Options under the Black-Scholes model

The paired sample t-test has been conducted to obtain the p-value between the index S&P CNX Nifty put closing price and index S&P CNX Nifty put calculated price under B&S model and presented in table 4.52-

| Table 4.52: Paired samples test for index S&P CNX Nifty put options under the B&S model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | T | df | Sig. (2-tailed) |
| Pair 1 | Closing Price and B&S Model Price | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| | | 7.2097 | 27.0167 | 0.5077 | 6.2142 | 8.2051 | 14.2014 | 2831 | 0.000 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | | | |

The results shown in table 4.52 are the outcome for the Hypothesis $H_{04}$. The P-value of SPSS output of Paired Samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the Mean values of the Index Nifty 50 (S&P CNX Nifty) Put options closing price and calculated price under the B&S Model.

## 4.7. SPSS OUTPUT FOR STAGE SECOND

**Error Matrices of the B&S Model after replacing Sport price (S) by the discounted value of Future price ($Fe^{-rt}$) for Call and Put Options**

### 4.7.1. For Stock call options under the modified Black-Scholes model

The paired sample t-test has been conducted between the stock call closing price and stock call calculated price under the modified B&S model and presented in table 4.53-

Table 4.53: Paired samples test for stock call options under the modified B&S model

| | | Paired Differences | | | | | T | Df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | closing Price and Modified B&S Model Price | -2.3028 | 22.3141 | 0.1107 | -2.5197 | -2.0859 | -20.8077 | 40652 | 0.000 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in table 4.53 are the outcome for the Hypothesis $H_{05}$. The P-value of SPSS output of Paired Samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the Mean values of the Stock Call options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S Model.

### 4.7.2. For Index Call Options under the modified Black-Scholes model

The paired sample t-test has been conducted between the index S&P CNX Nifty call closing price and index S&P CNX Nifty call calculated price under the modified B&S model and presented in table 4.54-

Table 4.54: Paired samples test for index S&P CNX Nifty call options under the modified B&S model

| | | Paired Differences | | | | | T | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| Pair 1 | Closing Price and Modified B&S Model Price | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval Lower | 95% Confidence Interval Upper | | | |
| | | -2.7506 | 27.1680 | 0.5112 | -3.753 | -1.7481 | -5.3802 | 2823 | 0.000 |

*Source: Compiled by Researcher on the Basis of Analysis*

The results shown in table 4.54 are the outcome for the Hypothesis $H_{06}$. The P-value of SPSS output of Paired Samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the Mean values of the Stock Call options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S Model on the basis of SPSS result.

### 4.7.3. For Stock Put options under the modified Black-Scholes model

The paired sample t-test has been conducted between the Stock put closing price and stock put calculated price under the modified B&S model and presented in table 4.55-

| Table 4.55: Paired samples test for stock put options under the modified B&S model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | T | df | Sig. (2-tailed) |
| Pair 1 | Closing Price and Modified B&S Model Price | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| | | -1.7469 | 23.1941 | 0.1199 | -1.9818 | -1.5118 | -14.5684 | 37415 | 0.000 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | | | |

The results shown in table 4.55 are the outcome for the Hypothesis $H_{07}$. The P-value of SPSS output of Paired Samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the Mean values of the stock Put options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S Model.

### 4.7.4. For Index Put Options under the modified Black-Scholes model

The paired sample t-test has been conducted between the index S&P CNX Nifty put closing price and index S&P CNX Nifty put calculated price under the modified B&S model and presented in table 4.56-

| Table 4.56: Paired samples test for index S&P CNX Nifty put options under the modified B&S model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | T | df | Sig. (2-tailed) |
| Pair 1 | Closing price and Modified B&S Model Price | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| | | 7.2881 | 25.9475 | 0.4876 | 6.3320 | 8.2441 | 14.947 | 2831 | .000 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | | | |

The results shown in table 4.56 are the outcome for the Hypothesis $H_{08}$. The P-value of SPSS output of Paired Samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the Mean values of the Index Nifty 50 Put options closing price and calculated price after replacing spot price (S) by the discounted value of the future price ($F.e^{-rt}$) in the B&S Model.

### 4.8. SPSS OUTPUT FOR STAGE THIRD

**Comparison of pricing errors between the B&S model and modified B&S model.**

Stage 3rd makes comparison between the models to show which model exhibits less pricing errors.

#### 4.8.1. For Stock call options under the Black-Scholes model and modified Black-Scholes model

The paired sample t-test has been conducted between the stock call calculated prices under the B&S model and modified B&S model. The results are presented in table 4.57-

| Table 4.57: Paired samples test for stock call options under the B&S model and the modified B&S model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | T | df | Sig. (2-tailed) |
| Pair 1 | B&S Model and Modified B&S Model Prices | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| | | 0.3297 | 3.0931 | 0.0153 | 0.2996 | 0.3598 | 21.4921 | 40652 | 0.000 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | | | |

The results shown in table 4.57 are the outcome for the Hypothesis $H_{09}$. The P-value of SPSS output of Paired Samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the Model after addressing the cost of carry problem and the original Black-Scholes model for pricing stock call options in Indian market.

**4.8.2. For Index Nifty 50 call options under the Black-Scholes model and modified Black-Scholes model**

The paired sample t-test has been conducted between the index Nifty 50 call calculated prices under the B&S model and modified B&S model. The results are presented in table 4.58-

| Table 4.58: Paired samples test for index Nifty 50 call options under the B&S model and modified Black-Scholes model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | T | Df | Sig. (2-tailed) |
| Pair 1 | B&S Model and Modified B&S Model Prices | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| | | 0.6574 | 11.2327 | 0.2114 | 0.2429 | 1.0718 | 3.1102 | 2823 | 0.002 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | | | |

The results shown in table 4.58 are the outcome for the Hypothesis $H_{010}$. The P-value of SPSS output of Paired Samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the model after addressing the cost of carry problem and the original Black-Scholes model for pricing index Nifty50 call options in Indian market.

**4.8.3. For Stock put options under the Black-Scholes model and modified Black-Scholes model**

The paired sample t-test has been conducted between the stock put calculated prices under the B&S model and modified B&S model and presented in table 4.59-

| Table 4.59: Paired samples test for stock put options under the B&S model and the modified B&S model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | T | Df | Sig. (2-tailed) |
| Pair 1 | B&S Model and Modified B&S Model Prices | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| | | -0.1742 | 2.2496 | 0.0116 | -0.1970 | -0.1514 | -14.9798 | 37415 | 0.000 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | | | |

The results shown in table 4.59 are the outcome for the Hypothesis $H_{011}$. The P-value of SPSS output of Paired Samples t-test is found less than 0.05. Consequently, it is more likely to reject the null hypothesis. Hence, there is a significant difference between the Model after addressing the cost of carry problem and the Original Black-Scholes Model for pricing stock put options in Indian market.

**4.8.4. For Index Nifty 50 put options under the Black-Scholes model and modified Black-Scholes model**

The paired sample t-test has been conducted between the index Nifty 50 put calculated prices under the B&S model and modified B&S model. The results are presented in table 4.60-

| Table 4.60: Paired samples test for index Nifty 50 put options under the B&S model and modified Black-Scholes model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | T | Df | Sig. (2-tailed) |
| Pair 1 | B&S Model and Modified B&S Model Price | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval | | | | |
| | | | | | Lower | Upper | | | |
| | | 0.0784 | 10.1822 | 0.1913 | -0.2968 | 0.4535 | .410 | 2831 | .682 |
| *Source: Compiled by Researcher on the Basis of Analysis* | | | | | | | | | |

The results shown in table 4.60 are the outcome for the Hypothesis $H_{012}$. The p-value of SPSS output of paired Samples t-test is found greater than 0.05. Consequently, it is more likely to accept the null hypothesis. Hence, there is no significant difference between the Model after addressing the cost of carry problem and the original Black-Scholes model for pricing index Nifty 50 put options in Indian market. Hence, it should be priced under the Black-Scholes model.

As a summary, it has been observed in this chapter that future prices of stock and index Nifty 50 quoting below the underlying spot prices are a common phenomenon in the Indian derivatives market. A visual inspection reveals stock and index Nifty 50 options are likely to be affected by the negative cost of carry problem.

One of the main assumptions of the B & S model is that stock returns follow log normal distribution. Mean-based statistics have been used to test normality. It has been found that the mean returns are almost zero in all cases and standard deviations are around 0.0 to 0.0309. That indicates the logarithmic returns of the stock of the companies are more or less normally distributed. The log normal assumptions of the model are mostly care taken but peakedness of the distribution is found. However, the mean of log-returns for all companies and index Nifty 50 is zero. Hence, Except the kurtosis all other tests point the log-returns are normally distributed.

**STAGE FIRST**

**Stock Call Option**

During the study period, a significant difference has been found between the mean values of the stock call options closing price and calculated price under the B&S model. The theoretical prices of stock call options have been calculated under the Black-Scholes model by using the stock spot prices. It has been found that the Black-Scholes model considerably overprices stock call option with a ME of -2.6325 when it is calculated using spot price of the stock. The subgroup measures of moneyness bias have been found for each category such as OTM, ATM and ITM for stock call options under the original Black-Scholes model. The original Black-Scholes model consistently overprices across all categories of moneyness and maturity.

**Index Call Option**

It has been found that there is a significant difference between the mean values of the index call options closing price and calculated price under the B&S model. The results of entire samples pricing errors produced under the Black-Scholes model shows that the model considerably overprices index call option with a ME of -3.408. The original Black-Scholes model also consistently overprices across all categories of given moneyness and maturity. The magnitude of mispricing increases as maturity increases in pricing index call option under the Black-Scholes model.

**Stock Put Option**

During the study period it has been found that there is a significant difference between the mean values of the stock put options closing price and calculated price under the B&S model. The Black-Scholes model considerably overprices stock put option with a ME of -1.5727. The model also overprices across all categories of moneyness. The values of mean errors show that the options prices calculated under the Black Scholes model using the stock spot prices for stock put options consistently overprices across all maturity. During the study period regarding the stock call to put bias under the Black-Scholes model, it has been found that the B&S model shows higher magnitude of errors in pricing of stock call as compare to pricing put options.

**Index Put Option**

During the study period, a significant difference has been found between the mean values of the S&P CNX Nifty index put options closing price and calculated price under the B&S model. It has been found that the model produces pricing errors for index put option and overall index put options are underpriced with the mean error of 7.2097 by the original Black-Scholes model during the study period of this research. It is evident that the original Black-Scholes model also consistently underprices across all categories of given moneyness. similarly, the next month and far month expiration index put options contracts whose prices are calculated under the Black-Scholes model using the index spot prices are underpriced while the near month contracts are overpriced by the model. During the study period regarding the index call to put bias under the

Black-Scholes model, it has been found that the magnitude of errors for pricing Index Nifty 50 put options is relatively higher under the Black-Scholes model.

**STAGE SECOND**

**Stock Call Option**

During the period of this research, a significant difference has been found between the mean values of the stock call options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model also produces pricing errors and overall stock call options are also overpriced by the modified Black-Scholes model when DVFP is used during the study period of this research. The modified Black-Scholes model considerably overprices stock call option with a ME of -2.3028. The negative ME has been produced by the modified Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock call options are overpriced with a ME of -5.9201, -2.0522 and -4.8459, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of moneyness and maturity.

**Index Call option**

During this research period, a significant difference has been found between the mean values of the S&P CNX Nifty index call options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably overprices index call option with a ME of -2.7506. The negative ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index call options. The OTM and ITM index call options both are overpriced with a ME of -0.1964 and -6.0846, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of given moneyness. The ME for the near month, next month and far month index call options contracts are -4.0651, -1.9345 and -2.417, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using discounting value of futures price for index call options consistently underprices across all maturity.

**Stock Put Options**

During this research period, a significant difference has been found between the mean values of the stock put options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably overprices stock put option with a ME of -1.7469. It is, hence, evident that model produces pricing errors and overall stock put options are also overpriced by the modified Black-Scholes model during the study period of this research. The OTM, ATM and ITM stock put options are overpriced with a ME of -3.3020, -0.6960, and -0.8374, respectively. Hence, it is evident that the original Black-Scholes model consistently overprices across all categories of moneyness. However, The OTM options have been highly overpriced with the ME of -5.2865. The ME for the near month, next month and far month stock put options contracts are -0.6426, -2.7822 and -4.0052, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the stock DVFP for stock put options consistently overprices across all maturity. the magnitude of mispricing increases as maturity increases in pricing stock put option under the Black-Scholes model.

During the study period regarding the stock call to put bias under the modified B&S model, it has been found that the modified Black-Scholes model shows higher magnitude of errors in pricing of stock call as compare to pricing put options.

**Index Put Option**

During this research period, a significant difference has been found between the mean values of the index put options closing price and calculated price under the B&S model using DVFP. The modified Black-Scholes model considerably underprices index put option with a ME of 7.0762. Hence, model produces pricing errors and overall stock put options are underpriced by the modified Black-Scholes model during the study period. The positive ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index put options. The OTM and ITM index put options both are underpriced with a ME of 3.0606 and 8.807, respectively. The ME for the near month, next month and far month index put options contracts are -0.2645, 5.1989 and 15.3879, respectively. On the basis of mean error, the index put next month options contracts are overpriced with a lowest mean error of -0.2645 while far month options contracts are underpriced with a highest mean error of 15.3879.

During the study period regarding the index call to put bias under the modified B&S model, it has been found that the magnitude of error for pricing Index Nifty 50 put options is relatively higher under the modified B&S model.

**STAGE THIRD**

**Stock Call Option**

During the study period of this research, a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock call options has been found with the ME value of (-) 0.3322. The overall stock call options are overpriced under the both cases with the mean errors of -2.6325 and -2.3028 but overpricing is improved by (-) 0.3322 if it is priced using the DVFP instead of spot price. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing stock call options are (-) 0.3322, 0.2652, 22.2905, 0.4915, 0.0027 and 1.3648, respectively. The comparative Improvements have been exhibited on the all the used parameters. Hence, the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing stock call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE and Theil's U statistic for pricing OTM stock call options are (-) 0.1672, 0.0875, 22.8638, 0.3183, 0.0004 and 1.2689, respectively. It may be noted that OTM stock call options are also overpriced under the both cases with the mean errors of -6.0873 and -5.9201 but overpricing is improved by (-) 0.1672 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters. The improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM stock call options in the Indian derivatives market.

ATM stock call options are also overpriced under the both cases with the mean errors of -2.0261 and -2.0522 but the magnitude of overpricing is higher by -0.0261 if it is priced using the DVFP instead of spot price. The comparative Improvements have not been found for stock call ATM options. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing ATM stock call options in the Indian derivatives market.

ITM stock call options are also overpriced under the both cases with the mean errors of -5.3775 and -4.8459 but overpricing is improved by (-) 0.5316 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM stock call options in the Indian derivatives market.

The near month stock call options are also overpriced under the both cases with the mean errors of -3.0254 and -2.8774 but overpricing is improved by (-) 0.1480 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. The performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the near month stock call options in the Indian derivatives market.

The next month stock call options are also overpriced under the both cases with the mean errors of -7.7576 and -7.3341 but overpricing is improved by (-) 0.4235 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month stock call options in the Indian derivatives market.

For far month stock call, the overall improvements with regard to ME, MAE, MSE, RMSE, Theil’s U statistic and MAPE for pricing the far month stock call options are (-) 0.9214, 0.0653, 41.1277, 0.4105, -0.0005 and 1.1604, respectively but the value of Theil’s u statistic does not support. The comparative Improvements has not been found. Hence, the performance of the Black-Scholes model based on the DVFP is not superior to that of the Black-Scholes model based on the spot price for pricing the far month stock call options in the Indian derivatives market.

**Index call option**

During this research period the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing index Nifty 50 call options differs with a ME value of (-) 0.6574. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistics and MAPE for pricing index call options are (-) 0.6574, 2.0106, 136.4566, 2.3940, 0.0019 and 1.5671, respectively. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing OTM index call options are (-) 0.4954, 0.5898, 31.1609, 0.6603, 0.0034 and 2.1759, respectively. It may be noted that OTM index call options are also overpriced under the both cases with the mean errors of -0.6918 and -0.1964 but overpricing is improved by (-) 0.4954 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing ITM index call options are (-) 0.8687, 3.8652, 273.8998, 4.0478, 0.0021 and 0.7721, respectively. It may be noted that ITM index call options are also overpriced under the both cases with the mean errors of -6.9533 and -6.0846 but overpricing is improved by (-) 0.8687 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the near month index call options are -0.8276, 1.7173, 71.5409, 1.9627, 0.0012 and -0.3311, respectively. It may be noted that the near month index call options are also overpriced under the both cases with the mean errors of-3.3974 and -4.0651 but overpricing is not improved if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters except ME and MAPE. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing near month index call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the next month index call options are (-) 0.3040, 1.9690, 185.3783, 3.0125, 0.0027 and 1.476, respectively. It may be noted that the next month index call options are also overpriced under the both cases with the mean errors of -2.2385 and -1.9345 but overpricing is improved by (-) 0.3040 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month index call options in the Indian derivatives market.

For the far month index option, overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month index call options are (-) 2.1770, 2.3100, 144.2601, 2.1764, 0.0020 and 3.3261, respectively. It may be noted that the far month index call options are also overpriced under the both cases with the mean errors of -4.5940 and -2.4170 but overpricing is improved by (-) 2.1770 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the far month index call options in the Indian derivatives market.

**Stock Put Option**

During the study period of this research, the overall improvements with regard to ME, MSE, RMSE, Theil U statistics and MAPE for pricing stock put options have not been found except MAE if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters except MAE. The Black-Scholes model based on the spot price produces overall lower pricing error for pricing stock put options in the Indian derivatives market. In other words, modification is not suitable for pricing stock put option. Hence, the improvements regarding its subgroups have not been discussed further.

**Index Put Option**

During the study period of this research, the overall improvements with regard to ME and RMSE for pricing index put options have not been found if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters. The Black-Scholes model based on the spot price produces overall lower pricing error for pricing index put options in the Indian derivatives market. In other words, modification is not suitable for pricing index put option. Hence, the improvements regarding its subgroups have not been discussed further.

The paired sample t-test has been also conducted to obtain the p-value in each stage. It may be noted that the error metrics have been calculated on the entire sample which consist with twenty-two companies. These twenty-two selected companies are from thirteen different sectors such as Bank & Finance, Telecommunication, Electrical Equipment, Oil Exploration, Construction, Aluminium, Computer Software, Cigarettes, Diversified, Automobiles, Engineering, Refineries, Steel. It may be noted that the value of standard deviation is relatively high in each stage. It might be because of the pricing errors of twenty-two stocks for four years have been pulled together then their respective single error has been calculated on the entire sample. These twenty-two selected stocks are from thirteen different sectors

# *CHAPTER V*

# FINDINGS AND CONCLUSION

## FINDINGS

In the previous chapter the efficiency of the Black-Scholes model has been determined using the underlying spot prices in stage first. The efficiency of the Black-Scholes model (modified) has been determined after replacing the underlying spot prices by their corresponding DVFPs to address the negative cost of carry problem in stage second. The stage third in the previous chapter has made a comparison between B&S model and modified B&S model to identify improvement, if any found. This chapter pulls together major findings from previous chapter. The present chapter consists of seven sections; The section **first** makes comparison between underlying future and spot prices. The section **second** deals with the stage first where error matrices of the B&S model for call and put options using spot price have been presented. The section **third** deals with deals with stage second where error matrices of the B&S model after replacing spot prices (s) by the discounted value of future price ($fe^{-(r-y)t}$) have been presented. The section **fourth** deals with stage third where comparison of pricing errors between B&S model and modified B&S model has been made. The section **fifth** draws conclusion from stage first. The section **sixth** draws conclusion from stage second. The section **seventh** draws conclusion from stage third.

## 5.1. COMPARISION BETWEEN UNDERLYING FUTURE AND SPOT PRICES

During the comparison of future price and spot price for addressing negative cost of carry problem following points have been observed:

### 5.1.1 For stock call options

The Future prices of 6,634 out of total 40,653 observations (16.32%) have been quoted lower than their corresponding spot prices.

When the stocks' future prices have been discounted, then17,137 out of total 40,653 observations are found lower than their corresponding spot prices. In other words, 42.15% of the total observations, the stocks' DVFP have been traded below their corresponding stock spot prices. Hence, comparing the discounting value of the futures prices of stocks with their corresponding spot prices, a visual inspection reveals that 42.15% of the total observations for stock call options are likely to be affected by the negative cost of carry problem.

#### 5.1.2. For Index Nifty 50 call options

The Future prices of 124 out of total 2,824 observations (4.39%) have been quoted lower than their corresponding spot prices.

When the equity index Nifty 50 future prices have been discounted, then 1,446 out of total 2,824 observations are found lower than their corresponding spot prices. In other words, 51.20% of the total observations, the Nifty 50's DVFP have been traded below their corresponding Nifty 50 spot prices. These findings are consistent with the findings of Mitra (2008 & 2012). Hence, comparing the discounting value of the futures prices of index nifty 50 with their corresponding spot prices, a visual inspection reveals that 51.20% of the total observations for index Nifty 50 call options are likely to be affected by the negative cost of carry problem. These findings are consistent with the Varma (2002), Mitra (2008 and 2012).

#### 5.1.3. For stock put options

The Future prices of 6,206 out of total 37,416 observations (16.59%) have been quoted lower than their corresponding spot prices.

When the stocks future prices have been discounted, then15,713 out of total 37,416 observations are found lower than their corresponding spot prices. In other words, 41.95% of the total observations, the stocks DVFP have been traded below their corresponding stock spot prices. Hence, comparing the discounting value of the futures prices of stocks with their corresponding spot prices, A visual inspection reveals that 41.99% of the total observations for stock put options are likely to be affected by the negative cost of carry problem.

#### 5.1.4. For Index Nifty 50 put options

The Future prices of 125 out of total 2,832 observations (4.41%) have been quoted lower than their corresponding spot prices.

When the equity index Nifty 50 future prices have been discounted, then 1,446 out of total 2,824 observations are found lower than their corresponding spot prices. In other words, 51.20% of the total observations, the Nifty 50 DVFP have been traded below their corresponding Nifty 50 spot prices. Hence, comparing the discounting value of the futures prices of index Nifty 50 with their corresponding spot prices, a visual inspection reveals that 51.20% of the total observations for index Nifty 50 put options are likely to be affected by the negative cost of carry problem. These findings are consistent with the findings of Mitra (2008 & 2012).

Futures prices have been used by various authors in derivatives products such by Draper and Fung (2002), Fung and Mok (2001) and Lung and Marshall (2002), Varma (2002), Garay, Ordonez and Gonzalez (2003), Lee and Nayar (1993), Sternberg (1994), Fung and Chan (1994), Fleming, Ostdiek, and Whaley (1996), Fung, Cheng and Chan (1997), Fung and Fung (1997), Mitra (2008 and 2012). However, Bharadwaj and Wiggins (2001) found violations in using this approach in the US market.

## 5.2. STAGE FIRST: ERROR MATRICES OF THE B&S MODEL FOR CALL AND PUT OPTIONS USING SPOT PRICE

### 5.2.1. Stock Call Option

During the study period, a significant difference has been found between the mean values of the stock call options closing price and calculated price under the B&S model (objective 1). This finding is consistent with the finding of Fortune (1996) that model exhibits pricing error. The theoretical prices of stock call options have been calculated under the Black-Scholes model by using the stock spot prices. It has been found that the Black-Scholes model considerably overprices stock call option with a ME of -2.6325 when it is calculated using spot price of the stock. This finding is inconsistent with Kakati (2006) that call options are underpriced.

The subgroup measures of moneyness bias have been found for each category such as OTM, ATM and ITM for stock call options under the original Black-Scholes model. The original

Black-Scholes model consistently overprices across all categories of moneyness (objective 2). The finding regarding ATM and OTM stock option is consistent with Kakati (2006) that the stock call ATM and ITM options are overvalued. Macbeth and Merville (1979) study also found that B&S model overprices OTM stock call options. The finding regarding stock call ITM is consistent with Bhattacharya (1980) that stock call ITM options are overvalued.

The maturity biasness for the near month, next month and far month expiration stock call options contracts have been found whose prices are calculated under the Black-Scholes model using the stock spot prices (objective 2). The magnitude of mispricing increases as maturity increases in pricing stock call option under the Black-Scholes model. Stock call options are consistently overprices across all maturity under the B&S model. However, the stock call near month options contracts are overpriced with a lowest mean error of -3.0254, consistent with result from Kakati (2006) while far month options contracts are overpriced with a highest mean error of -10.9202. Panduranga (2013a & b) found that B&S model is suitable for pricing stock call option written on banking and cement industries.

### 5.2.2. Index Nifty 50 Call Option

It has been found that there is a significant difference between the mean values of the index call options closing price and calculated price under the B&S model ((objective 1). This is in line with the findings of Gencay and Salih (2003) that model exhibits pricing error of index call and put options. The results of entire samples pricing errors produced under the Black-Scholes model shows that the model considerably overprices index call option with a ME of -3.408. This is in line with the findings of Singh and Dixit (2016) that the Black-Scholes model shows consistent overpricing with more than 90% call options as overpriced. But this is also inconsistent with the findings of McKenzie, Gerace, and Subedar (2007) that model is relatively accurate for pricing call options.

The original Black-Scholes model also consistently overprices across all categories of given moneyness and maturity (objective 2). The magnitude of mispricing increases as maturity increases in pricing index call option under the Black-Scholes model. This confirms the literature of Kakati (2006). This also confirms the literature of Barunikova (2009) that the Black-Scholes model exhibits Index call maturity and moneyness biases.

### 5.2.3. Stock Put Option

During the study period it has been found that there is a significant difference between the mean values of the stock put options closing price and calculated price under the B&S model (objective 1). The Black-Scholes model considerably overprices stock put option with a ME of -1.5727. This confirms the literature of Fortune (1996) that the stock put options are overpriced by the B&S model.

The model also overprices across all categories of moneyness. The values of mean errors show that the options prices calculated under the Black Scholes model using the stock spot prices for stock put options consistently overprices across all maturity (objective 2). These all findings confirm the literature of Kakati (2006) that stock put options, its moneyness and all categories of maturity are also overpriced.

During the study period regarding the stock call to put bias under the Black-Scholes model, it has been found that the B&S model shows higher magnitude of errors in pricing of stock call as compare to pricing put options (objective 2). This finding is consistent with Berg, Brevik and Saettem (1996) and Kakati (2006) that the magnitude of error for stock call option is comparatively higher than stock put option. But this finding is also inconsistent with the findings of Kala and Pandey (2012) that the Black-Scholes model is more useful in call option pricing than the put option pricing.

### 5.2.4. Index Put Option

During the study period, a significant difference has been found between the mean values of the S&P CNX Nifty index put options closing price and calculated price under the B&S model (objective 1). This is in line with the findings of Gencay and Salih (2003) that model exhibits pricing error of index call and put options. It has been found that the model produces pricing errors for index put option and overall index put options are underpriced with the mean error of 7.2097 by the original Black-Scholes model during the study period of this research. This finding is contradicting to Shehgal and Narayanamurthy (2009) finding.

It is further evident that the original Black-Scholes model also consistently underprices across all categories of given moneyness. This finding is in line with the findings of Singh and Ahmad (2011) that the Black-Scholes model shows maturity and moneyness biases in pricing index options. Similarly, the next month and far month expiration index put options contracts whose prices are calculated under the Black-Scholes model using the index spot prices are underpriced while the near month contracts are overpriced by the model (objective 2).

During the study period regarding the index call to put bias under the Black-Scholes model, it has been found that the magnitude of errors for pricing Index Nifty 50 put options is relatively higher under the Black-Scholes model (objective 2). This finding is in line with the findings of Kala and Pandey (2012) that the Black-Scholes model is more usefull in call option pricing than the put option pricing. This finding is inconsistent with Kakati (2006) study on BSE and Kala & Pandey (2012) study on NSE. But this finding is also inconsistent with Puttonen (1993) and Dixit, Yadav and Jain (2009) studies where they have found that the B&S model shows higher magnitude of pricing error in pricing index call option as compare to index put option.

## 5.3. STAGE SECOND: ERROR MATRICES OF THE B&S MODEL AFTER REPLACING SPOT PRICES (S) BY THE DISCOUNTED VALUE OF FUTURE PRICE ($Fe^{-(r-y)t}$)

### 5.3.1. Stock Call Option

During the period of this research, a significant difference has been found between the mean values of the stock call options closing price and calculated price under the B&S model using DVFP (objective 3). The modified Black-Scholes model also produces pricing errors and overall stock call options are also overpriced by the modified Black-Scholes model when DVFP is used during the study period of this research. The modified Black-Scholes model considerably overprices stock call option with a ME of -2.3028.

The negative ME has been produced by the modified Black-Scholes model in each category of moneyness. The OTM, ATM and ITM stock call options are overpriced with a ME of -5.9201, -2.0522 and -4.8459, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of moneyness (objective 2).

Pricing errors calculated on the basis all parameters state that mispricing increases as maturity increases under the modified B&S model (objective 2). The ME for the near month, next month and far month stock call options contracts are -2.8774, -7.3341 and -9.9988, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using the discounting value of futures price for stock call options also consistently overprices across all maturity. This confirms the literature of Raj and Thurston (1998) that the all three maturity categories are significantly overpriced under the Black model for index call option.

### 5.3.2. Index Call Option

During this research period, a significant difference has been found between the mean values of the S&P CNX Nifty index call options closing price and calculated price under the B&S model using DVFP (objective 3). The modified Black-Scholes model considerably overprices index call option with a ME of -2.7506. This confirms literature of Raj and Thurston (1998) that the model overprices index call options. But this finding is also inconsistent with the finding of Varma (2002) that the model underprices index call option.

The negative ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index call options. The OTM and ITM index call options both are overpriced with a ME of -0.1964 and -6.0846, respectively. Hence, it is evident that the modified Black-Scholes model also consistently overprices across all categories of given moneyness (objective 2). This finding also is consistent with the finding of Raj and Thurston (1998) that the model overprices all categories moneyness for index call option.

The ME for the near month, next month and far month index call options contracts are -4.0651, -1.9345 and -2.417, respectively. The values of mean errors show that the options prices calculated under the modified Black Scholes model using discounting value of futures price for index call options consistently underprices across all maturity (objective 2). This finding also is consistent with the finding of Raj and Thurston (1998) that the model overprices all categories maturity for index call option.

### 5.3.3. Stock Put Options

During this research period, a significant difference has been found between the mean values of the stock put options closing price and calculated price under the B&S model using DVFP (objective 3). The modified Black-Scholes model considerably overprices stock put option with a ME of -1.7469. It is, hence, evident that model produces pricing errors and overall stock put options are also overpriced by the modified Black-Scholes model during the study period of this research.

The OTM, ATM and ITM stock put options are overpriced with a ME of -3.3020, -0.6960, and -0.8374, respectively (objective 2). Hence, it is evident that the modified Black-Scholes model consistently overprices across all categories of moneyness. This finding is inconsistent with the finding of Whaley (1985) that the model underprices in-the-money options. However, The OTM options have been highly overpriced with the ME of -5.2865.

The ME for the near month, next month and far month stock put options contracts are -0.6426, -2.7822 and -4.0052, respectively (objective 2). The values of mean errors show that the options prices calculated under the modified Black Scholes model using the stock DVFP for stock put options consistently overprices across all maturity. the magnitude of mispricing increases as maturity increases in pricing stock put option under the Black-Scholes model.

During the study period regarding the stock call to put bias under the modified B&S model, it has been found that the modified Black-Scholes model shows higher magnitude of errors in pricing of stock call as compare to pricing put options (objective 2).

### 5.3.4. Index Put Option

During this research period, a significant difference has been found between the mean values of the index put options closing price and calculated price under the B&S model using DVFP (objective 3).The modified Black-Scholes model considerably underprices index put option with a ME of 7.0762.Hence, model produces pricing errors and overall index put options are underpriced by the modified Black-Scholes model during the study period. Raj and Thurston (1998) found that model overprices index put options.

The positive ME has been also produced by the modified Black-Scholes model in the category OTM and ITM index put options (objective 2). The OTM and ITM index put options both are underpriced with a ME of3.0606 and 8.807, respectively. This finding also is inconsistent with the finding of Raj and Thurston (1998) that the model overprices all categories moneyness.

The ME for the near month, next month and far month index put options contracts are -0.2645, 5.1989 and 15.3879, respectively (objective 2). On the basis of mean error, the index put next month options contracts are overpriced with a lowest mean error of -0.2645 while far month options contracts are underpriced with a highest mean error of 15.3879. The near month finding is consistent with the finding of Raj and Thurston (1998).

During the study period regarding the index call to put bias under the modified B&S model, it has been found that the magnitude of error for pricing Index Nifty 50 put options is relatively higher under the modified B&S model (objective 2).

## 5.4. STAGE THIRD: COMPARISON OF PRICING ERRORS BETWEEN B&S MODEL AND MODIFIED B&S MODEL

### 5.4.1. Stock Call Option

During the study period of this research, a significance difference between the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing stock call options has been found with the ME value of (-) 0.3322. The overall stock call options are overpriced under the both cases with the mean errors of -2.6325 and -2.3028 but overpricing is improved by (-) 0.3322 if it is priced using the DVFP instead of spot price. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil’s U statistic and MAPE for pricing stock call options are (-) 0.3322, 0.2652, 22.2905, 0.4915, 0.0027 and 1.3648, respectively. The comparative Improvements have been exhibited on the all the used parameters (objective 4). Hence, the improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing stock call options in the Indian derivatives market.

The overall improvements with regard to ME, MAE, MSE, RMSE and Theil's U statistic for pricing OTM stock call options are (-) 0.1672, 0.0875, 22.8638, 0.3183, 0.0004 and 1.2689, respectively. It may be noted that OTM stock call options are also overpriced under the both cases with the mean errors of -6.0873 and -5.9201 but overpricing is improved by (-) 0.1672 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters (objective 2). The improvements shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM stock call options in the Indian derivatives market.

ATM stock call options are also overpriced under the both cases with the mean errors of -2.0261 and -2.0522 but the magnitude of overpricing is higher by -0.0261 if it is priced using the DVFP instead of spot price. The comparative Improvements have not been found for stock call ATM options. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing ATM stock call options in the Indian derivatives market (objective 2).

ITM stock call options are also overpriced under the both cases with the mean errors of -5.3775 and -4.8459 but overpricing is improved by (-) 0.5316 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all above mentioned parameters. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM stock call options in the Indian derivatives market (objective 2).

The near month stock call options are also overpriced under the both cases with the mean errors of -3.0254 and -2.8774 but overpricing is improved by (-) 0.1480 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. The performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the near month stock call options in the Indian derivatives market (objective 2).

The next month stock call options are also overpriced under the both cases with the mean errors of -7.7576 and -7.3341 but overpricing is improved by (-) 0.4235 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all prescribed parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month stock call options in the Indian derivatives market (objective 2).

For far month stock call, the overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month stock call options are (-) 0.9214, 0.0653, 41.1277, 0.4105, -0.0005 and 1.1604, respectively but the value of Theil's u statistic does not support. The comparative Improvements has not been found. Hence, the performance of the Black-Scholes model based on the DVFP is not superior to that of the Black-Scholes model based on the spot price for pricing the far month stock call options in the Indian derivatives market (objective 2).

### 5.4.2. Index call option

During this research period the mean values of the original Black-Scholes model and the model after addressing the cost of carry problem for pricing index Nifty 50 call options differs with a ME value of (-) 0.6574. The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistics and MAPE for pricing index call options are (-) 0.6574, 2.0106, 136.4566, 2.3940, 0.0019 and 1.5671, respectively. Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing index call options in the Indian derivatives market (objective 4). This finding is consistent with Mitra (2008 & 2012) study on index Nifty 50 call option traded. This finding is also in line with the finding of Raj and Thurston (1998) that model overprices call and put options traded on the Nikkei.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing OTM index call options are (-) 0.4954, 0.5898, 31.1609, 0.6603, 0.0034 and 2.1759, respectively. It may be noted that OTM index call options are also overpriced under the both cases with the mean errors of -0.6918 and -0.1964 but overpricing is improved by (-) 0.4954 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all used parameters (objective 2). Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing OTM index call options in the Indian derivatives market. This finding is in line with the finding of Raj and Thurston (1998) there is some evidence that the model overprices ITM and OTM options

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing ITM index call options are (-) 0.8687, 3.8652, 273.8998, 4.0478, 0.0021 and 0.7721, respectively. It may be noted that ITM index call options are also overpriced under the both cases with the mean errors of -6.9533 and -6.0846 but overpricing is improved by (-) 0.8687 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters (objective 2). Hence, the improvements have been shown by the Black-Scholes model based on the DVFP over the Black-Scholes model based on the spot price for pricing ITM index call options in the Indian derivatives market. This finding is in line with the finding of Raj and Thurston (1998) there is some evidence that the model overprices ITM and OTM options But this finding is inconsistent with the finding of whaley (1996) there is some evidence that the model underprices in-the-money options in USA.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the near month index call options are -0.8276, 1.7173, 71.5409, 1.9627, 0.0012 and -0.3311, respectively. It may be noted that the near month index call options are also overpriced under the both cases with the mean errors of-3.3974 and -4.0651 but overpricing is not improved if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters except ME Theil's U statistic. Hence, the Black-Scholes model based on the spot price produces lower pricing error for pricing near month index call options in the Indian derivatives market (objective 2). This finding is in line with the finding of Raj and Thurston (1998) there is some evidence that the model overprices all category of maturity.

The overall improvements with regard to ME, MAE, MSE, RMSE, Theil's U statistic and MAPE for pricing the next month index call options are (-) 0.3040, 1.9690, 185.3783, 3.0125, 0.0027 and 1.476, respectively. It may be noted that the next month index call options are also overpriced under the both cases with the mean errors of -2.2385 and -1.9345 but overpricing is improved by (-) 0.3040 if it is priced using the DVFP instead of spot price. This finding is in line with the finding of Raj and Thurston (1998) there is some evidence that the model overprices next month options contract. The comparative Improvements have been found on the all selected parameters (objective 2). Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the next month index call options in the Indian derivatives market.

For the far month index option, overall improvements with regard to ME, MAE, MSE, RMSE, Theil's u statistic and MAPE for pricing the far month index call options are (-) 2.1770, 2.3100, 144.2601, 2.1764, 0.0020 and 3.3261, respectively. It may be noted that the far month index call options are also overpriced under the both cases with the mean errors of -4.5940 and-2.4170 but overpricing is improved by (-) 2.1770 if it is priced using the DVFP instead of spot price. The comparative Improvements have been found on the all selected parameters. Hence, the performance of the Black-Scholes model based on the DVFP is superior to that of the Black-Scholes model based on the spot price for pricing the far month index call options in the Indian derivatives market (objective 2). These findings regarding next month and far month are consistent with the finding of Raj and Thurston (1998) that model overprices across all categories of maturity.

### 5.4.3. Stock Put Option

During the study period of this research, the overall improvements with regard to ME, MSE, RMSE, Theil U statistics and MAPE for pricing stock put options have not been found except MAE if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters except MAE. The Black-Scholes model based on the spot price produces overall lower pricing error for pricing stock put options in the Indian derivatives market (objective 4). In other words, modification is not suitable for pricing stock put option. Hence, the improvements regarding its subgroups have not been discussed further.

### 5.4.4. Index Put Option

During the study period of this research, the overall improvements with regard to ME and RMSE for pricing index put options have not been found if it is priced using the DVFP instead of spot price. Hence, the comparative Improvements have not been exhibited on the all above mentioned parameters. The Black-Scholes model based on the spot price produces overall lower pricing error for pricing index put options in the Indian derivatives market (objective 4). In other words, modification is not suitable for pricing index put option. Hence, the improvements regarding its subgroups have not been discussed further. This finding is in line with the findings of Shehgal and Narayanamurthy (2009) stated that the Black-Scholes model is a good descriptor of S&P CNX Nifty Index option pricing subjective to the trading asymmetry condition (short selling restrictions) prevailing in India.

# CONCLUSION

A visual inspection reveals that stock and index futures sometimes suffer from a negative cost-of-carry bias, as future prices of stock and index trade below their corresponding spot prices.

## 5.5. CONCLUSION FROM STAGE FIRST: ERROR MATRICES OF THE B&S MODEL FOR CALL AND PUT OPTIONS USING SPOT PRICE

The Black-Scholes model overall suffers from the pricing errors for the calculation of the prices of Stocks and Index Nifty 50 options using underlying spot price. It has been observed that stock call, index call and Stock put options are overpriced while index put options are underpriced by the Black-Scholes model.

### 5.5.1. Stock and Index Nifty 50 Moneyness Bias Under the B&S Model:

1. Stock call ITM, OTM and ATM options are overpriced by the B&S model.
2. Index call ITM and OTM options are overpriced by the B&S model.
3. Stock put ITM, ATM and OTM options are overpriced by the B&S model.
4. Index put ITM and OTM options are underpriced by the B&S.

### 5.5.2. Stock and Index Nifty 50 Maturity Bias Under the B&S Model:

1. Stock call Near Month, Next Month and Far Month options are overpriced by the B&S model.
2. Index call Near Month, Next Month and Far Month options are overpriced by the B&S model.

3. Stock put Near Month, Next Month and Far Month options are overpriced by the B&S model.
4. Index put Near Month option is overpriced while Next Month and Far Month options are underpriced by the B&S model.

**5.5.3. Stock Call to Put Bias:** Stock call and put options both are overpriced by the B&S model. However, the B&S model shows high magnitude of errors in pricing of stock call as compare to pricing put options on the basis of Mean Error.

**5.5.4. Index Nifty 50 Call to Put Bias:** Index Nifty 50 call options are overpriced while Index put options are underpriced by the B&S model. However, the magnitude of error for pricing Index Nifty50 put options is relatively high on the basis of Mean Error.

## 5.6. CONCLUSION FROM STAGE SECOND: ERROR MATRICES OF THE B&S MODEL AFTER REPLACING SPORT PRICE (S) BY THE DISCOUNTED VALUE OF FUTURE PRICE ($FE^{-(R-Y)T}$)

The Modified Black-Scholes model also overall suffers from the pricing errors for the calculation of the prices Stocks and Index Nifty50 options using underlying DVFP instead of spot price. It has been observed that stock call, index call and Stock put options are overpriced while index put options are underpriced by the modified Black-Scholes model.

**5.6.1. Stock and Index Nifty 50 Moneyness Bias Under the Modified B&S Model:**

1. Stock call ITM, ATM and OTM options are overpriced by the modified B&S model.
2. Index call ITM and OTM options are overpriced by the modified B&S model. ATM option trading data have not been found for Index Nifty50 call option under the modified B& S model.
3. Stock put ITM, ATM and OTM options are overpriced by the modified B&S model.
4. Index put ITM and OTM option are underpriced by the modified B&S.

**5.6.2. Stock and Index Nifty 50 Maturity Bias Under the Modified B&S Model:**

1. Stock call Near Month, Next Month and Far Month options are overpriced by the modified B&S model.
2. Index call Near Month, Next Month and Far Month options are overpriced by the modified B&S model.
3. Stock put Near Month, Next Month and Far Month options are overpriced by the modified B&S.
4. Index put Near Month option is overpriced while the Next Month and Far Month options are underpriced by the modified B&S model.

**5.6.3. Stock Call to Put Bias:** For stock option, the modified B&S shows high magnitude of errors in pricing of stock call as compare to pricing put options.

**5.6.4. Index Nifty 50 Call to Put Bias:** For index Nifty 50 option, the modified B&S shows high magnitude of errors in pricing of index Nifty 50 put options as compare to call options.

## 5.7. CONCLUSION FROM STAGE THIRD: COMPARISON OF PRICING ERRORS BETWEEN B & S MODEL AND AFTER BRINGING MODIFICATION IN B & S MODEL

**5.7.1. For Stock Call Options:** The Modified Black-Scholes model provides overall better result in comparison to the Black-Scholes Model for pricing stock call options in Indian market. The Modified Black-Scholes model shows lower pricing errors for stock call OTM and ITM options and higher errors for ATM options. Regarding the maturity bias, the Modified Black-Scholes model also shows lower pricing errors for the stock call Near month and next month options contracts and higher errors for stock call far month options contracts.

**5.7.2. For Index Call Options:** The Modified Black-Scholes model provides overall better result in comparison to the Black-Scholes Model for pricing Index Nifty 50 call options in Indian market. The Modified Black-Scholes model shows lower pricing errors for index call OTM and ITM options. Regarding the maturity bias, the modified Black-Scholes model shows lower pricing errors for the index call next month and far month options contracts and higher errors for index call near month options contracts.

**5.7.3. For Stock Put Options:** The Modified Black-Scholes model does not provide overall better result in comparison to the Black-Scholes Model for pricing stock put options in Indian market. Hence, the B&S model is suitable for pricing stock put options.

**5.7.4. For Index Put Options:** The Modified Black-Scholes model does not provide overall better result in comparison to the Black-Scholes Model for pricing Index Nifty 50 put options in Indian market. Hence, the B&S model is suitable for pricing index put options.

During the study period of this research, it has been observed that stock and index futures sometimes suffer from a negative cost-of-carry bias, as future prices of stock and index trade below their corresponding spot prices. The Black-Scholes model overall suffers from the pricing errors for the calculation of the prices of Stocks and Index Nifty 50 options using underlying spot price. It has been observed that stock call, index call and Stock put options are overpriced while index put options are underpriced by the Black-Scholes model. Stock call ITM, OTM and ATM options are overpriced by the B&S model and its Near Month, Next Month and Far Month options are overpriced by the B&S model. Index call ITM and OTM options are overpriced by the B&S model and its Near Month, Next Month and Far Month options are overpriced by the B&S model. Stock put ITM, ATM and OTM options are overpriced by the B&S model and its Near Month, Next Month and Far Month options are overpriced by the B&S model. Index put ITM and OTM options are underpriced by the B&S and its Near Month option is overpriced while Next Month and Far Month options are underpriced by the B&S model. Stock call and put options both are overpriced by the B&S model. However, the B&S model shows high magnitude of errors in pricing of stock call as compare to pricing put options on the basis of Mean Error. Index Nifty 50 call options are overpriced while Index put options are underpriced by the B&S model. However, the magnitude of error for pricing Index Nifty50 put options is relatively high on the basis of Mean Error.

The Modified Black-Scholes model, after replacing spot price by the discounting value of future prices to address the negative cost of carry problem, also overall suffers from the pricing errors for the calculation of the prices Stocks and Index Nifty50 options. It has been observed that stock call, index call and Stock put options are overpriced while index put options are underpriced by the modified Black-Scholes model. Stock call ITM, ATM and OTM options are overpriced by the modified B&S model and its Near Month, Next Month and Far Month options are overpriced by the modified B&S model. Index call ITM and OTM options are overpriced by the modified B&S model its Index call Near Month, Next Month and Far Month options are overpriced by the modified B&S model. Stock put ITM, ATM and OTM options are overpriced by the modified B&S model and Stock put Near Month, Next Month and Far Month options are overpriced by the modified B&S. Index put ITM and OTM option are underpriced by the modified B&S. ATM option trading data have not been found for Index Nifty50 put option under the modified B& S model and its Near Month option is overpriced while the Next Month and Far Month options are underpriced by the modified B&S model. When Call to Put Bias has been analysed under the modified Black-Scholes model, it has been found that the modified B&S shows high magnitude of errors in pricing of stock call as compare to pricing put options. For index Nifty 50 option, the modified B&S shows high magnitude of errors in pricing of index Nifty 50 put options as compare to its own call options.

The overall Improvements have been found in pricing stock call and index call option when they have been priced under the modified Black-Scholes model, after replacing spot price by the discounting value of future prices to address the negative cost of carry problem. The Modified Black-Scholes model shows lower pricing errors for stock call OTM and ITM options and higher errors for stock call ATM options. Regarding the maturity bias, the Modified Black-Scholes model also shows lower pricing errors for the stock call Near month and next month options contracts and higher errors for stock call far month options contracts.

The Modified Black-Scholes model shows lower pricing errors for index call OTM and ITM options. Regarding the maturity bias, the modified Black-Scholes model shows lower pricing errors for the index call next month and far month options contracts and higher errors for index call next month options contracts.

However, the modified Black-Scholes model does not provide overall better result in comparison to the Black-Scholes Model for pricing stock put options in Indian market. Hence, the B&S model is suitable for pricing stock put options. Similarly, the modified Black-Scholes model also does not provide overall better result in comparison to the Black-Scholes Model for pricing Index Nifty 50 put options in Indian market. Hence, the B&S model is suitable for pricing index put options.

# *CHAPTER VI*

# SUGGESTIONS, LIMITATIONS, CONTRIBUTION AND FURTHER SCOPE

The present chapter consists of four sections; The section **first** gives suggestions. The section **second** deals with limitation of the study. The section **third** gives contribution and Section **fourth** highlights scope for the further study.

## 6.1. SUGGESTIONS

The following suggestions can be given for pricing stock call, index call, stock put and index put option:

1. Stock Call option: Stock Call Options should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model.

1.1. Stock Call OTM and ITM Options should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model while ATM Options should be priced using the B&S model.

1.2. Stock Call Near Month and Next month Option should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model while far month options should be priced under the B&S model.

2. Index Nifty 50 Call option: Index Nifty 50 Call option should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model.

1.1. Nifty 50 Call ITM and OTM options should be priced under the modified B&S model as it shows less pricing error in comparison to the B&S model.

1.2. Nifty 50 Call Next month and Far month options should be priced under the modified B & S model as it shows less pricing error in comparison to the B&S model while the Near Month options should be priced under the B&S model.

3. Stock Put Options: Stock Put options should be priced under the B&S model as it shows less pricing error including its ITM, ATM, OTM, near month, next month and far month options contracts.

4. Index Nifty 50 Put options: Index Nifty50 Put options should be priced under the B&S model including its ITM, ATM, OTM, near month, next month and far month options contracts.

**6.2. LIMITATIONS**

1. The observed closing market prices of options (stock and index Nifty 50 options) traded on the NSE and theoretical options prices (stock and index Nifty 50 options) calculated under the models are compared to gauge the pricing accuracy. Hence, the stocks other than from the list of Nifty 50 and index other than Nifty 50 traded on the NSE have not been taken under this research during the period from 1$^{st}$ April, 2012 to 31$^{st}$ March, 2016.

2. The tests conducted in this research are based on only the closing prices of the underlying assets which are considered to be efficient. In other words, this research considers stocks closing price, stocks futures closing price, stocks options closing price, stock Nifty 50 closing price, stock Nifty 50 futures closing price and stock Nifty 50 options closing price. Here, stock means equity.

3. This research is conducted on NSE in India and hence, no comparison is made with foreign market. This research also assumes the impact of holidays on the stock exchange (NSE) as constant.

4. This study entirely focuses on the efficiency and the same has to be examined under the models and hence, the impacts on the efficiency caused by volatility, risk-free rate of interest, strike price, log normal distribution with constant volatility, transaction costs, arbitrage

opportunities, short selling restriction of security in the Indian market, dividend and time to expiration of option have not been tested.

5. Stock and future prices follow a random walk have not been tested.

6. The problem of Negative "cost of carry" has been addressed by replacing the spot price (S) by their respective discounted value of future price ($F.e^{-rt}$) in the original Black-Scholes model to minimize the pricing errors.

7. The residuals are assumed to be normally generated.

8. The market efficiency has not been tested as the specific focus of this research is on the pricing efficiency of the B&S model.

9. The cost of carry issue has not been tested at all in this research.

10. The data of stocks' and index's spot and futures prices are assumed to be stationary.

11. This research is not tested on the by-products of the model which are known as the Greeks such as Delta (sensitivity to underlying's price), Theta (sensitivity to time decay), Gamma (sensitivity to delta), Rho (sensitivity to interest rate) and Vega (sensitivity to underlying's volatility).

12. The mathematical derivation of the B&S model has not been conducted.

**6.3. CONTRIBUTION**

The purpose of derivative market is to provide product and techniques applicable for risk hedging, price discovery, and also for price accuracy. This research has entirely focused on the pricing errors of options produced by the B&S model and how pricing errors can be minimized. Less pricing errors will be produced, if traders and investors price Stock Call options and Index Nifty50 call options on the basis of discounting value of future price instead of spot price in the original B&s model. Hence, the model, which shows less pricing errors in the calculation of different types of options' prices written on different types of underlying assets, will create and maintain confidence level among the various stock market participants.

## 6.4. SCOPE FOR FURTHER WORK

The applicability of the Black-Scholes model can be tested on implied volatility with replacing spot price by the discounting value of future price. The produced pricing errors can also be empirically tested with relatively larger number of observations with increase in the number of contract size and period of study. Further research can be carried out by using conditional volatility or Skedastic function for calculating the future volatility to replace constant volatility in the Black-Scholes option pricing model. Research can be carried to exhibit the impact of major change in underlying spot price on the option price.

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and other internet data base.

**Appendix-1** List of Nifty 50 stocks with Number of stock option contracts

Table 1: List of Nifty 50 stocks with Number of stock option contracts accessed on 2nd April, 2012

| Sr. No. | Security Symbol | No. of Cont. CE | No. of Cont. PE | No of Contracts Fut. | Decision: Selected or Rejected | Security Name | Industry |
|---|---|---|---|---|---|---|---|
| 1 | ACC | 38 | 27 | 2116 | Rejected | ACC Ltd. | Cement and cement products |
| 2 | AMBUJACEM | 129 | 10 | 1079 | Rejected | Ambuja Cements Ltd. | Cement and cement products |
| 3 | ASIANPAINT | 2 | 0 | 172 | Rejected | Asian Paints Ltd. | Paints |
| 4 | AXISBANK | 1717 | 828 | 7917 | Selected | Axis Bank Ltd. | Banks |
| 5 | BAJAJ-AUTO | 61 | 37 | 2415 | Rejected | Bajaj Auto Ltd. | Automobiles - 2 and 3 wheelers |
| 6 | BANKBARODA | 5 | 1 | 1132 | Rejected | Bank of Baroda | Banks |
| 7 | BHARTIARTL | 880 | 464 | 2152 | Selected | Bharti Airtel Ltd. | Telecommunication – services |
| 8 | BHEL | 1040 | 446 | 6155 | Selected | Bharat Heavy Electricals Ltd. | Electrical equipment |
| 9 | BPCL | 72 | 30 | 1138 | Rejected | Bharat Petroleum | Refineries |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Corporation Ltd. | |
| 10 | CAIRN | 858 | 208 | 4846 | Rejected | Cairn India Ltd. | Oil exploration/production |
| 11 | CIPLA | 97 | 31 | 674 | Rejected | Cipla Ltd. | Pharmaceuticals |
| 12 | COALINDIA | 212 | 178 | 1567 | Rejected | Coal India Ltd. | Mining |
| 13 | DLF | 2651 | 3398 | 9146 | Selected | DLF Ltd. | Construction |
| 14 | DRREDDY | 12 | 22 | 1104 | Rejected | Dr. Reddy's Laboratories Ltd. | Pharmaceuticals |
| 15 | GAIL | 92 | 27 | 974 | Rejected | GAIL (India) Ltd. | Gas |
| 16 | GRASIM | 6 | 10 | 682 | Rejected | Grasim Industries Ltd. | Cement and cement products |
| 17 | HCLTECH | 26 | 2 | 884 | Rejected | HCL Technologies Ltd. | Computers – software |
| 18 | HDFC | 1191 | 741 | 5036 | Selected | Housing Development Finance Corporation Ltd. | Finance – housing |
| 19 | HDFCBANK | 272 | 205 | 4477 | Selected | HDFC Bank Ltd. | Banks |
| 20 | HEROMOTOCO | 285 | 101 | 2509 | Rejected | Hero MotoCorp | Automobiles - 2 and 3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Ltd. | wheelers |
| 21 | HINDALCO | 1426 | 452 | 5028 | Selected | Hindalco Industries Ltd. | Aluminium |
| 22 | HINDUNILVR | 422 | 207 | 1458 | Selected | Hindustan Unilever Ltd. | Diversified |
| 23 | ICICIBANK | 2458 | 2133 | 10429 | Selected | ICICI Bank Ltd. | Banks |
| 24 | IDFC | 545 | 352 | 2659 | Selected | Infrastructure Development Finance Co. Ltd. | Financial institution |
| 25 | INFY | 2630 | 2040 | 4502 | Selected | Infosys Ltd. | Computers – software |
| 26 | ITC | 315 | 235 | 2706 | Selected | I T C Ltd. | Cigarettes |
| 27 | JINDALSTEL | 74 | 30 | 2015 | Rejected | Jindal Steel & Power Ltd. | Steel and steel products |
| 28 | JPASSOCIAT | 2440 | 1060 | 8668 | Selected | Jaiprakash Associates Ltd. | Construction |
| 29 | KOTAKBANK | 24 | 16 | 2015 | Rejected | Kotak Mahindra Bank Ltd. | Banks |
| 30 | LT | 2285 | 939 | 8041 | Selected | Larsen & Toubro Ltd. | Engineering |
| 31 | M&M | 815 | 204 | 4552 | Selected | Mahindra & Mahindra Ltd. | Automobiles - 4 wheelers |
| 32 | MARUTI | 232 | 177 | 3025 | Rejected | Maruti Suzuki India Ltd. | Automobiles - 4 wheelers |
| 33 | NTPC | 298 | 102 | 326 | Rejected | NTPC Ltd. | Power |
| 34 | ONGC | 602 | 127 | 2181 | Rejected | Oil & Natural | Oil |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Gas Corporation Ltd. | exploration/production |
| 35 | PNB | 34 | 13 | 1636 | Rejected | Punjab National Bank | Banks |
| 36 | POWERGRID | 30 | 8 | 523 | Rejected | Power Grid Corporation of India Ltd. | Power |
| 37 | RANBAXY | 221 | 80 | 2375 | Rejected | Ranbaxy Laboratories Ltd. | Pharmaceuticals |
| 38 | RELIANCE | 7132 | 3314 | 12314 | Selected | Reliance Industries Ltd. | Refineries |
| 39 | RELINFRA | 866 | 387 | 6635 | Selected | Reliance Infrastructure Ltd. | Power |
| 40 | SAIL | 253 | 45 | 1613 | Rejected | Steel Authority of India Ltd. | Steel and steel products |
| 41 | SBIN | 10145 | 4415 | 17989 | Selected | State Bank of India | Banks |
| 42 | SESAGOA | 250 | 51 | 2813 | Rejected | Sesa Goa Ltd. | Mining |
| 43 | SIEMENS | 6 | 1 | 707 | Rejected | Siemens Ltd. | Electrical equipment |
| 44 | STER | 426 | 104 | 3576 | Rejected | Sterlite Industries (India) Ltd. | Metals |
| 45 | SUNPHARMA | 17 | 9 | 1063 | Rejected | Sun Pharmaceutical Industries | Pharmaceuticals |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Ltd. | |
| 46 | TATAMOTORS | 2083 | 829 | 6809 | Selected | Tata Motors Ltd. | Automobiles - 4 wheelers |
| 47 | TATAPOWER | 57 | 20 | 851 | Rejected | Tata Power Co. Ltd. | Power |
| 48 | TATASTEEL | 3180 | 1614 | 11719 | Selected | Tata Steel Ltd. | Steel and steel products |
| 49 | TCS | 1304 | 551 | 3966 | Selected | Tata Consultancy Services Ltd. | Computers – software |
| 50 | WIPRO | 58 | 16 | 1085 | Rejected | Wipro Ltd. | Computers – software |

Source: Compiled by Researcher from data available at www.nseindia.com

CE- Call European, PE- Put European and Fut- Futures

**Appendix-2** List of Selected Companies

Table 1: List of Selected Companies

| Sr. No. | Security Symbol | No. of Cont. CE | No. of Cont. PE | No of Contracts Fut. | Decision: Selected or Rejected | Security Name | Industry |
|---|---|---|---|---|---|---|---|
| 1 | AXISBANK | 1717 | 828 | 7917 | Selected | Axis Bank Ltd. | Banks |
| 2 | BHARTIARTL | 880 | 464 | 2152 | Selected | Bharti Airtel Ltd. | Telecommunication – services |
| 3 | BHEL | 1040 | 446 | 6155 | Selected | Bharat Heavy Electricals Ltd. | Electrical equipment |
| 4 | CAIRN | 858 | 208 | 4846 | Rejected | Cairn India Ltd. | Oil exploration/production |
| 5 | DLF | 2651 | 3398 | 9146 | Selected | DLF Ltd. | Construction |
| 6 | HDFC | 1191 | 741 | 5036 | Selected | Housing Development Finance Corporation Ltd. | Finance – housing |
| 7 | HDFCBANK | 272 | 205 | 4477 | Selected | HDFC Bank Ltd. | Banks |
| 8 | HINDALCO | 1426 | 452 | 5028 | Selected | Hindalco Industries Ltd. | Aluminium |
| 9 | HINDUNILVR | 422 | 207 | 1458 | Selected | Hindustan Unilever | Diversified |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Ltd. | |
| 10 | ICICIBANK | 2458 | 2133 | 10429 | Selected | ICICI Bank Ltd. | Banks |
| 11 | IDFC | 545 | 352 | 2659 | Selected | Infrastructure Development Finance Co. Ltd. | Financial institution |
| 12 | INFY | 2630 | 2040 | 4502 | Selected | Infosys Ltd. | Computers – software |
| 13 | ITC | 315 | 235 | 2706 | Selected | I T C Ltd. | Cigarettes |
| 14 | JPASSOCIAT | 2440 | 1060 | 8668 | Selected | Jaiprakash Associates Ltd. | Construction |
| 15 | LT | 2285 | 939 | 8041 | Selected | Larsen & Toubro Ltd. | Engineering |
| 16 | M&M | 815 | 204 | 4552 | Selected | Mahindra & Mahindra Ltd. | Automobiles - 4 wheelers |
| 17 | RELIANCE | 7132 | 3314 | 12314 | Selected | Reliance Industries Ltd. | Refineries |
| 18 | RELINFRA | 866 | 387 | 6635 | Selected | Reliance Infrastructure Ltd. | Power |
| 19 | SBIN | 10145 | 4415 | 17989 | Selected | State Bank of India | Banks |
| 20 | TATAMOTORS | 2083 | 829 | 6809 | Selected | Tata Motors Ltd. | Automobiles - 4 wheelers |
| 21 | TATASTEEL | 3180 | 1614 | 11719 | Selected | Tata Steel Ltd. | Steel and steel products |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 22 | TCS | 1304 | 551 | 3966 | Selected | Tata Consultancy Services Ltd. | Computers – software |
| Source: Compiled by Researcher from data available at www.nseindia.com | | | | | | | |

**Appendix-3** 91-day Govt. of India T. Bills Yield

| Table 1: 91-day Govt. of India T. Bills Yield as a Risk-free rate of interest | | | | |
|---|---|---|---|---|
| Month | Yield: Year 2012-13 | Yield: Year 2013-14 | Yield: Year 2014-15 | Yield: Year 2015-16 |
| April | 8.22 | 7.47 | 8.51 | 7.66 |
| May | 8.08 | 7.13 | 8.4 | 7.63 |
| June | 7.96 | 7.17 | 8.21 | 7.41 |
| July | 7.89 | 8.31 | 8.24 | 7.24 |
| August | 7.91 | 10.74 | 8.26 | 7.14 |
| September | 7.82 | 10 | 8.23 | 7.17 |
| October | 7.78 | 8.56 | 8.13 | 6.84 |
| November | 7.85 | 8.48 | 7.96 | 6.89 |
| December | 7.56 | 8.33 | 7.96 | 6.95 |
| January | 7.71 | 8.39 | 7.98 | 6.99 |
| February | 7.71 | 8.7 | 7.99 | 5.37 |
| March | 7.79 | 8.73 | 7.96 | 7.01 |
| *Source: Compiled by Researcher from data available at www.rbi.org.in* | | | | |

**Appendix-4** Stocks Dividend Yield

| Table 1: Stocks Dividend Yield | | | | | | | |
|---|---|---|---|---|---|---|---|
| S. No. | Stocks | Div.Y (Ex-Dividend Date) | Div.Y (Ex-Dividend Date) | Div.Y (Ex-Dividend Date) | Div.Y (Ex-Dividend Date) | Div.Y (Ex-Dividend Date) | Div.Y (Ex-Dividend Date) |
| 1 | AXISBANK | 1.1 (6/8/2011) | 1.5 (6/14/2012) | 1.3 (7/5/2013) | 1 (7/12/2014) | 0.7 (7/9/2015) | 0.9 (7/7/2016) |
| 2 | BHARTIARTL | 0.2 (8/17/2011) | 0.3 (8/16/2012) | 0.3 (5/23/2013) | 0.4 (8/21/2014) | 0.5 (8/13/2015) | 0.3 (8/11/2016) |
| | BHEL | 0.9 (8/10/2011) | 0.9 (3/6/2012) | 1.8 (9/6/2012) | 0.9 (2/5/2013) | 2.2 (9/6/2013) | 0.8 (2/7/2014) |
| 3 | BHEL | 0.6 (9/8/2014) | 0.2 (2/16/2015) | 0.2 (9/14/2015) | 0.2 (9/14/2016) | | |
| | CAIRN | 0 (8/9/2011) AGM | 0 (8/8/2012) AGM | 1.5 (11/5/2012) | 2.2 (7/10/2013) | 1.9 (10/25/2013) | 1.8 (7/9/2014) |
| 4 | CAIRN | 1.5 (9/22/2014) | 2.3 (7/8/2015) | 2 (7/8/2016) | | | |
| | DLF | 0.8 (7/27/2011) | 0.9 (8/24/2012) | 1.2 (7/30/2013) | 0.9 (8/19/2014) | 1.5 (8/17/2015) | 1.8 (28-March-16) |
| 5 | DLF | 1.04 (9/19/2017) | | | | | |
| 6 | HDFC | 1.3 (6/22/2011) | 1.7 (6/22/2012) | 1.4 (6/27/2013) | 1.4 (7/4/2014) | 0.9 (7/15/2015) | 1 (7/15/2016) |
| 7 | HDFCBANK | 0.6 (6/2/2011) | 0.7 (6/28/2012) | 0.8 (6/13/2013) | 0.8 (6/5/2014) | 0.7 (7/2/2015) | 0.8 (6/29/2016) |
| 8 | HINDALCO | 1 (9/14/2011) | 1.4 (8/31/2012) | 1.3 (8/30/2013) | 0.5 (9/8/2014) | 1.3 (9/7/2015) | 0.6 (9/6/2016) |
| 9 | HINDUNILVR | 1 | 0.9 | 1 | 1.2 | 1 | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | (7/8/2011) | (7/4/2012) | (7/10/2013) | (6/11/2014) | (6/19/2015) | (6/22/2016) |
| 10 | ICICIBANK | 1.3 (6/2/2011) | 2.1 (5/31/2012) | 1.6 (5/30/2013) | 1.5 (6/5/2014) | 1.7 (6/4/2015) | 2 (6/16/2016) |
| 11 | IDFC | 1.4 (7/14/2011) | 1.7 (6/28/2012) | 2 (7/18/2013) | 1.6 (7/17/2014) | 1.6 (7/23/2015) | 0.41 (7/20/2017) |
| 12 | INFY | 0.7 (5/26/2011) | 0.9 (5/24/2012) | 1.1 (5/30/2013) | 1.4 (5/29/2014) | 2.9 (6/15/2015) | 1.1 (6/9/2016) |
| 13 | ITC | 2.2 (6/10/2011) | 1.8 (6/11/2012) | 1.5 (5/31/2013) | 1.7 (6/3/2014) | 2 (6/3/2015) | 2.3 (5/30/2016) |
| 14 | JPASSOCIAT | 0.5 (9/19/2011) | 0.6 (9/18/2012) | 0.9 (7/19/2013) | 0 (12/15/2015) AGM | 0 (9/20/2016) AGM | |
| 15 | LT | 0.8 (8/17/2011) | 1.1 (8/14/2012) | 1.5 (8/13/2013) | 0.9 (8/13/2014) | 1 (9/1/2015) | 1.2 (8/18/2016) |
| 16 | M&M | 1.6 (7/14/2011) | 1.7 (7/12/2012) | 1.4 (7/18/2013) | 1.2 (7/17/2014) | 0.9 (7/16/2015) | 0.83 (7/21/2016) |
| 17 | RELIANCE | 0.8 (5/5/2011) | 1.1 (5/31/2012) | 1.2 (5/10/2013) | 0.8 (5/16/2014) | 1.1 (5/8/2015) | 1 (3/17/2016) |
| 18 | RELINFRA | 1.6 (9/5/2011) | 1.4 (8/23/2012) | 2 (8/14/2013) | 1.1 (9/18/2014) | 2.3 (9/16/2015) | 1.4 (9/15/2016) |
| 19 | SBIN | 1.2 (5/20/2011) | 1.7 (5/24/2012) | 1.9 (5/28/2013) | 0.8 (3/11/2014) | 1.2 (5/28/2015) | 1.3 (6/3/2016) |
| 20 | TATAMOTOR | 2 (7/19/2011) | 1.7 (7/18/2012) | 0.6 (7/30/2013) | 0.4 (7/9/2014) | 0 (7/22/2015) AGM | 0.04 (7/18/2016) |
| 21 | TATASTEEL | 1.9 (7/4/2011) | 2.8 (7/16/2012) | 3.1 (7/15/2013) | 1.9 (7/14/2014) | 2.9 (7/23/2015) | 2.2 (7/28/2016) |
| 22 | TCS | 0.6 (6/8/2011) | 0.6 (6/7/2012) | 0.8 (6/6/2013) | 0.9 (6/6/2014) | 0.9 (6/5/2015) | 1 (6/6/2016) |
| *Source: Compiled by Researcher from data available at www.nseindia.com* | | | | | | | |

**Appendix-5** Equity Index Nifty 50 Div. Yield

Table 1: Equity Index Nifty 50 Div. Yield- 2012-13 (Part A)

| Date: Apr-12 | Div. Yield | Date: May-12 | Div. Yield | Date: Jun-12 | Div. Yield | Date: Jul-12 | Div. Yield | Date: Aug-12 | Div. Yield | Date: Sep-12 | Div. Yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1.5 | 2 | 1.53 | 1 | 1.69 | 2 | 1.51 | 1 | 1.54 | 3 | 1.58 |
| 3 | 1.49 | 3 | 1.54 | 4 | 1.68 | 3 | 1.51 | 2 | 1.54 | 4 | 1.57 |
| 4 | 1.5 | 4 | 1.57 | 5 | 1.68 | 4 | 1.51 | 3 | 1.54 | 5 | 1.58 |
| 9 | 1.52 | 7 | 1.56 | 6 | 1.6 | 5 | 1.5 | 6 | 1.52 | 6 | 1.58 |
| 10 | 1.52 | 8 | 1.6 | 7 | 1.58 | 6 | 1.5 | 7 | 1.51 | 7 | 1.55 |
| 11 | 1.52 | 9 | 1.61 | 8 | 1.58 | 9 | 1.51 | 8 | 1.51 | 8 | 1.54 |
| 12 | 1.51 | 10 | 1.61 | 11 | 1.58 | 10 | 1.49 | 9 | 1.51 | 10 | 1.54 |
| 13 | 1.53 | 11 | 1.62 | 12 | 1.56 | 11 | 1.51 | 10 | 1.51 | 11 | 1.53 |
| 16 | 1.52 | 14 | 1.63 | 13 | 1.56 | 12 | 1.53 | 13 | 1.5 | 12 | 1.52 |
| 17 | 1.5 | 15 | 1.62 | 14 | 1.58 | 13 | 1.53 | 14 | 1.52 | 13 | 1.52 |
| 18 | 1.5 | 16 | 1.64 | 15 | 1.55 | 16 | 1.54 | 16 | 1.51 | 14 | 1.48 |
| 19 | 1.49 | 17 | 1.64 | 18 | 1.58 | 17 | 1.54 | 17 | 1.54 | 17 | 1.47 |
| 20 | 1.5 | 18 | 1.63 | 19 | 1.57 | 18 | 1.53 | 21 | 1.53 | 18 | 1.48 |
| 23 | 1.53 | 21 | 1.63 | 20 | 1.56 | 19 | 1.52 | 22 | 1.53 | 20 | 1.49 |
| 24 | 1.52 | 22 | 1.64 | 21 | 1.55 | 20 | 1.53 | 23 | 1.53 | 21 | 1.45 |
| 25 | 1.53 | 23 | 1.65 | 22 | 1.55 | 23 | 1.56 | 24 | 1.54 | 24 | 1.46 |
| 26 | 1.53 | 24 | 1.62 | 25 | 1.56 | 24 | 1.56 | 27 | 1.55 | 25 | 1.46 |
| 27 | 1.54 | 25 | 1.62 | 26 | 1.56 | 25 | 1.58 | 28 | 1.55 | 26 | 1.46 |
| 28 | 1.54 | 28 | 1.6 | 27 | 1.55 | 26 | 1.6 | 29 | 1.56 | 27 | 1.46 |
| 30 | 1.52 | 29 | 1.6 | 28 | 1.55 | 27 | 1.58 | 30 | 1.56 | 28 | 1.42 |
|  |  | 30 | 1.65 | 29 | 1.51 | 30 | 1.55 | 31 | 1.57 |  |  |
|  |  | 31 | 1.66 |  |  | 31 | 1.54 |  |  |  |  |

*Source: Compiled by Researcher from data available at* *www.nseindia.com*

| Table 2: Equity Index Nifty 50 Div. Yield- 2012-13 (Part B) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: Oct-12 | Div. Yield | Date: Nov-12 | Div. Yield | Date: Dec-12 | Div. Yield | Date: Jan-13 | Div. Yield | Date: Feb-13 | Div. Yield | Date: Mar-13 | Div. Yield |
| 1 | 1.41 | 1 | 1.43 | 3 | 1.4 | 1 | 1.39 | 1 | 1.37 | 1 | 1.44 |
| 3 | 1.41 | 2 | 1.42 | 4 | 1.4 | 2 | 1.38 | 5 | 1.38 | 4 | 1.44 |
| 4 | 1.4 | 5 | 1.43 | 5 | 1.4 | 3 | 1.37 | 6 | 1.38 | 5 | 1.42 |
| 5 | 1.41 | 6 | 1.43 | 6 | 1.39 | 4 | 1.37 | 7 | 1.39 | 6 | 1.41 |
| 8 | 1.43 | 7 | 1.43 | 7 | 1.4 | 7 | 1.38 | 8 | 1.4 | 7 | 1.4 |
| 9 | 1.42 | 8 | 1.43 | 10 | 1.4 | 8 | 1.37 | 11 | 1.4 | 8 | 1.38 |
| 10 | 1.43 | 9 | 1.45 | 11 | 1.4 | 9 | 1.38 | 12 | 1.39 | 11 | 1.39 |
| 11 | 1.42 | 12 | 1.44 | 12 | 1.4 | 10 | 1.38 | 13 | 1.39 | 12 | 1.4 |
| 12 | 1.43 | 13 | 1.45 | 13 | 1.41 | 11 | 1.39 | 14 | 1.4 | 13 | 1.41 |
| 15 | 1.42 | 15 | 1.45 | 14 | 1.4 | 14 | 1.37 | 15 | 1.4 | 14 | 1.4 |
| 16 | 1.41 | 16 | 1.47 | 17 | 1.41 | 15 | 1.36 | 18 | 1.39 | 15 | 1.41 |
| 17 | 1.4 | 19 | 1.47 | 18 | 1.4 | 16 | 1.37 | 19 | 1.38 | 18 | 1.42 |
| 18 | 1.39 | 20 | 1.47 | 19 | 1.39 | 17 | 1.36 | 20 | 1.38 | 19 | 1.44 |
| 19 | 1.4 | 21 | 1.46 | 20 | 1.39 | 18 | 1.36 | 21 | 1.4 | 20 | 1.45 |
| 22 | 1.39 | 22 | 1.46 | 21 | 1.41 | 21 | 1.36 | 22 | 1.41 | 21 | 1.46 |
| 23 | 1.42 | 23 | 1.46 | 24 | 1.41 | 22 | 1.36 | 25 | 1.4 | 22 | 1.46 |
| 25 | 1.41 | 26 | 1.45 | 26 | 1.4 | 23 | 1.36 | 26 | 1.43 | 25 | 1.47 |
| 26 | 1.42 | 27 | 1.43 | 27 | 1.4 | 24 | 1.37 | 27 | 1.42 | 26 | 1.47 |
| 29 | 1.42 | 29 | 1.41 | 28 | 1.4 | 25 | 1.36 | 28 | 1.44 | 28 | 1.46 |
| 30 | 1.44 | 30 | 1.4 | 31 | 1.4 | 28 | 1.36 | | | | |
| 31 | 1.44 | | | | | 29 | 1.36 | | | | |
| | | | | | | 30 | 1.36 | | | | |
| | | | | | | 31 | 1.37 | | | | |
| *Source: Compiled by Researcher from data available at www.nseindia.com* | | | | | | | | | | | |

| Table 3: Equity Index Nifty 50 Div. Yield- 2013-14 (Part A) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: Apr-13 | Div. Yield | Date: May-13 | Div. Yield | Date: Jun-13 | Div. Yield | Date: Jul-13 | Div. Yield | Date: Aug-13 | Div. Yield | Date: Sep-13 | Div. Yield |
| 1 | 1.46 | 2 | 1.38 | 3 | 1.4 | 1 | 1.4 | 1 | 1.47 | 2 | 1.52 |
| 2 | 1.44 | 3 | 1.4 | 4 | 1.4 | 2 | 1.41 | 2 | 1.48 | 3 | 1.58 |
| 3 | 1.46 | 6 | 1.39 | 5 | 1.4 | 3 | 1.42 | 5 | 1.48 | 4 | 1.55 |
| 4 | 1.49 | 7 | 1.37 | 6 | 1.4 | 4 | 1.42 | 6 | 1.52 | 5 | 1.51 |
| 5 | 1.49 | 8 | 1.37 | 7 | 1.41 | 5 | 1.41 | 7 | 1.53 | 6 | 1.48 |
| 8 | 1.5 | 9 | 1.37 | 10 | 1.41 | 8 | 1.42 | 8 | 1.51 | 10 | 1.42 |
| 9 | 1.51 | 10 | 1.36 | 11 | 1.43 | 9 | 1.41 | 12 | 1.5 | 11 | 1.41 |
| 10 | 1.49 | 11 | 1.36 | 12 | 1.44 | 10 | 1.42 | 13 | 1.48 | 12 | 1.44 |
| 11 | 1.48 | 13 | 1.39 | 13 | 1.45 | 11 | 1.39 | 14 | 1.47 | 13 | 1.44 |
| 12 | 1.5 | 14 | 1.38 | 14 | 1.43 | 12 | 1.38 | 16 | 1.53 | 16 | 1.45 |
| 15 | 1.49 | 15 | 1.35 | 17 | 1.42 | 15 | 1.37 | 19 | 1.56 | 17 | 1.45 |
| 16 | 1.46 | 16 | 1.35 | 18 | 1.43 | 16 | 1.39 | 20 | 1.56 | 18 | 1.49 |
| 17 | 1.46 | 17 | 1.34 | 19 | 1.42 | 17 | 1.38 | 21 | 1.59 | 19 | 1.42 |
| 18 | 1.44 | 20 | 1.35 | 20 | 1.47 | 18 | 1.37 | 22 | 1.56 | 20 | 1.47 |
| 22 | 1.42 | 21 | 1.36 | 21 | 1.46 | 19 | 1.37 | 23 | 1.54 | 23 | 1.5 |
| 23 | 1.42 | 22 | 1.36 | 24 | 1.48 | 22 | 1.37 | 27 | 1.59 | 24 | 1.51 |
| 25 | 1.4 | 23 | 1.39 | 25 | 1.48 | 23 | 1.36 | 28 | 1.6 | 25 | 1.55 |
| 26 | 1.41 | 24 | 1.39 | 26 | 1.48 | 24 | 1.38 | 29 | 1.56 | 26 | 1.55 |
| 29 | 1.41 | 27 | 1.36 | 27 | 1.46 | 25 | 1.4 | 30 | 1.54 | 27 | 1.56 |
| 30 | 1.4 | 28 | 1.36 | 28 | 1.43 | 26 | 1.4 | | | 30 | 1.56 |
| | | 29 | 1.36 | | | 29 | 1.44 | | | | |
| | | 30 | 1.36 | | | 30 | 1.46 | | | | |
| | | 31 | 1.39 | | | 31 | 1.47 | | | | |
| *Source: Compiled by Researcher from data available at www.nseindia.com* | | | | | | | | | | | |

| Table 4: Equity Index Nifty 50 Div. Yield- 2013-14 (Part B) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: Oct-13 | Div. Yield | Date: Nov-13 | Div. Yield | Date: Dec-13 | Div. Yield | Date: Jan-14 | Div. Yield | Date: Feb-14 | Div. Yield | Date: Mar-14 | Div. Yield |
| 1 | 1.56 | 1 | 1.46 | 2 | 1.5 | 1 | 1.49 | 3 | 1.56 | 3 | 1.5 |
| 3 | 1.54 | 3 | 1.46 | 3 | 1.51 | 2 | 1.5 | 4 | 1.56 | 4 | 1.49 |
| 4 | 1.56 | 5 | 1.47 | 4 | 1.52 | 3 | 1.51 | 5 | 1.56 | 5 | 1.48 |
| 7 | 1.56 | 6 | 1.48 | 5 | 1.5 | 6 | 1.51 | 6 | 1.55 | 6 | 1.46 |
| 8 | 1.56 | 7 | 1.49 | 6 | 1.49 | 7 | 1.52 | 7 | 1.54 | 7 | 1.43 |
| 9 | 1.54 | 8 | 1.5 | 9 | 1.47 | 8 | 1.52 | 10 | 1.55 | 10 | 1.43 |
| 10 | 1.53 | 11 | 1.52 | 10 | 1.47 | 9 | 1.52 | 11 | 1.54 | 11 | 1.44 |
| 11 | 1.52 | 12 | 1.53 | 11 | 1.48 | 10 | 1.52 | 12 | 1.54 | 12 | 1.44 |
| 14 | 1.51 | 13 | 1.54 | 12 | 1.5 | 13 | 1.49 | 13 | 1.56 | 13 | 1.44 |
| 15 | 1.52 | 14 | 1.52 | 13 | 1.51 | 14 | 1.5 | 14 | 1.55 | 14 | 1.44 |
| 17 | 1.53 | 18 | 1.49 | 16 | 1.52 | 15 | 1.48 | 17 | 1.54 | 18 | 1.44 |
| 18 | 1.49 | 19 | 1.49 | 17 | 1.52 | 17 | 1.5 | 18 | 1.53 | 19 | 1.43 |
| 21 | 1.49 | 20 | 1.51 | 18 | 1.5 | 20 | 1.49 | 19 | 1.52 | 20 | 1.44 |
| 22 | 1.49 | 21 | 1.54 | 19 | 1.51 | 21 | 1.48 | 20 | 1.54 | 21 | 1.44 |
| 23 | 1.49 | 22 | 1.55 | 20 | 1.49 | 22 | 1.48 | 21 | 1.52 | 22 | 1.44 |
| 24 | 1.5 | 25 | 1.52 | 23 | 1.49 | 23 | 1.48 | 24 | 1.51 | 24 | 1.42 |
| 25 | 1.5 | 26 | 1.53 | 24 | 1.49 | 24 | 1.49 | 25 | 1.51 | 25 | 1.42 |
| 28 | 1.51 | 27 | 1.54 | 27 | 1.48 | 27 | 1.53 | 26 | 1.5 | 26 | 1.42 |
| 29 | 1.48 | 28 | 1.53 | 30 | 1.49 | 28 | 1.53 | 28 | 1.49 | 27 | 1.41 |
| 30 | 1.47 | 29 | 1.51 | 31 | 1.48 | 29 | 1.53 | | | 28 | 1.37 |
| 31 | 1.46 | | | | | 30 | 1.54 | | | 31 | 1.37 |
| | | | | | | 31 | 1.54 | | | | |
| *Source: Compiled by Researcher from data available at [www.nseindia.com](http://www.nseindia.com)* | | | | | | | | | | | |

| Table 5: Equity Index Nifty 50 Div. Yield- 2014-15 (Part A) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: Apr-14 | Div. Yield | Date: May-14 | Div. Yield | Date: Jun-14 | Div. Yield | Date: Jul-14 | Div. Yield | Date: Aug-14 | Div. Yield | Date: Sep-14 | Div. Yield |
| 1 | 1.37 | 2 | 1.42 | 2 | 1.31 | 1 | 1.28 | 1 | 1.32 | 1 | 1.26 |
| 2 | 1.36 | 5 | 1.42 | 3 | 1.3 | 2 | 1.27 | 4 | 1.31 | 2 | 1.25 |
| 3 | 1.37 | 6 | 1.41 | 4 | 1.31 | 3 | 1.27 | 5 | 1.3 | 3 | 1.25 |
| 4 | 1.37 | 7 | 1.43 | 5 | 1.29 | 4 | 1.26 | 6 | 1.32 | 4 | 1.25 |
| 7 | 1.37 | 8 | 1.45 | 6 | 1.28 | 7 | 1.26 | 7 | 1.32 | 5 | 1.25 |
| 9 | 1.35 | 9 | 1.41 | 9 | 1.26 | 8 | 1.29 | 8 | 1.34 | 8 | 1.24 |
| 10 | 1.35 | 12 | 1.38 | 10 | 1.26 | 9 | 1.29 | 11 | 1.33 | 9 | 1.24 |
| 11 | 1.36 | 13 | 1.36 | 11 | 1.28 | 10 | 1.3 | 12 | 1.31 | 10 | 1.25 |
| 15 | 1.37 | 14 | 1.36 | 12 | 1.28 | 11 | 1.31 | 13 | 1.31 | 11 | 1.25 |
| 16 | 1.38 | 15 | 1.36 | 13 | 1.28 | 14 | 1.31 | 14 | 1.3 | 12 | 1.25 |
| 17 | 1.36 | 16 | 1.34 | 16 | 1.28 | 15 | 1.3 | 18 | 1.29 | 15 | 1.26 |
| 21 | 1.35 | 19 | 1.33 | 17 | 1.28 | 16 | 1.29 | 19 | 1.28 | 16 | 1.28 |
| 22 | 1.35 | 20 | 1.33 | 18 | 1.3 | 17 | 1.28 | 20 | 1.29 | 17 | 1.27 |
| 23 | 1.34 | 21 | 1.33 | 19 | 1.3 | 18 | 1.28 | 21 | 1.29 | 18 | 1.25 |
| 25 | 1.36 | 22 | 1.33 | 20 | 1.3 | 21 | 1.28 | 22 | 1.28 | 19 | 1.25 |
| 28 | 1.36 | 23 | 1.31 | 23 | 1.31 | 22 | 1.26 | 25 | 1.28 | 22 | 1.25 |
| 29 | 1.37 | 26 | 1.31 | 24 | 1.29 | 23 | 1.26 | 26 | 1.28 | 23 | 1.27 |
| 30 | 1.37 | 27 | 1.32 | 25 | 1.29 | 24 | 1.25 | 27 | 1.28 | 24 | 1.31 |
| | | 28 | 1.32 | 26 | 1.31 | 25 | 1.26 | 28 | 1.27 | 25 | 1.33 |
| | | 29 | 1.34 | 27 | 1.31 | 28 | 1.27 | | | 26 | 1.31 |
| | | 30 | 1.34 | 30 | 1.29 | 30 | 1.27 | | | 29 | 1.32 |
| | | | | | | 31 | 1.3 | | | 30 | 1.31 |
| *Source: Compiled by Researcher from data available at www.nseindia.com* | | | | | | | | | | | |

| Table 6: Equity Index Nifty 50 Div. Yield- 2014-15 (Part B) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: Oct-14 | Div. Yield | Date: Nov-14 | Div. Yield | Date: Dec-14 | Div. Yield | Date: Jan-15 | Div. Yield | Date: Feb-15 | Div. Yield | Date: Mar-15 | Div. Yield |
| 1 | 1.32 | 3 | 1.27 | 1 | 1.24 | 1 | 1.27 | 2 | 1.2 | 2 | 1.23 |
| 7 | 1.34 | 5 | 1.27 | 2 | 1.24 | 2 | 1.26 | 3 | 1.21 | 3 | 1.22 |
| 8 | 1.34 | 7 | 1.27 | 3 | 1.24 | 5 | 1.26 | 4 | 1.21 | 4 | 1.23 |
| 9 | 1.33 | 10 | 1.27 | 4 | 1.23 | 6 | 1.3 | 5 | 1.21 | 5 | 1.23 |
| 10 | 1.35 | 11 | 1.27 | 5 | 1.24 | 7 | 1.3 | 6 | 1.22 | 9 | 1.25 |
| 13 | 1.34 | 12 | 1.26 | 8 | 1.25 | 8 | 1.28 | 9 | 1.24 | 10 | 1.26 |
| 14 | 1.34 | 13 | 1.27 | 9 | 1.27 | 9 | 1.27 | 10 | 1.23 | 11 | 1.26 |
| 16 | 1.36 | 14 | 1.26 | 10 | 1.27 | 12 | 1.27 | 11 | 1.22 | 12 | 1.25 |
| 17 | 1.36 | 17 | 1.25 | 11 | 1.27 | 13 | 1.27 | 12 | 1.21 | 13 | 1.27 |
| 20 | 1.34 | 18 | 1.26 | 12 | 1.29 | 14 | 1.27 | 13 | 1.2 | 16 | 1.27 |
| 21 | 1.33 | 19 | 1.26 | 15 | 1.29 | 15 | 1.24 | 16 | 1.25 | 17 | 1.26 |
| 22 | 1.32 | 20 | 1.26 | 16 | 1.31 | 16 | 1.24 | 18 | 1.24 | 18 | 1.26 |
| 23 | 1.32 | 21 | 1.25 | 17 | 1.32 | 19 | 1.23 | 19 | 1.24 | 19 | 1.27 |
| 27 | 1.32 | 24 | 1.24 | 18 | 1.3 | 20 | 1.21 | 20 | 1.25 | 20 | 1.28 |
| 28 | 1.32 | 25 | 1.25 | 19 | 1.29 | 21 | 1.21 | 23 | 1.26 | 23 | 1.28 |
| 29 | 1.31 | 26 | 1.25 | 22 | 1.27 | 22 | 1.2 | 24 | 1.26 | 24 | 1.29 |
| 30 | 1.29 | 27 | 1.25 | 23 | 1.28 | 23 | 1.19 | 25 | 1.26 | 25 | 1.29 |
| 31 | 1.27 | 28 | 1.23 | 24 | 1.29 | 27 | 1.18 | 26 | 1.27 | 26 | 1.32 |
| | | | | 26 | 1.29 | 28 | 1.18 | 27 | 1.24 | 27 | 1.3 |
| | | | | 29 | 1.28 | 29 | 1.18 | 28 | 1.24 | 30 | 1.28 |
| | | | | 30 | 1.28 | 30 | 1.2 | | | 31 | 1.28 |
| | | | | 31 | 1.27 | | | | | | |
| *Source: Compiled by Researcher from data available at www.nseindia.com* | | | | | | | | | | | |

| Table 7: Equity Index Nifty 50 Div. Yield- 2015-16 (Part A) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: April-15 | Div. Yield | Date: May-15 | Div. Yield | Date: Jun-15 | Div. Yield | Date: July-15 | Div. Yield | Date: Aug-15 | Div. Yield | Date: Sep-15 | Div. Yield |
| 1 | 1.27 | 4 | 1.43 | 1 | 1.39 | 1 | 1.42 | 3 | 1.41 | 1 | 1.52 |
| 6 | 1.26 | 5 | 1.43 | 2 | 1.43 | 2 | 1.42 | 4 | 1.42 | 2 | 1.53 |
| 7 | 1.25 | 6 | 1.47 | 3 | 1.45 | 3 | 1.43 | 5 | 1.41 | 3 | 1.51 |
| 8 | 1.25 | 7 | 1.47 | 4 | 1.45 | 6 | 1.42 | 6 | 1.4 | 4 | 1.54 |
| 9 | 1.24 | 8 | 1.45 | 5 | 1.45 | 7 | 1.42 | 7 | 1.4 | 7 | 1.56 |
| 10 | 1.24 | 11 | 1.42 | 8 | 1.47 | 8 | 1.45 | 10 | 1.41 | 8 | 1.54 |
| 13 | 1.23 | 12 | 1.45 | 9 | 1.47 | 9 | 1.45 | 11 | 1.42 | 9 | 1.51 |
| 15 | 1.25 | 13 | 1.43 | 10 | 1.45 | 10 | 1.45 | 12 | 1.44 | 10 | 1.52 |
| 16 | 1.25 | 14 | 1.44 | 11 | 1.48 | 13 | 1.44 | 13 | 1.44 | 11 | 1.52 |
| 17 | 1.27 | 15 | 1.43 | 12 | 1.49 | 14 | 1.44 | 14 | 1.42 | 14 | 1.5 |
| 20 | 1.29 | 18 | 1.41 | 15 | 1.48 | 15 | 1.43 | 17 | 1.43 | 15 | 1.51 |
| 21 | 1.3 | 19 | 1.41 | 16 | 1.48 | 16 | 1.41 | 18 | 1.43 | 16 | 1.5 |
| 22 | 1.29 | 20 | 1.4 | 17 | 1.47 | 17 | 1.42 | 19 | 1.42 | 18 | 1.48 |
| 23 | 1.3 | 21 | 1.4 | 18 | 1.45 | 20 | 1.42 | 20 | 1.44 | 21 | 1.48 |
| 24 | 1.4 | 22 | 1.4 | 19 | 1.44 | 21 | 1.43 | 21 | 1.42 | 22 | 1.51 |
| 27 | 1.4 | 25 | 1.41 | 22 | 1.42 | 22 | 1.41 | 24 | 1.51 | 23 | 1.51 |
| 28 | 1.39 | 26 | 1.42 | 23 | 1.41 | 23 | 1.42 | 25 | 1.5 | 24 | 1.5 |
| 29 | 1.4 | 27 | 1.42 | 24 | 1.42 | 24 | 1.43 | 26 | 1.51 | 29 | 1.48 |
| 30 | 1.45 | 28 | 1.42 | 25 | 1.41 | 27 | 1.46 | 27 | 1.48 | 30 | 1.46 |
| | | 29 | 1.39 | 26 | 1.42 | 28 | 1.46 | 28 | 1.48 | | |
| | | | | 29 | 1.43 | 29 | 1.45 | 31 | 1.48 | | |
| | | | | 30 | 1.44 | 30 | 1.45 | | | | |
| | | | | | | 31 | 1.41 | | | | |
| *Source: Compiled by Researcher from data available at www.nseindia.com* | | | | | | | | | | | |

| Table 8: Equity Index Nifty 50 Div. Yield- 2015-16 (Part B) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: Oct-15 | Div. Yield | Date: Nov-15 | Div. Yield | Date: Dec-15 | Div. Yield | Date: Jan-16 | Div. Yield | Date: Feb-16 | Div. Yield | Date: Mar-16 | Div. Yield |
| 1 | 1.43 | 2 | 1.42 | 1 | 1.43 | 1 | 1.45 | 1 | 1.53 | 1 | 1.6 |
| 5 | 1.4 | 3 | 1.41 | 2 | 1.44 | 4 | 1.48 | 2 | 1.55 | 2 | 1.57 |
| 6 | 1.39 | 4 | 1.42 | 3 | 1.45 | 5 | 1.49 | 3 | 1.57 | 3 | 1.55 |
| 7 | 1.39 | 5 | 1.43 | 4 | 1.46 | 6 | 1.49 | 4 | 1.56 | 4 | 1.55 |
| 8 | 1.4 | 6 | 1.43 | 7 | 1.47 | 7 | 1.53 | 5 | 1.54 | 8 | 1.55 |
| 9 | 1.39 | 9 | 1.44 | 8 | 1.48 | 8 | 1.52 | 8 | 1.57 | 9 | 1.54 |
| 12 | 1.39 | 10 | 1.46 | 9 | 1.5 | 11 | 1.53 | 9 | 1.58 | 10 | 1.55 |
| 13 | 1.4 | 11 | 1.45 | 10 | 1.48 | 12 | 1.54 | 10 | 1.6 | 11 | 1.54 |
| 14 | 1.4 | 13 | 1.47 | 11 | 1.52 | 13 | 1.53 | 11 | 1.66 | 14 | 1.54 |
| 15 | 1.39 | 16 | 1.46 | 14 | 1.51 | 14 | 1.53 | 12 | 1.66 | 15 | 1.55 |
| 16 | 1.38 | 17 | 1.45 | 15 | 1.5 | 15 | 1.55 | 15 | 1.61 | 16 | 1.55 |
| 17 | 1.38 | 18 | 1.47 | 16 | 1.49 | 18 | 1.57 | 16 | 1.64 | 17 | 1.54 |
| 20 | 1.38 | 19 | 1.45 | 17 | 1.47 | 19 | 1.56 | 17 | 1.63 | 18 | 1.52 |
| 21 | 1.38 | 20 | 1.45 | 18 | 1.49 | 20 | 1.58 | 18 | 1.61 | 21 | 1.5 |
| 23 | 1.38 | 23 | 1.45 | 21 | 1.48 | 21 | 1.59 | 19 | 1.6 | 22 | 1.5 |
| 26 | 1.38 | 24 | 1.45 | 22 | 1.49 | 22 | 1.56 | 22 | 1.6 | 23 | 1.5 |
| 27 | 1.39 | 26 | 1.44 | 23 | 1.47 | 25 | 1.56 | 23 | 1.63 | 28 | 1.52 |
| 28 | 1.4 | 27 | 1.43 | 24 | 1.47 | 27 | 1.55 | 24 | 1.65 | 29 | 1.52 |
| 29 | 1.41 | 30 | 1.43 | 28 | 1.46 | 28 | 1.56 | 25 | 1.66 | 30 | 1.49 |
| 30 | 1.41 | | | 29 | 1.46 | 29 | 1.53 | 26 | 1.65 | 31 | 1.49 |
| | | | | 30 | 1.46 | | | 29 | 1.66 | | |
| | | | | 31 | 1.46 | | | | | | |
| *Source: Compiled by Researcher from data available at www.nseindia.com* | | | | | | | | | | | |

**Appendix-6** Annual Standard Deviation

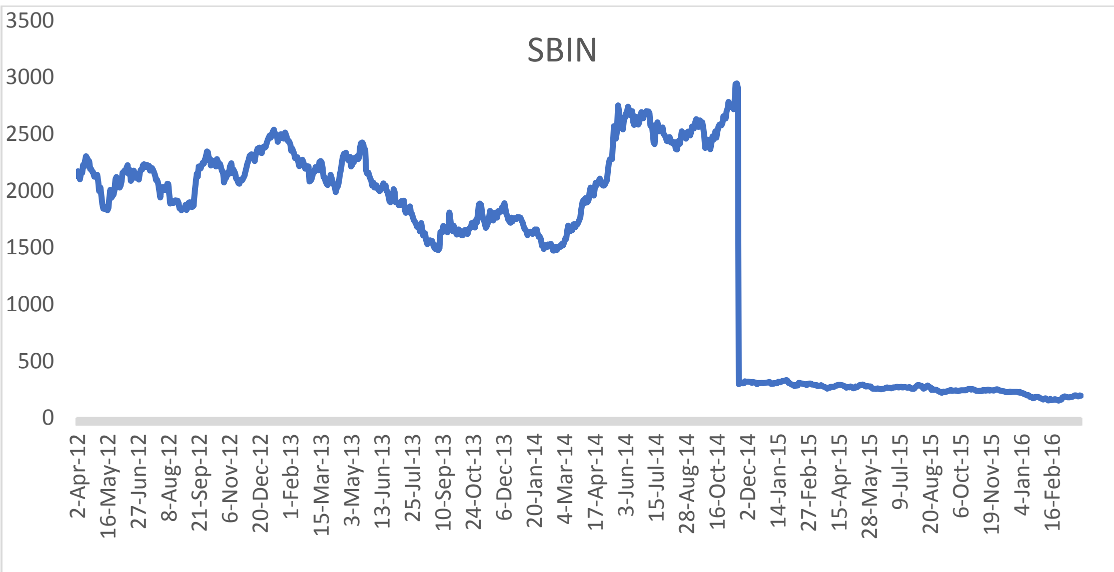
| Table 1: Stocks and Equity Index Nifty 50 Annual Standard Deviation | | | | |
|---|---|---|---|---|
| Stock | 2012-13 | 2013-14 | 2014-15 | 2015-16 |
| AXISBANK | 0.29 | 0.43 | 0.16 | 0.34 |
| BHARTIARTL | 0.31 | 0.35 | 0.28 | 0.27 |
| BHEL | 0.33 | 0.49 | 0.43 | 0.4 |
| CAIRN | 0.26 | 0.23 | 0.3 | 0.44 |
| DLF | 0.38 | 0.51 | 0.6 | 0.56 |
| HDFC | 0.21 | 0.32 | 0.28 | 0.28 |
| HDFCBANK | 0.19 | 0.3 | 0.19 | 0.17 |
| HINDALCO | 0.32 | 0.41 | 0.41 | 0.44 |
| HINDUNILVR | 0.22 | 0.29 | 0.25 | 0.23 |
| ICICIBANK | 0.26 | 0.36 | 0.20 | 0.34 |
| IDFC | 0.33 | 0.45 | 0.34 | 0.91 |
| INFY | 0.3 | 0.34 | 0.21 | 0.11 |
| ITC | 0.22 | 0.26 | 0.25 | 0.26 |
| JPASSOCIAT | 0.43 | 0.63 | 0.63 | 0.65 |
| LT | 0.28 | 0.52 | 0.29 | 0.28 |
| M&M | 0.21 | 0.29 | 0.28 | 0.28 |
| RELIANCE | 0.21 | 0.27 | 0.24 | 0.28 |
| RELINFRA | 0.4 | 0.44 | 0.44 | 0.47 |
| SBIN | 0.29 | 0.32 | 0.25 | 0.36 |
| TATAMOTORS | 0.37 | 0.34 | 0.3 | 0.4 |
| TATASTEEL | 0.27 | 0.41 | 0.32 | 0.44 |
| TCS | 0.24 | 0.28 | 0.24 | 0.2 |
| Nifty 50 | 0.13 | 0.18 | 0.13 | 0.17 |
| *Source: Compiled by Researcher* | | | | |

**Appendix-7** Lin Chart Drawn from Stock Price

Chart 3.1 A

SHARE PRICES OF SBIN (without Adjustment)

FROM 2.4.2012 TO 31.3.2016

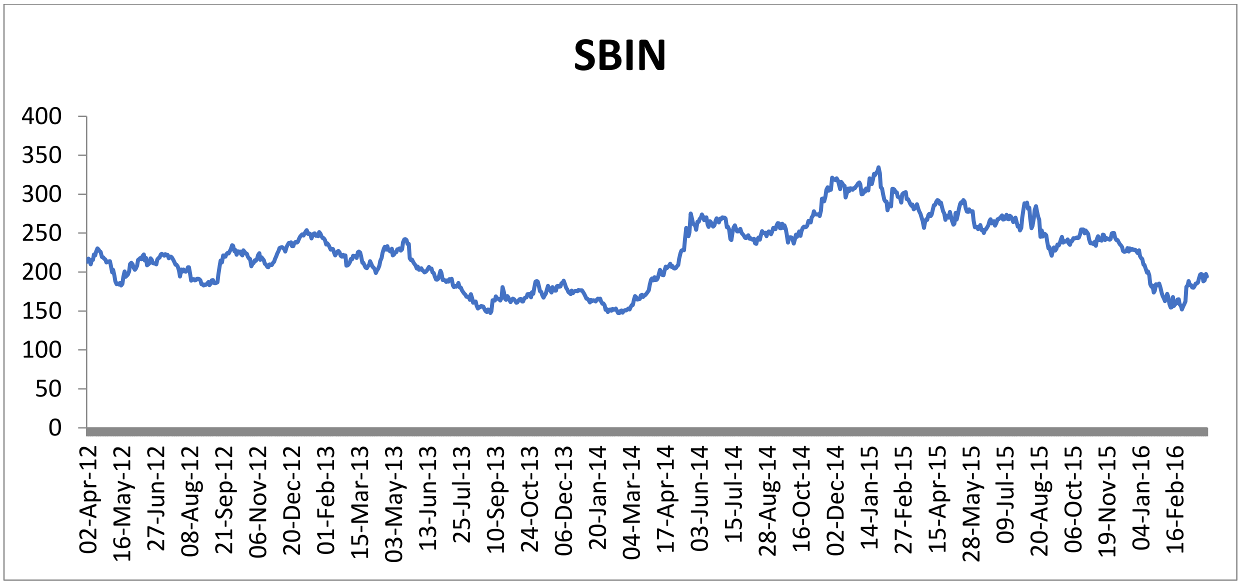



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.1 B

SHARE PRICES OF SBIN (with Adjustment)

FROM 2.4.2012 TO 31.3.2016

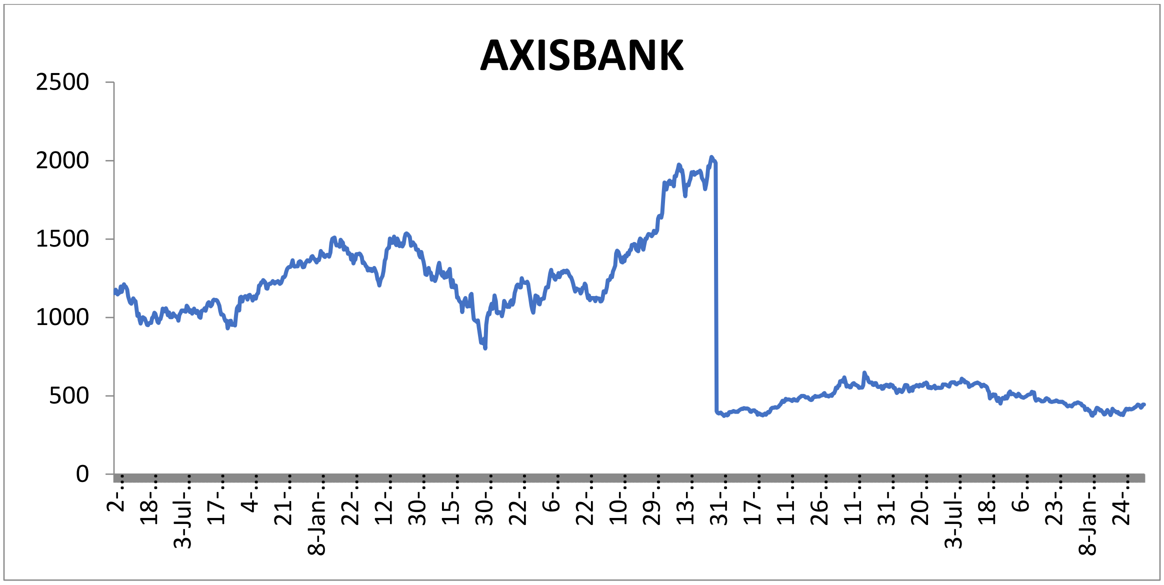



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.2 A

SHARE PRICES OF AXISBANK (without Adjustment)

FROM 2.4.2012 TO 31.3.2016

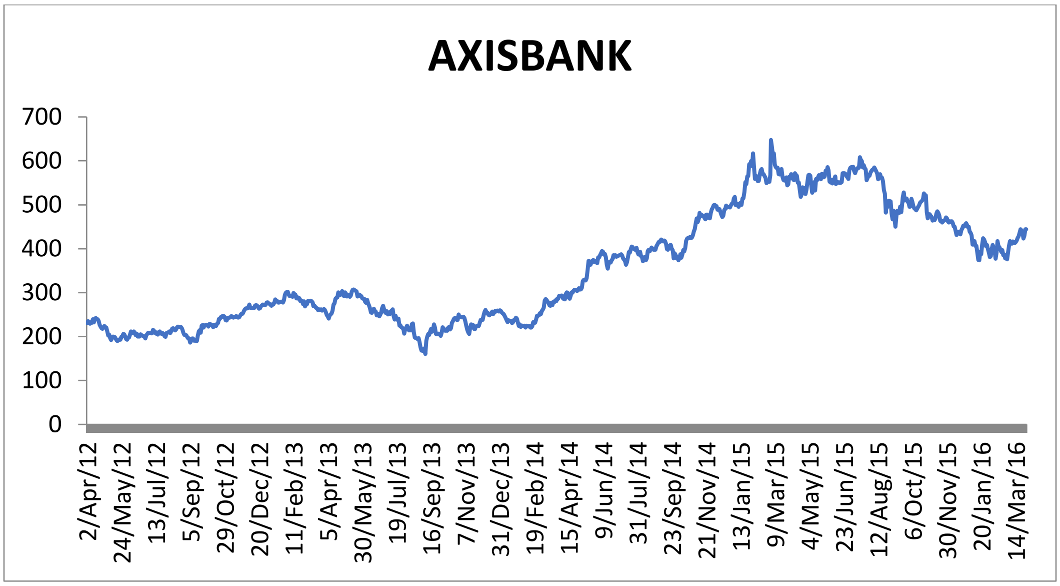



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.2 B

SHARE PRICES OF AXISBANK (with Adjustment)

FROM 2.4.2012 TO 31.3.2016

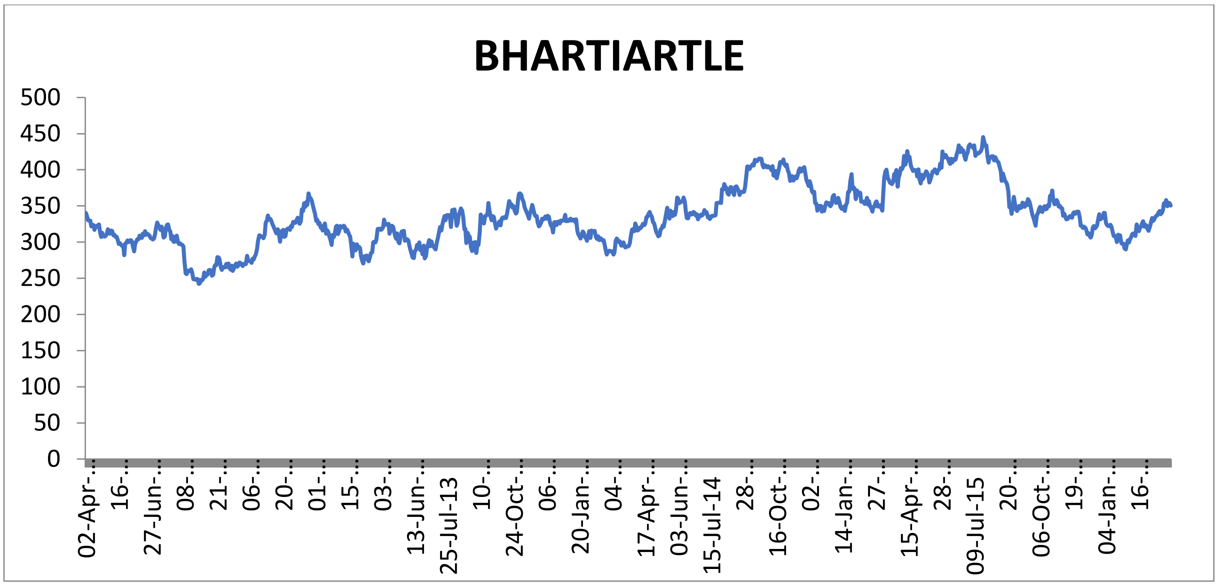



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.3

SHARE PRICES OF BHARTIARTLE

FROM 2.4.2012 TO 31.3.2016

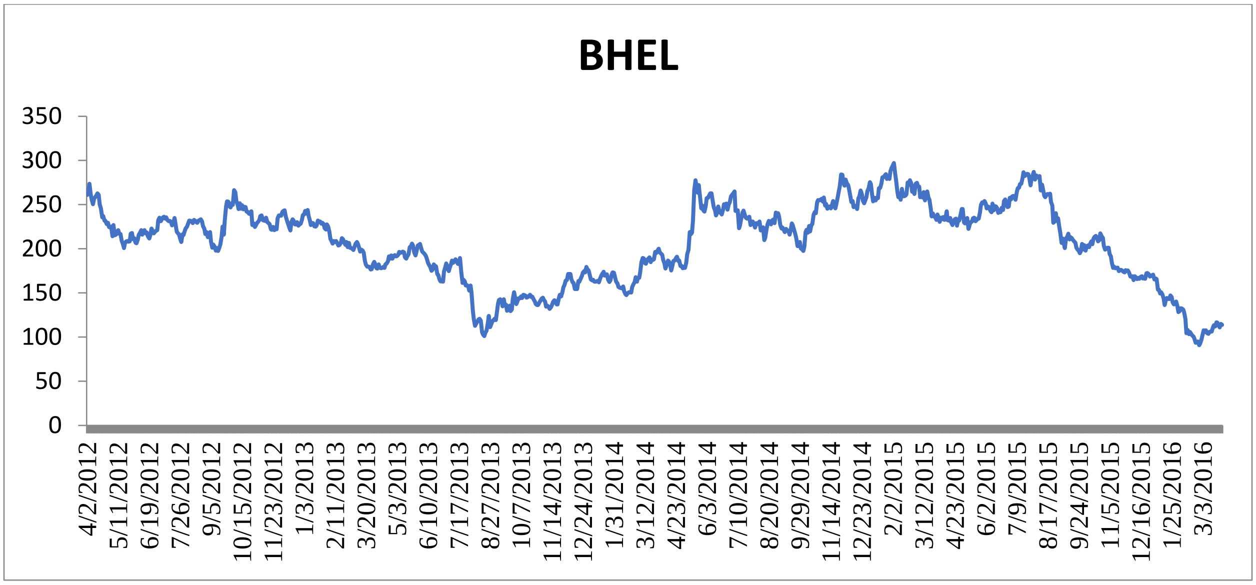



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.4

SHARE PRICES OF BHEL

FROM 2.4.2012 TO 31.3.2016

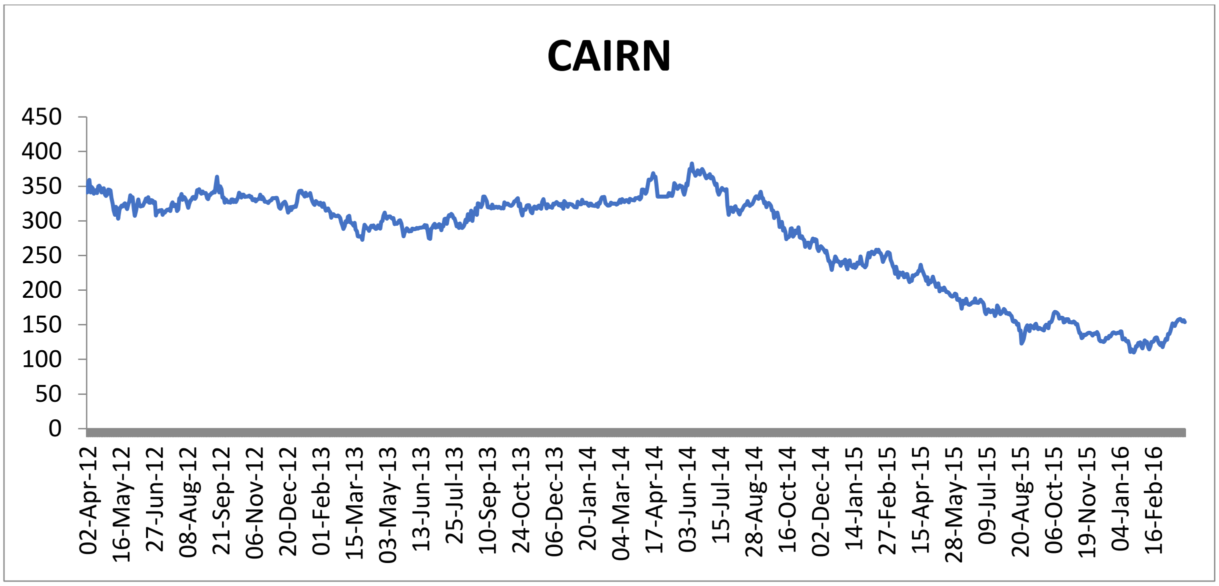



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.5

SHARE PRICES OF CAIRN

FROM 2.4.2012 TO 31.3.2016

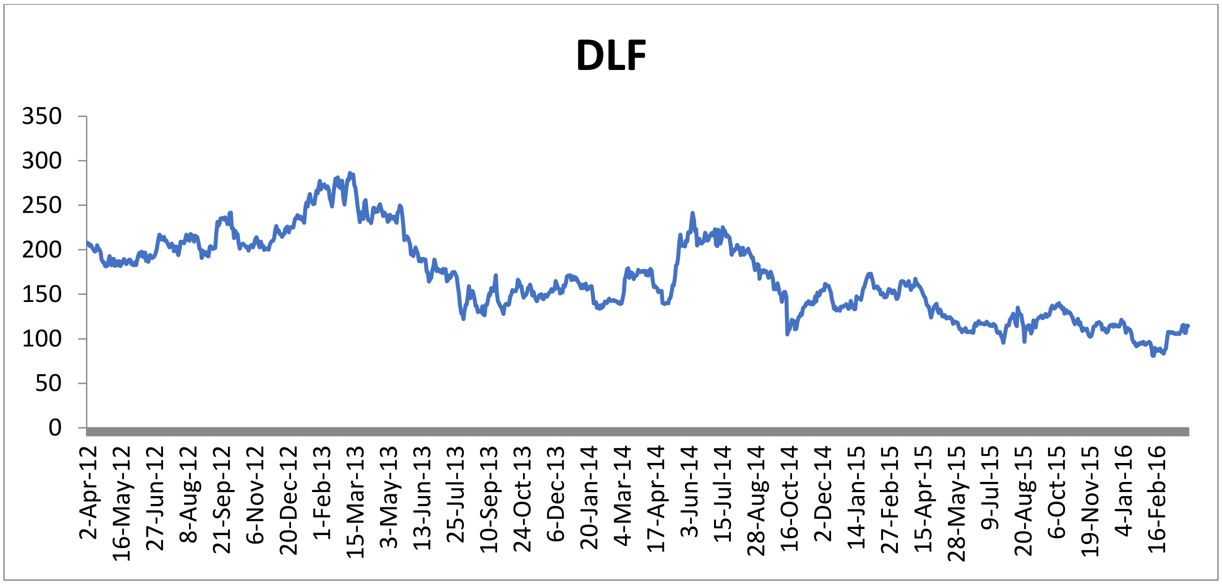



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.6

SHARE PRICES OF DLF

FROM 2.4.2012 TO 31.3.2016

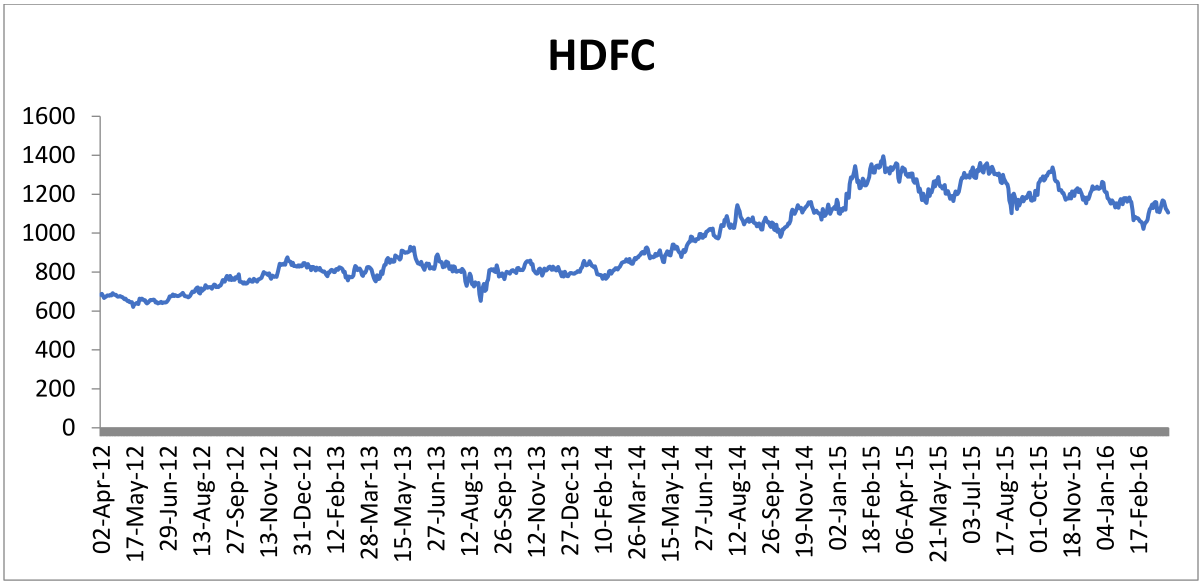



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.7

SHARE PRICES OF HDFC

FROM 2.4.2012 TO 31.3.2016

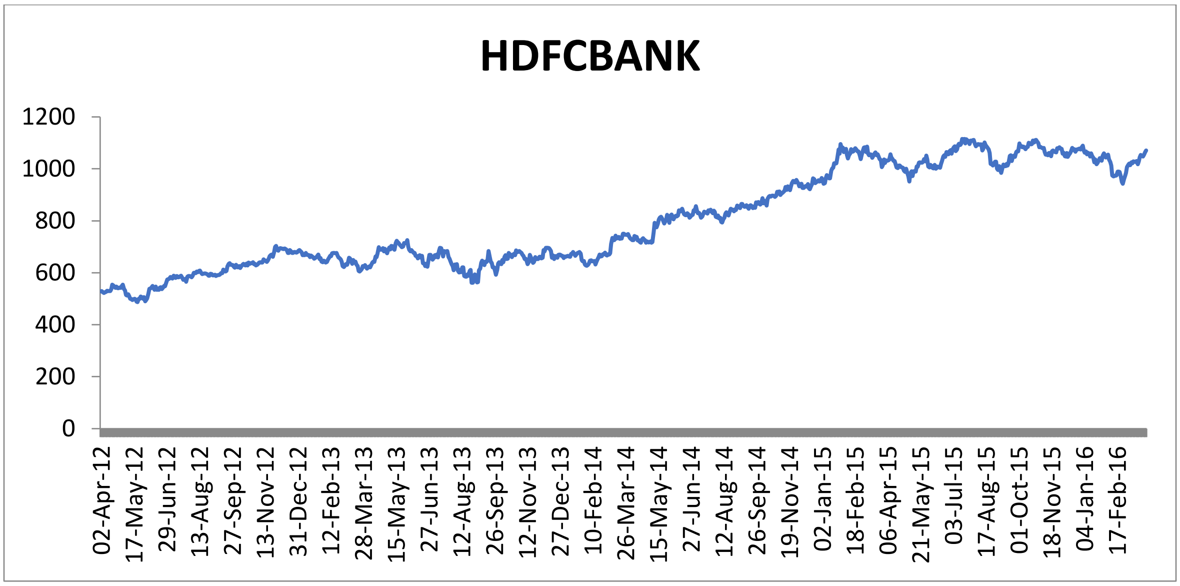



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.8

SHARE PRICES OF HDFC BANK

FROM 2.4.2012 TO 31.3.2016

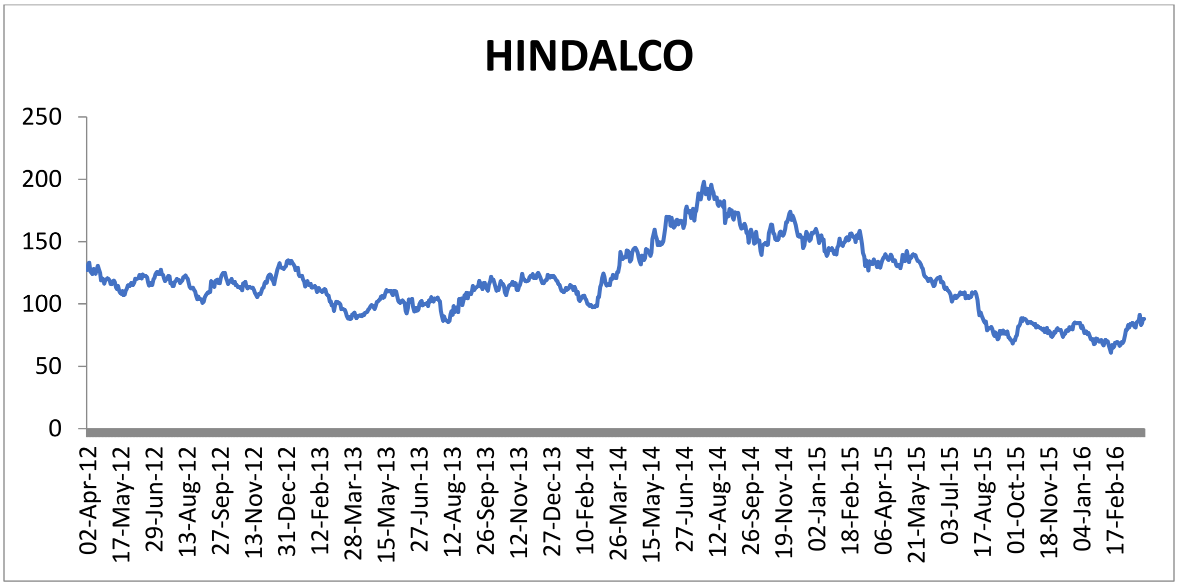



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.9

SHARE PRICES OF HINDALCO

FROM 2.4.2012 TO 31.3.2016

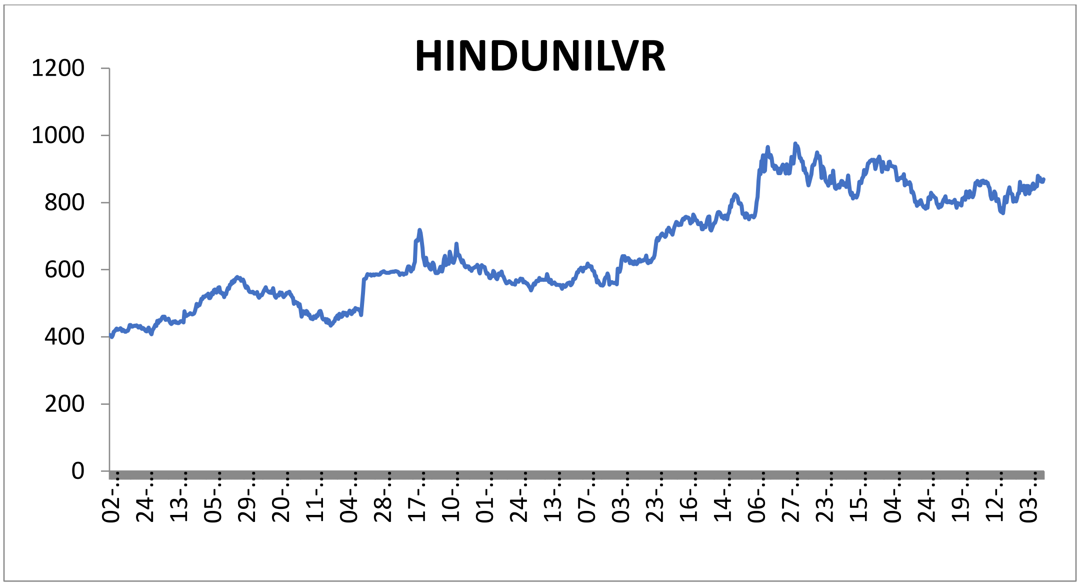



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.10

SHARE PRICES OF HINDUNILVR

FROM 2.4.2012 TO 31.3.2016

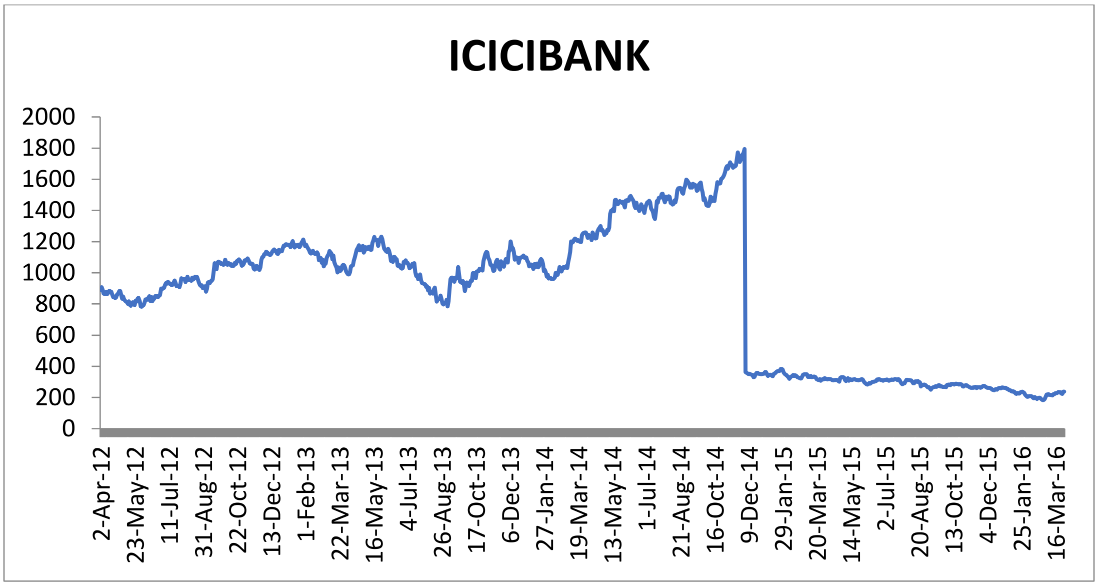



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.11 A

SHARE PRICES OF ICICIBANK (Without Adjustment)

FROM 2.4.2012 TO 31.3.2016

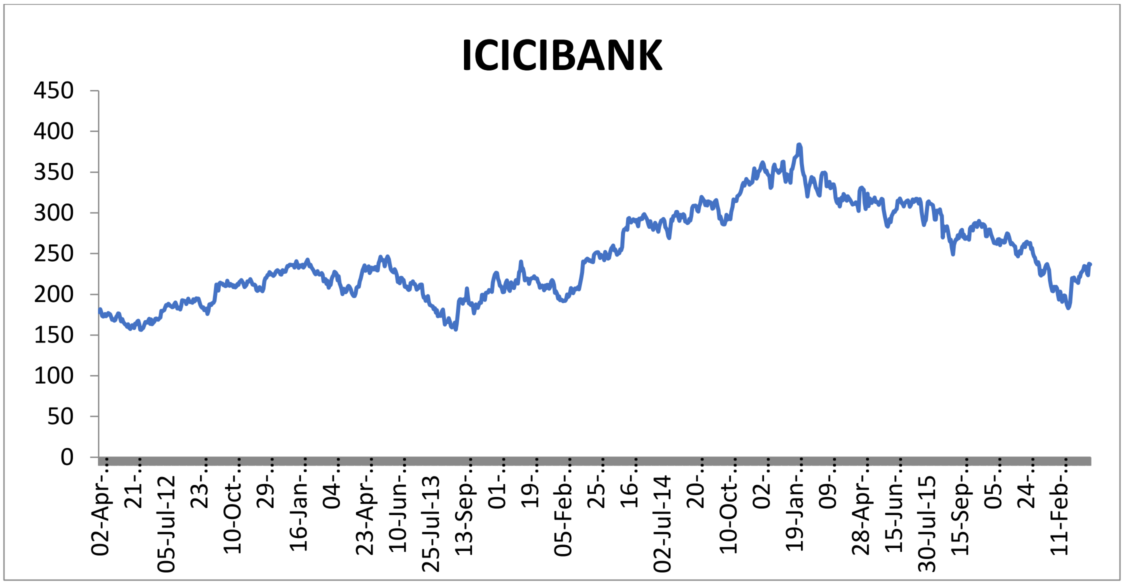



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.11 B

SHARE PRICES OF ICICIBANK (With Adjustment)

FROM 2.4.2012 TO 31.3.2016

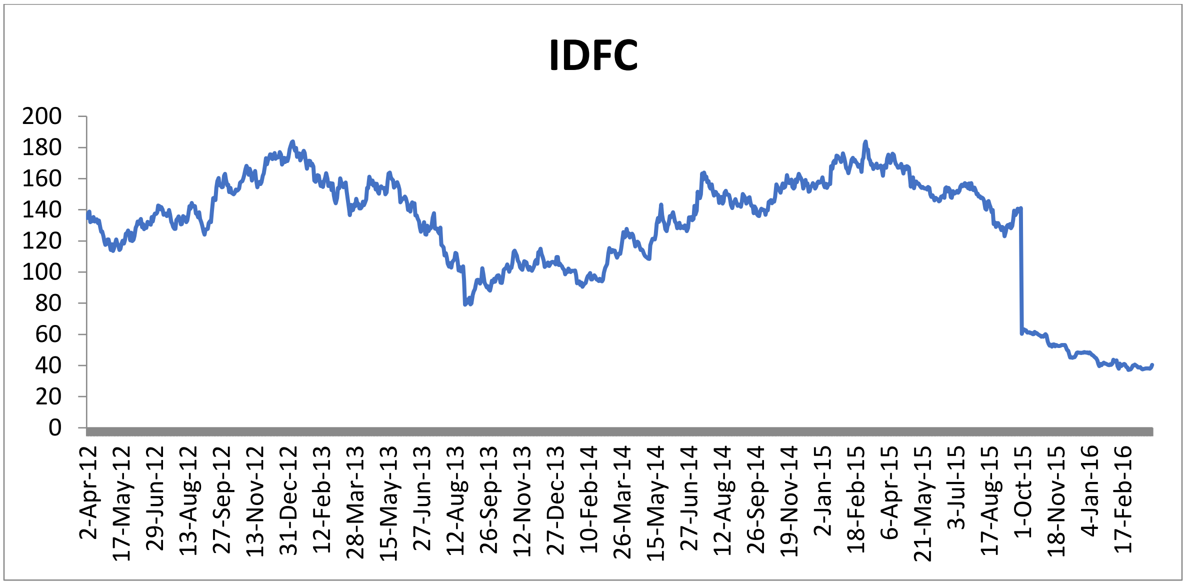



*Source: Compiled and Developed by Researcher from NSE*

Chart 3. 12 A

SHARE PRICES OF IDFC (Without Adjustment)

FROM 2.4.2012 TO 31.3.2016

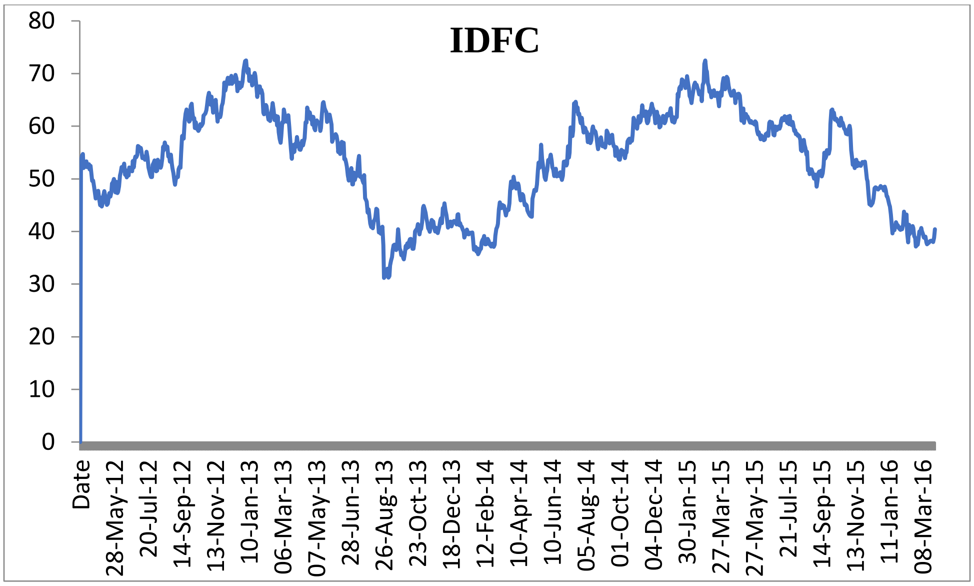



*Source: Compiled and Developed by Researcher from NSE*

Chart 3. 12 B

SHARE PRICES OF IDFC (With Adjustment)

FROM 2.4.2012 TO 31.3.2016




*Source: Compiled and Developed by Researcher from NSE*

Chart 3. 13 A

SHARE PRICES OF INFY (Without Adjustment)

FROM 2.4.2012 TO 31.3.2016

Chart 3. 13 B

SHARE PRICES OF INFY (With Adjustment)

FROM 2.4.2012 TO 31.3.2016

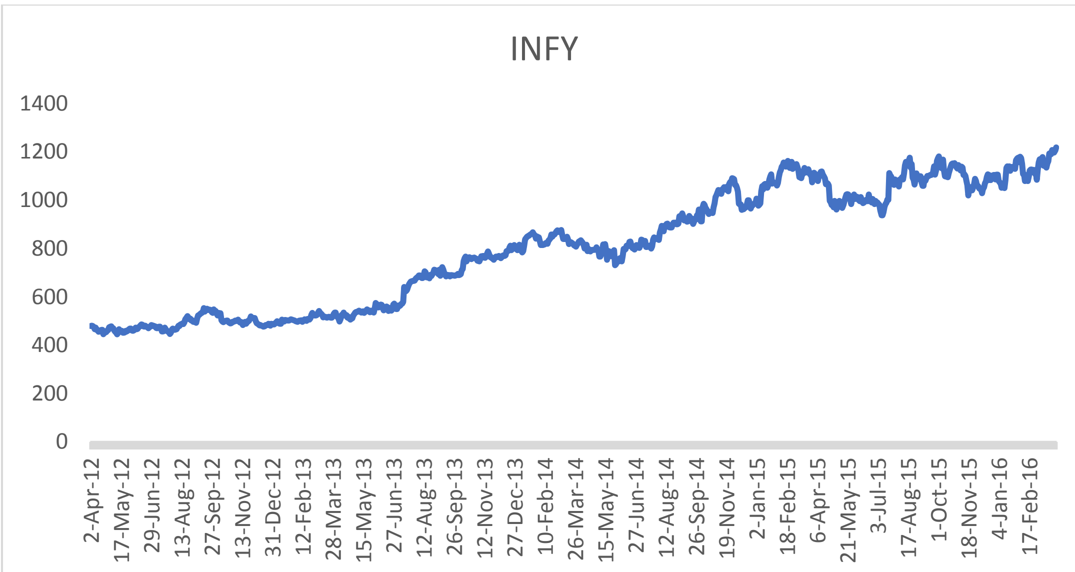
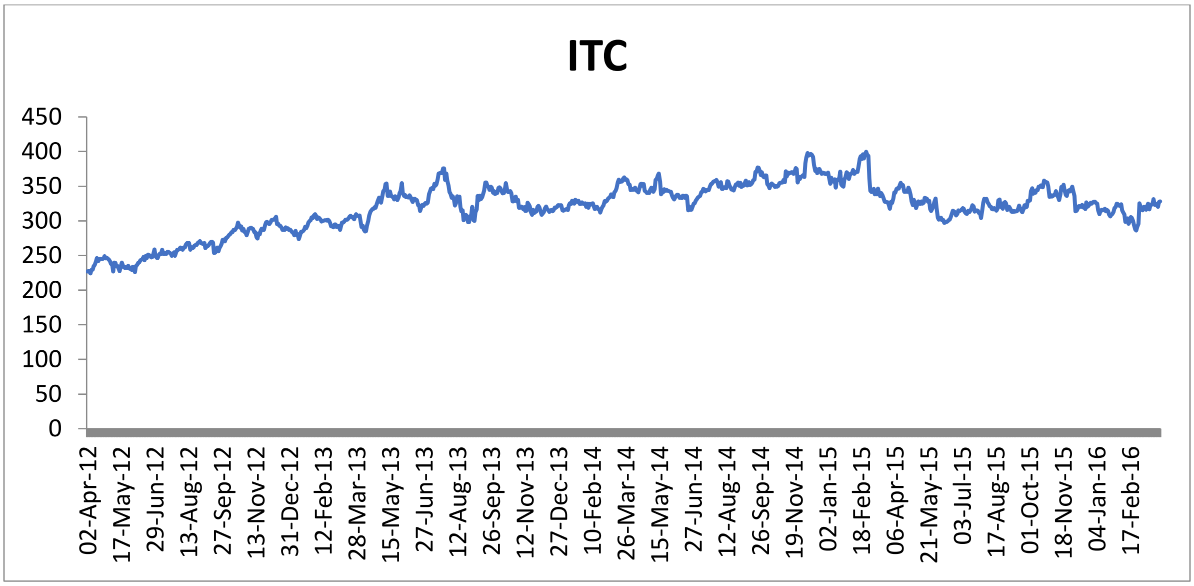


Chart 3. 14

SHARE PRICES OF ITC

FROM 2.4.2012 TO 31.3.2016

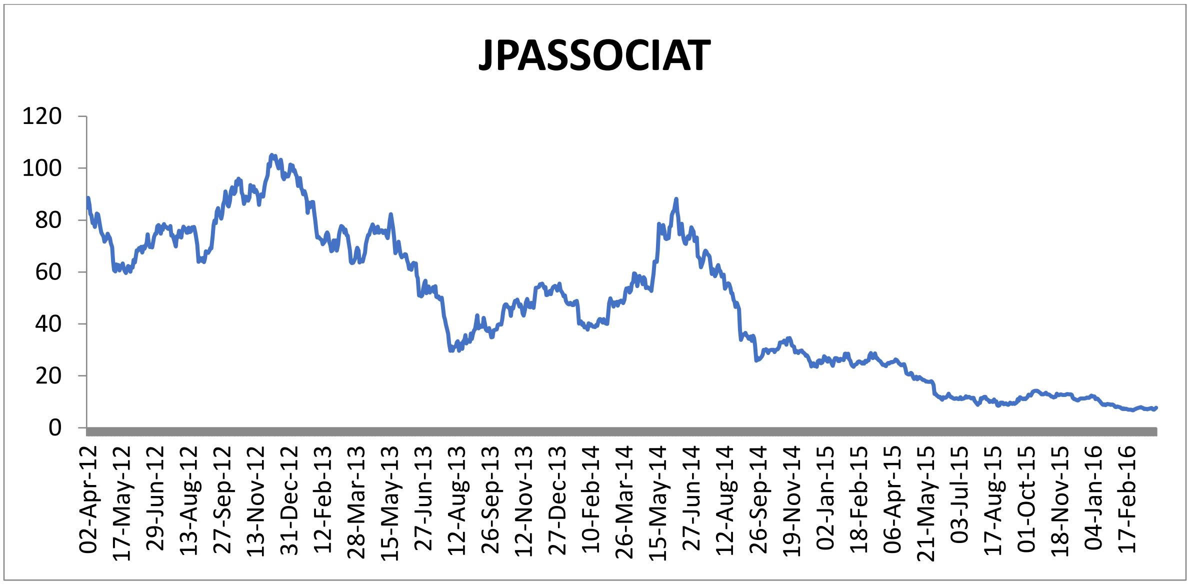



*Source: Compiled and Developed by Researcher from NSE*

Chart 3. 15

SHARE PRICES OF JPASSOCIAT

FROM 2.4.2012 TO 31.3.2016

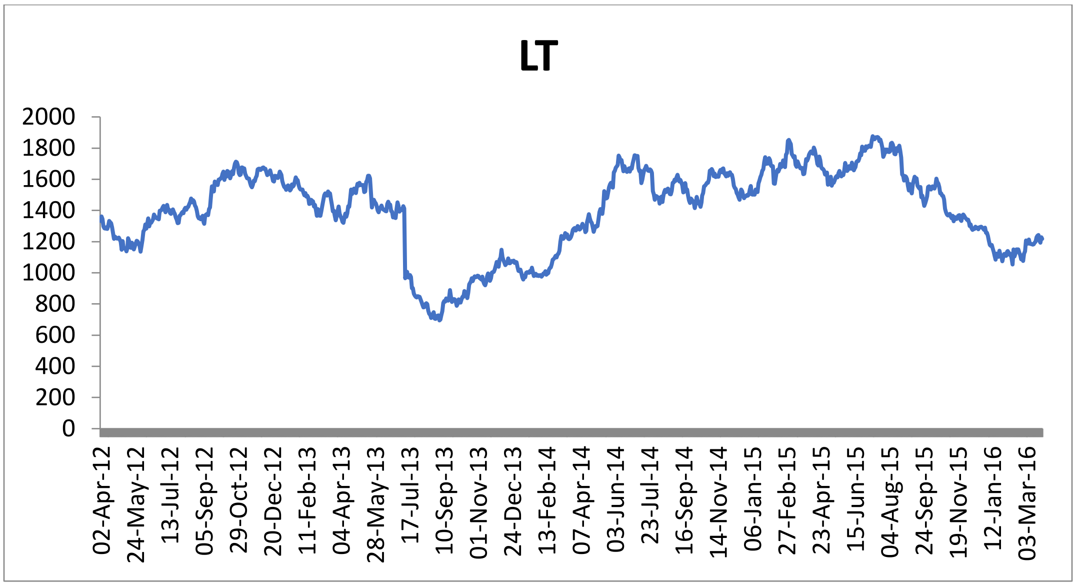



*Source: Compiled and Developed by Researcher from NSE*

Chart 3. 16 A

SHARE PRICES OF LT (Without Adjustment)

FROM 2.4.2012 TO 31.3.2016

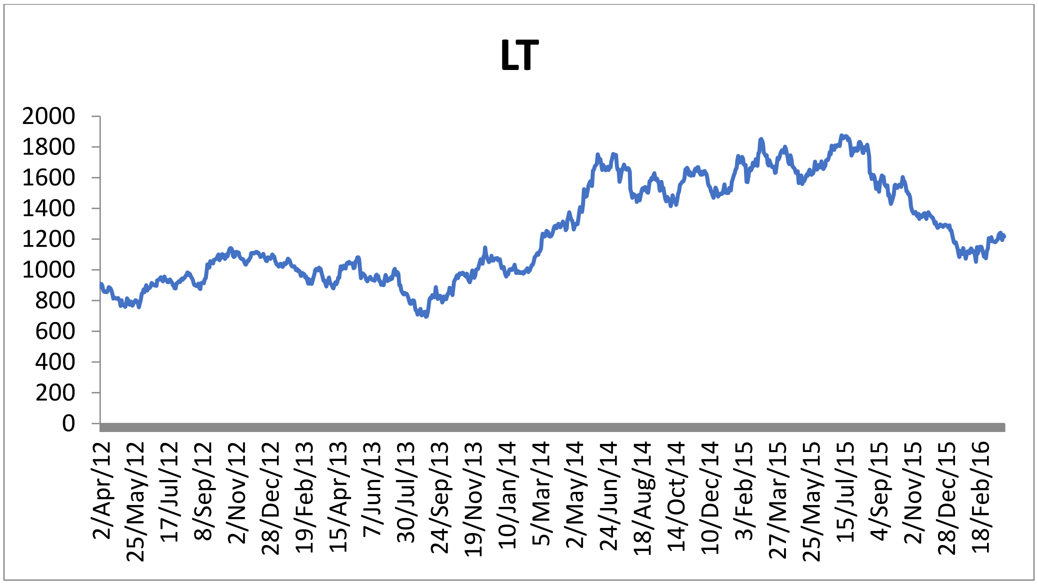



*Source: Compiled and Developed by Researcher from NSE*

Chart 3. 16 B

SHARE PRICES OF LT (With Adjustment)

FROM 2.4.2012 TO 31.3.2016

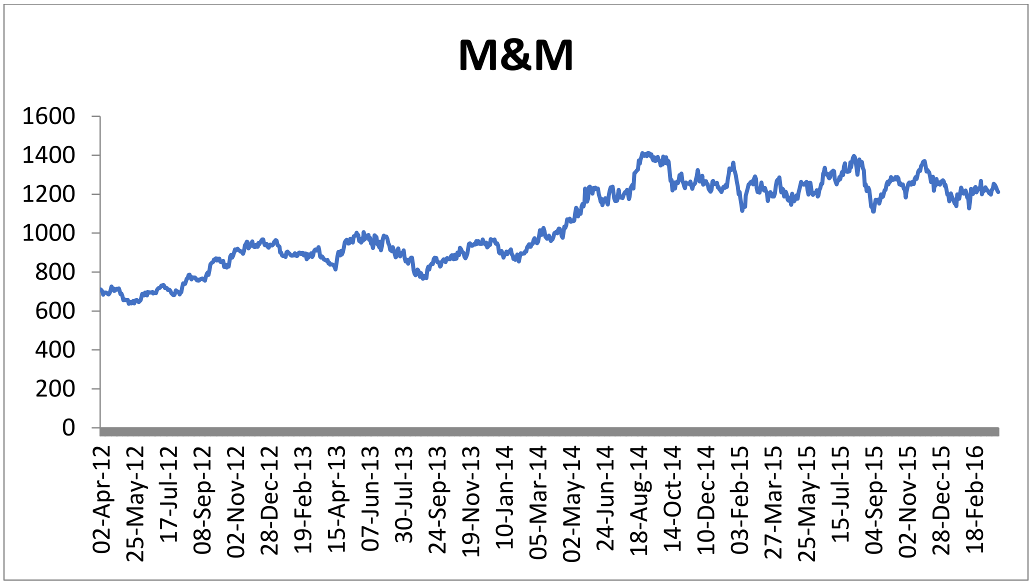



*Source: Compiled and Developed by Researcher from NSE*

Chart 3. 17

SHARE PRICES OF M&M

FROM 2.4.2012 TO 31.3.2016

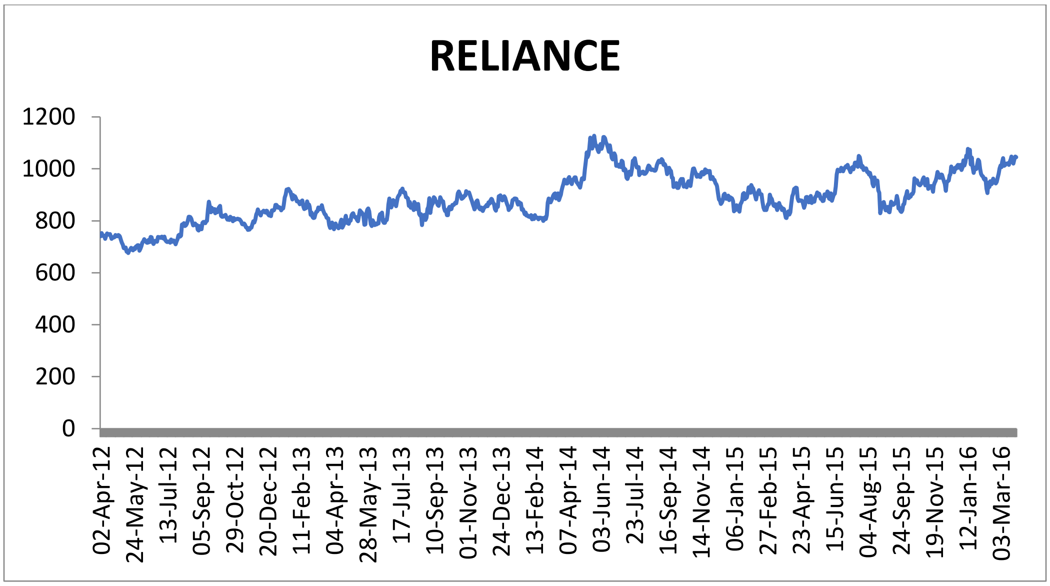



*Source: Compiled and Developed by Researcher from NSE*

Chart 3. 18

SHARE PRICES OF RELIANCE

FROM 2.4.2012 TO 31.3.2016

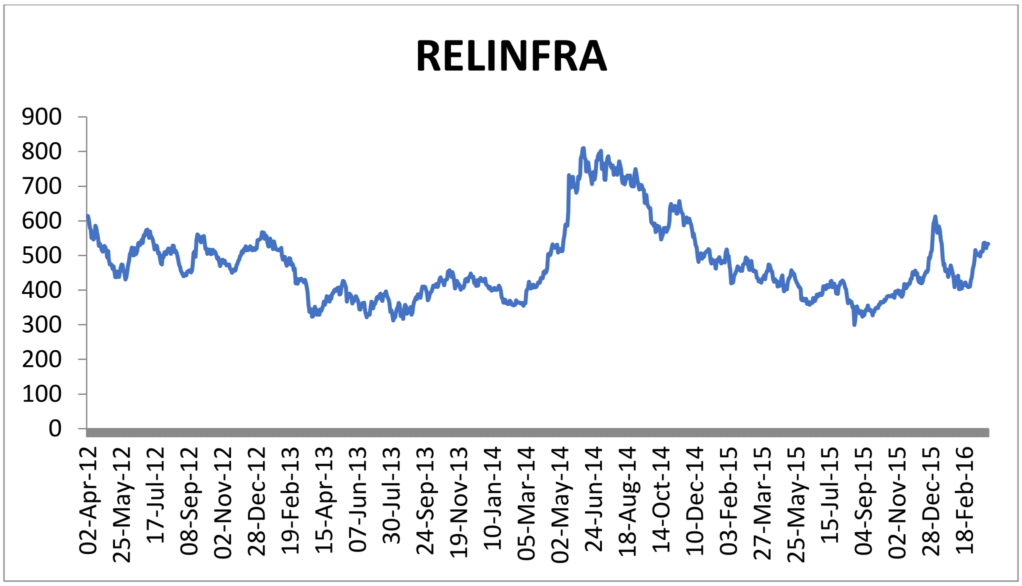



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.19

SHARE PRICES OF RELINFRA

FROM 2.4.2012 TO 31.3.2016

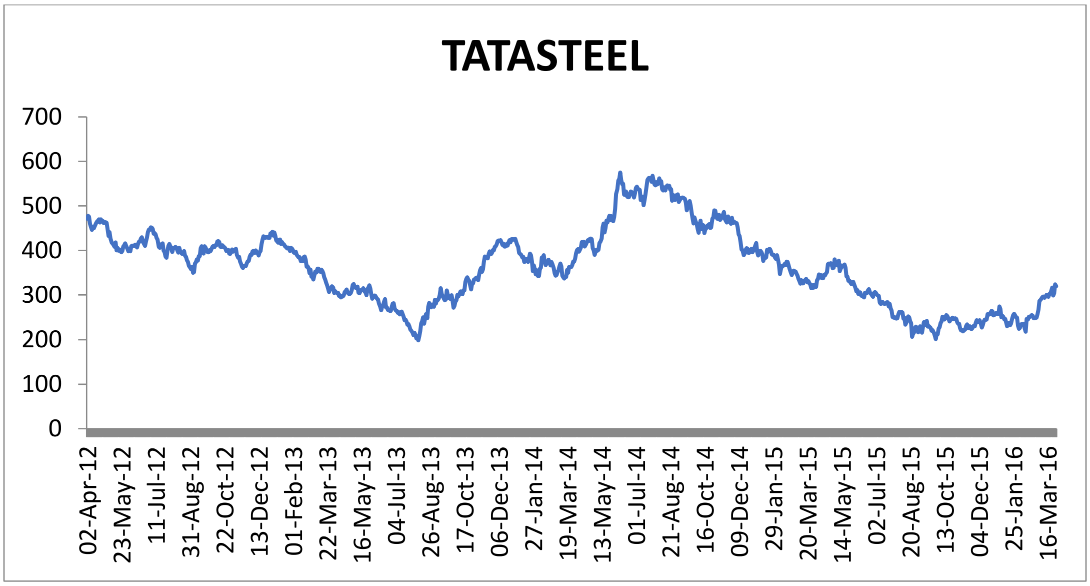



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.20

SHARE PRICES OF TATASTEEL

FROM 2.4.2012 TO 31.3.2016

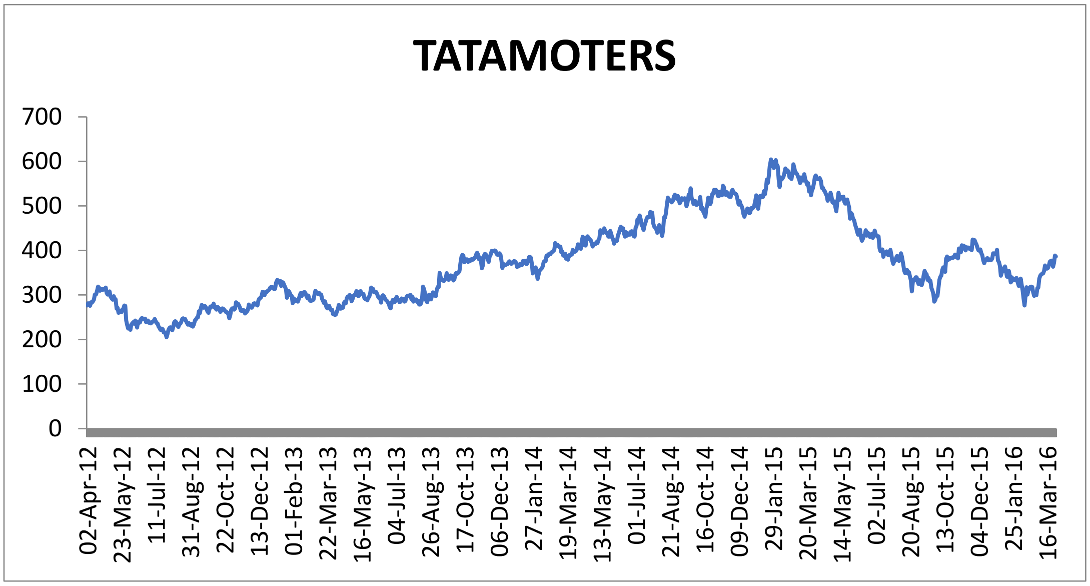



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.21

SHARE PRICES OF TATAMOTERS

FROM 2.4.2012 TO 31.3.2016

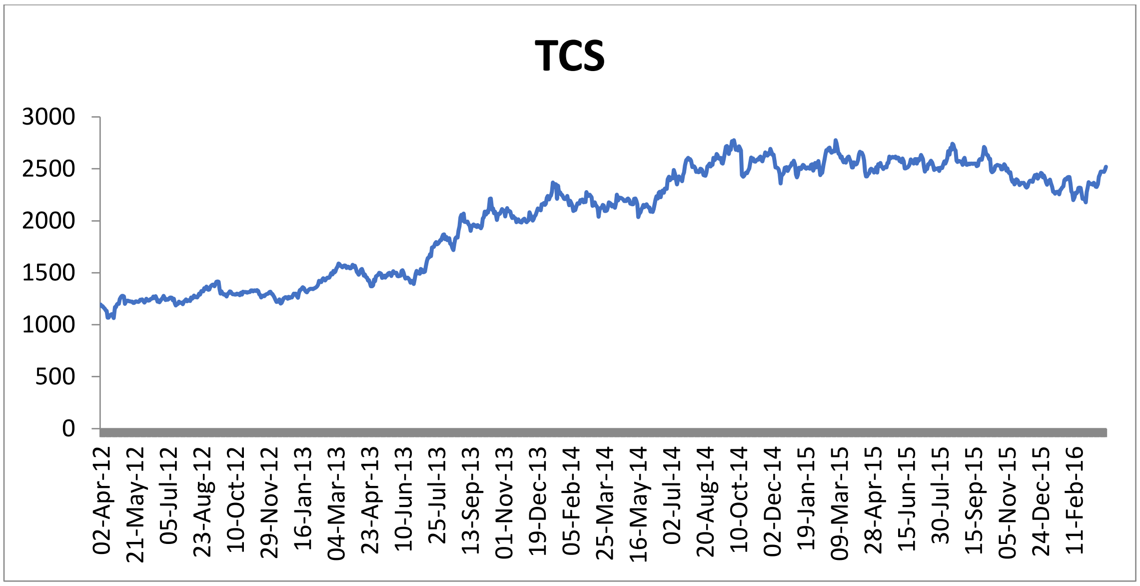



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.22

SHARE PRICES OF TCS

FROM 2.4.2012 TO 31.3.2016

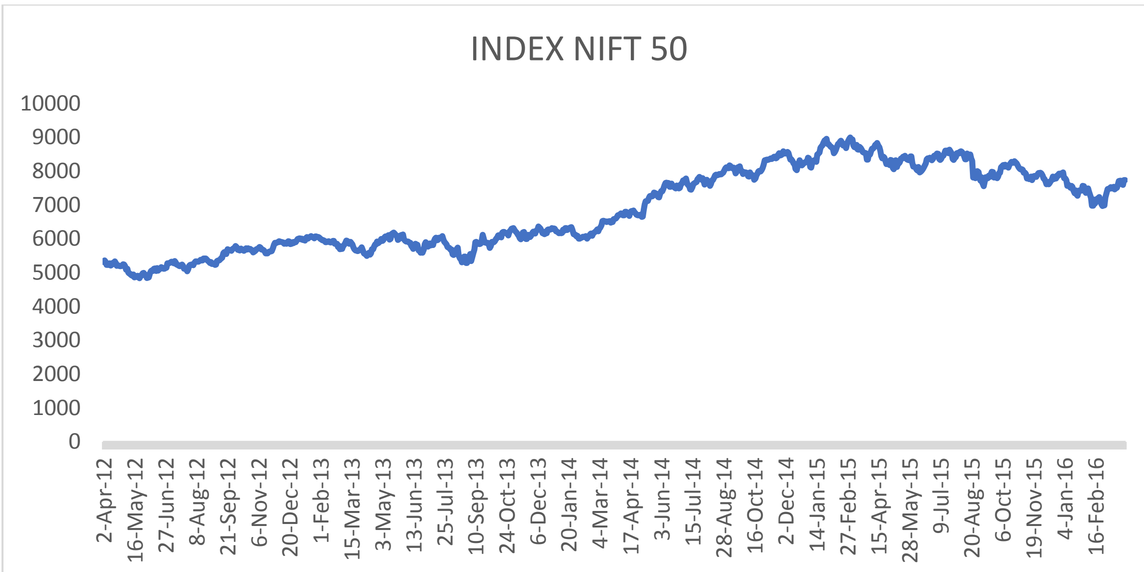



*Source: Compiled and Developed by Researcher from NSE*

Chart 3.23

SHARE PRICES OF INDEX NIFTY 50

FROM 2.4.2012 TO 31.3.2016




*Source: Compiled and Developed by Researcher from NSE*

**Appendix-8** Histogram Drawn from Stock Returns

Chart 4.1

Distribution of Log Returns

BHEL

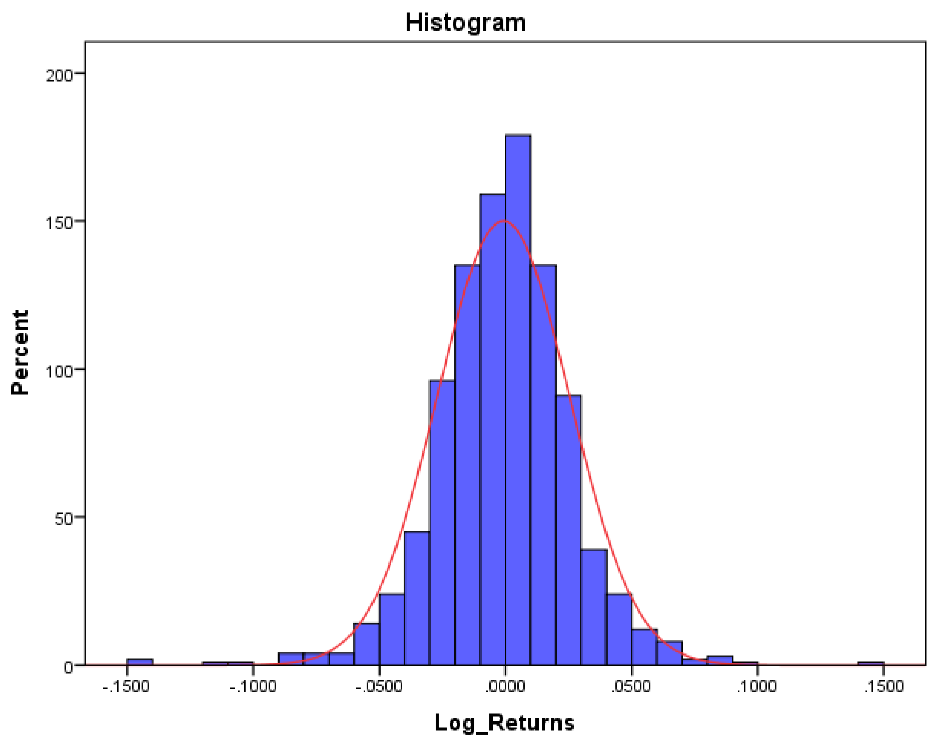


Chart 4.2

Distribution of Log Returns

DLF

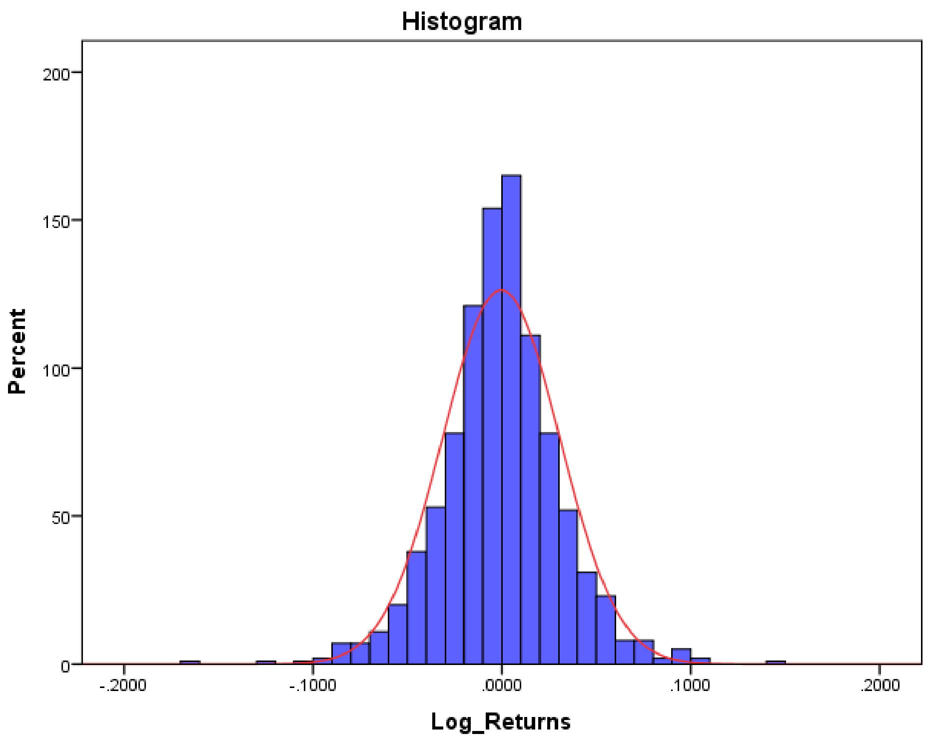


**Chart 4.3**

Distribution of Log Returns

AXIS BANK

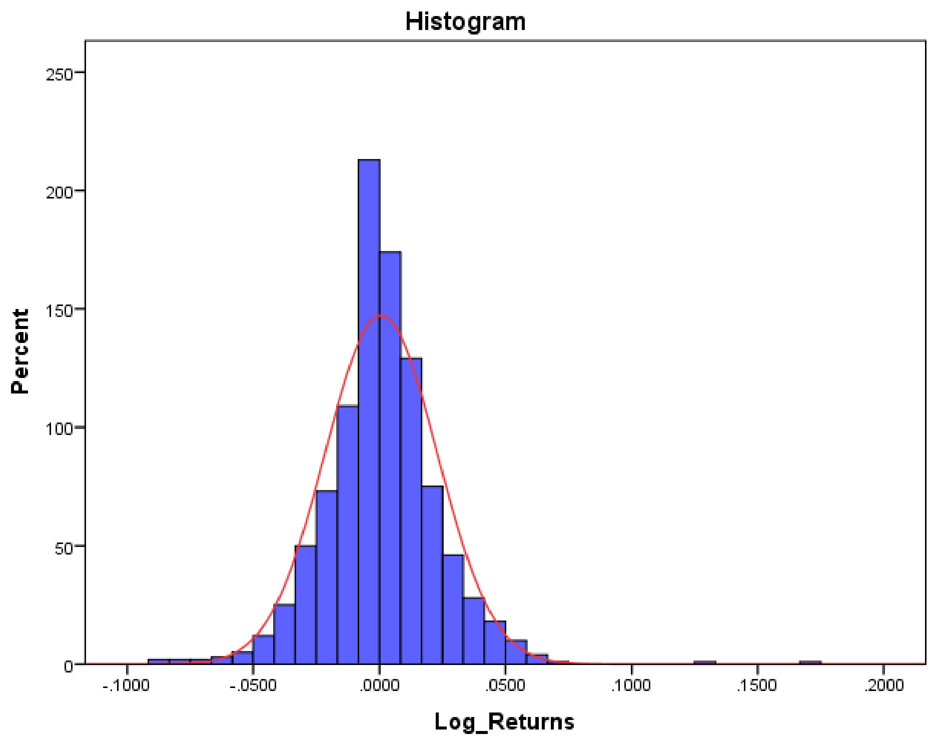


**Chart 4.4**

Distribution of Log Returns

BHARTIAIRTLE

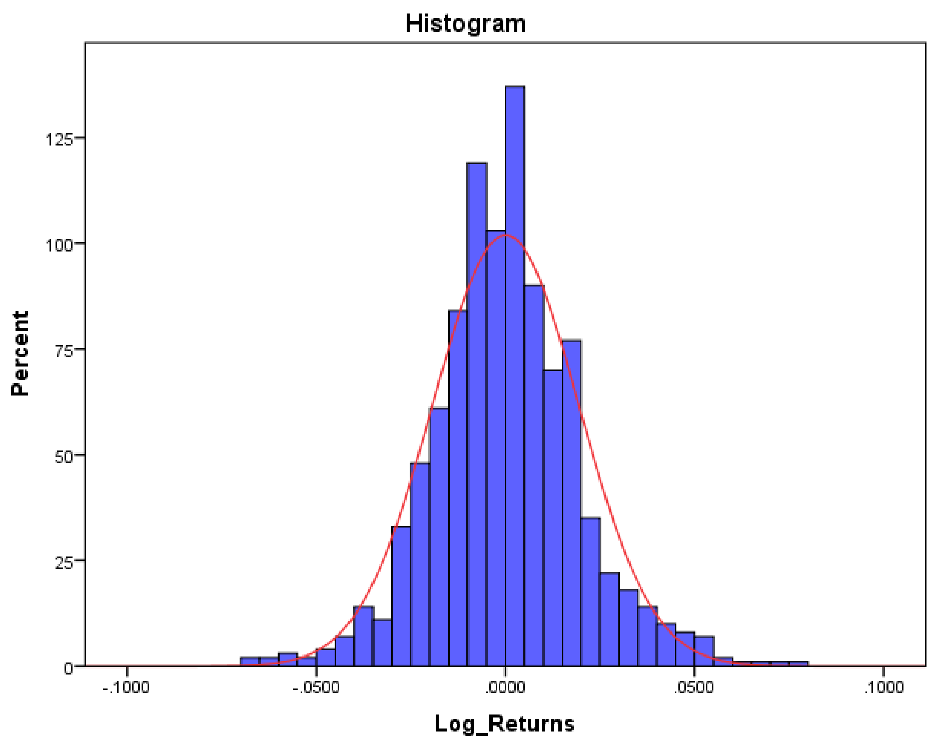


**Chart 4.5**

Distribution of Log Returns

CAIRN

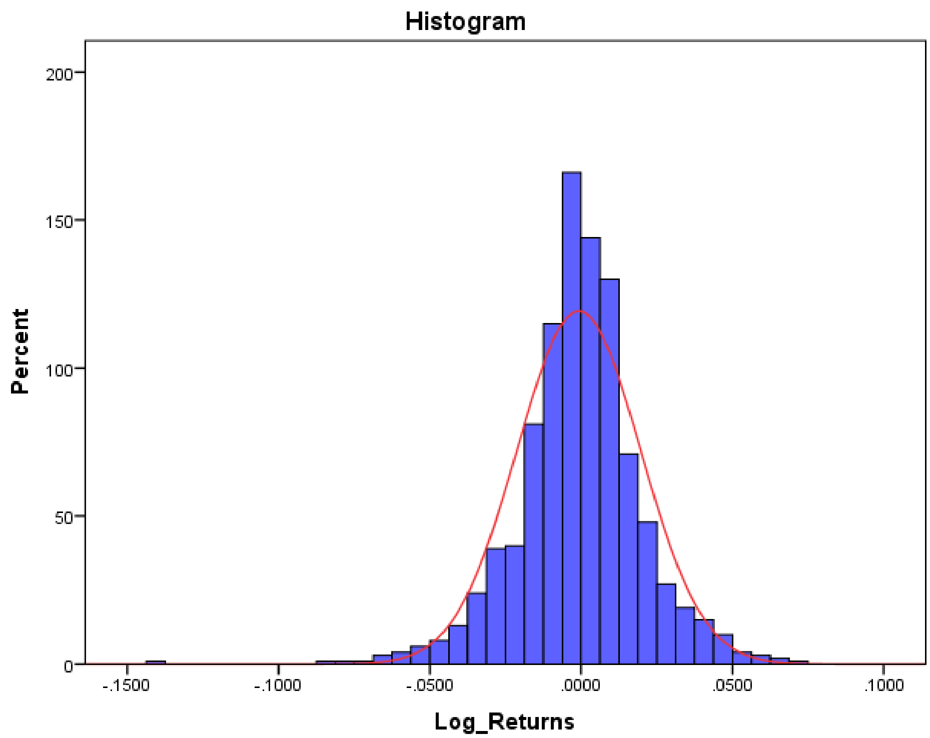


**Chart 4.6**

Distribution of Log Returns

HDFC

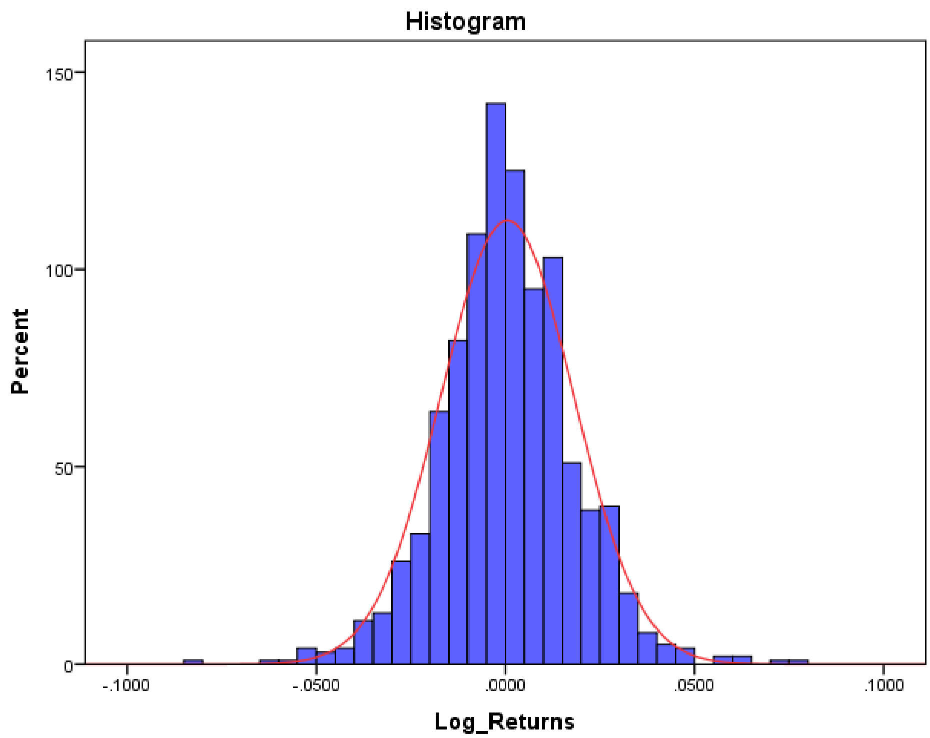


**Chart 4.7**

Distribution of Log Returns

HDFC BANK

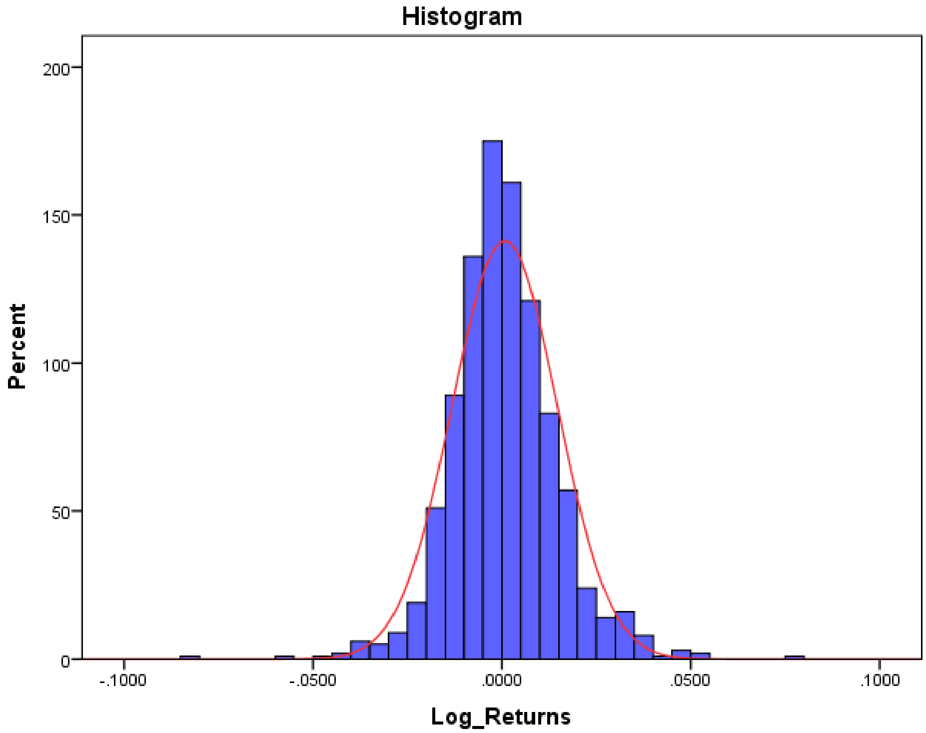


**Chart 4.8**

Distribution of Log Returns

HINDALCO

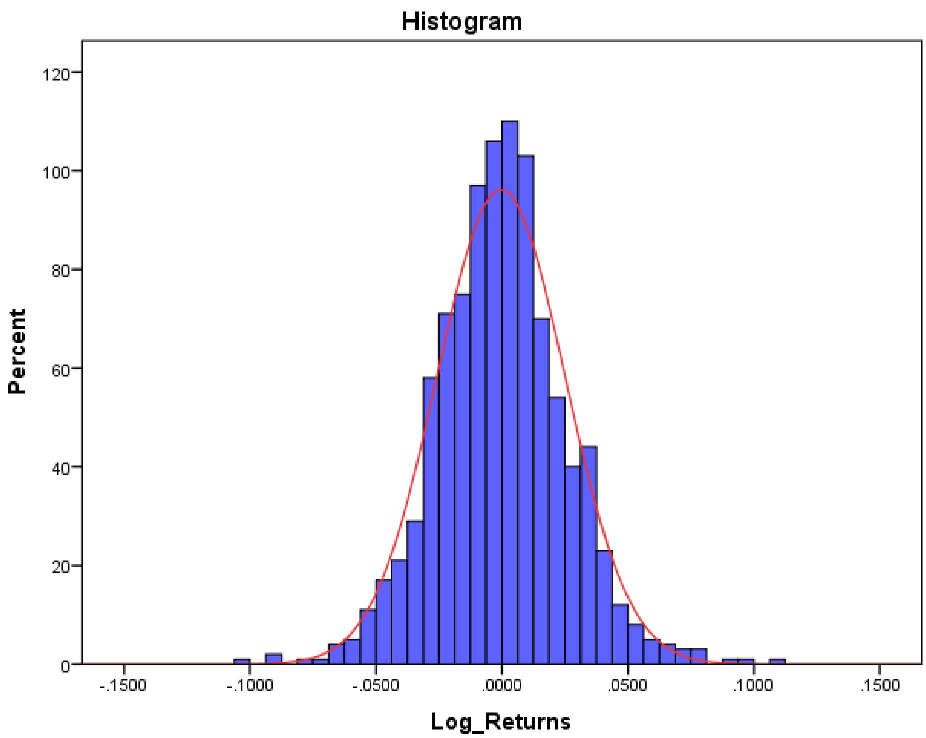


**Chart 4.9**

Distribution of Log Returns

HINDUNILVR

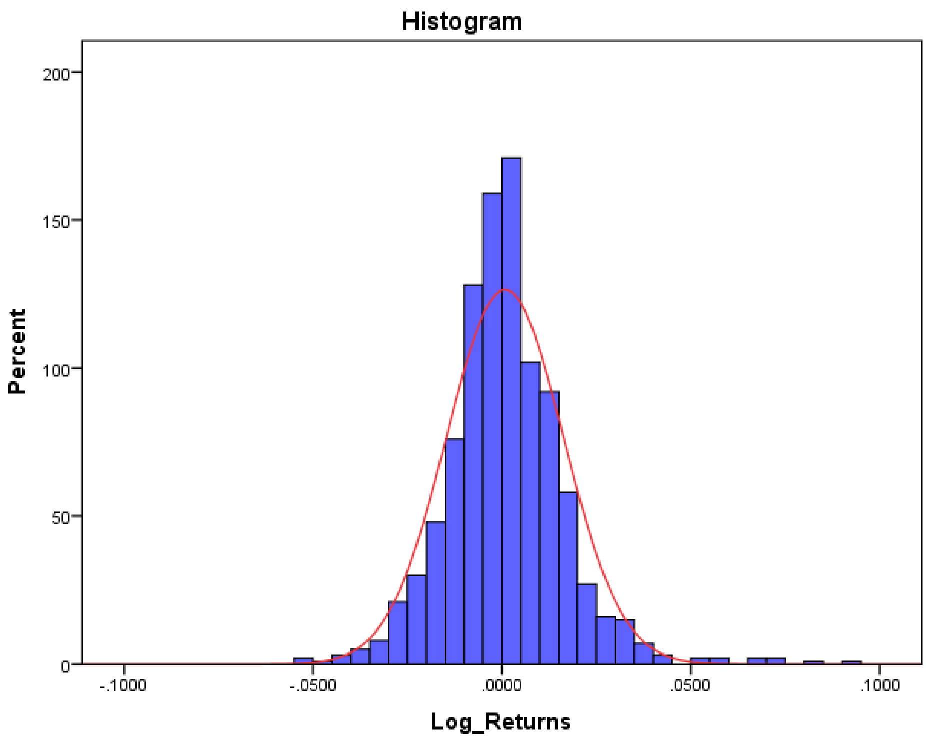


**Chart 4.10**

Distribution of Log Returns

ICICIBANK

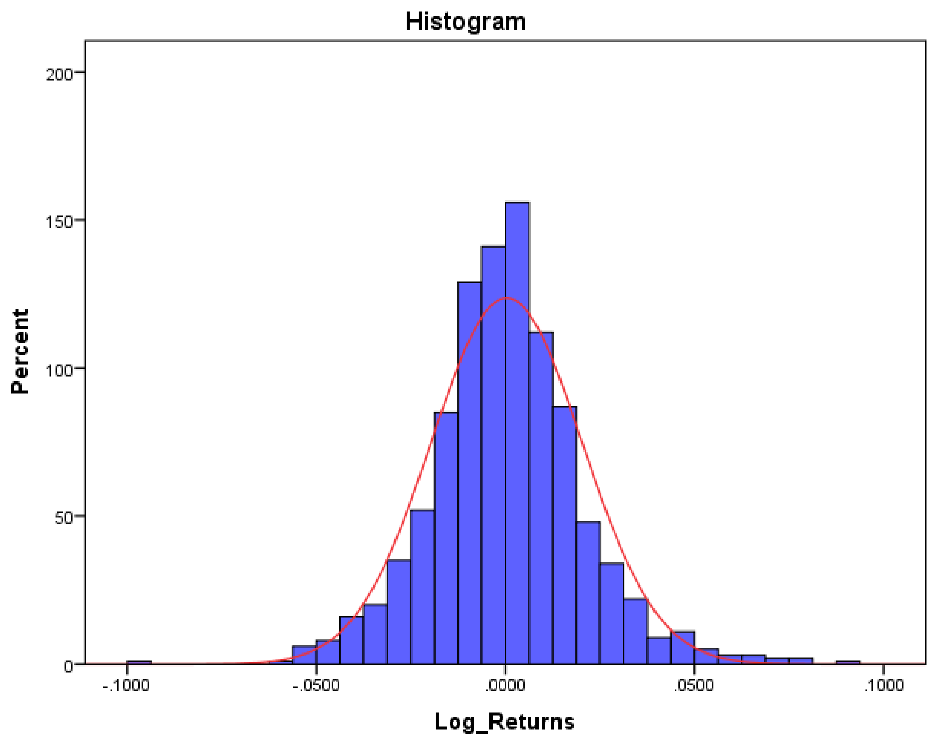


**Chart 4.11**

Distribution of Log Returns

IDFC

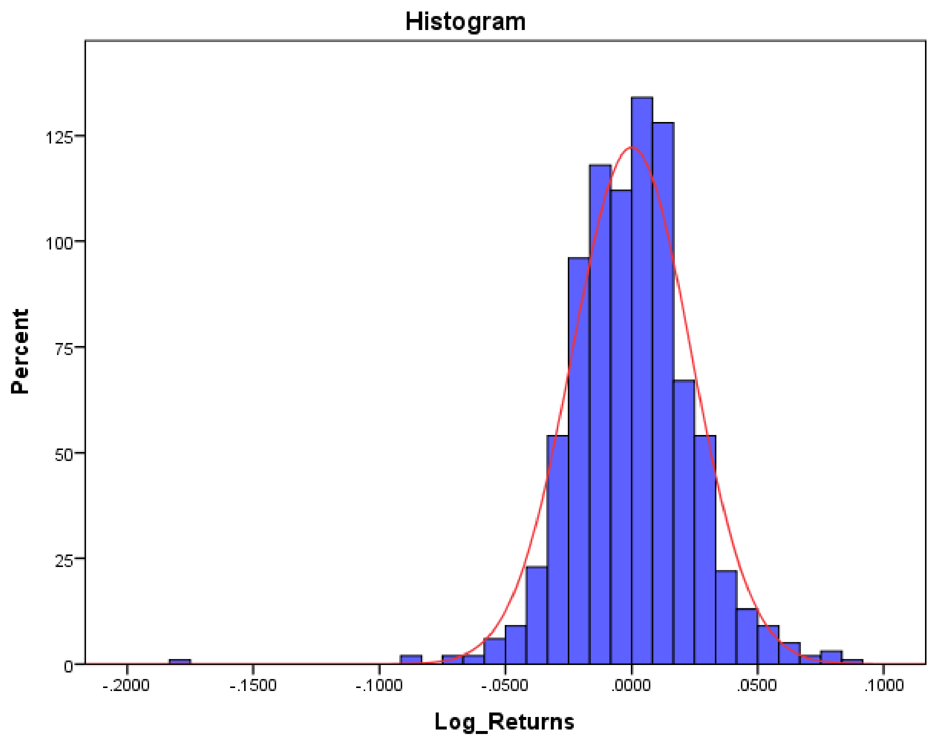


**Chart 4.12**

Distribution of Log Returns

INFY

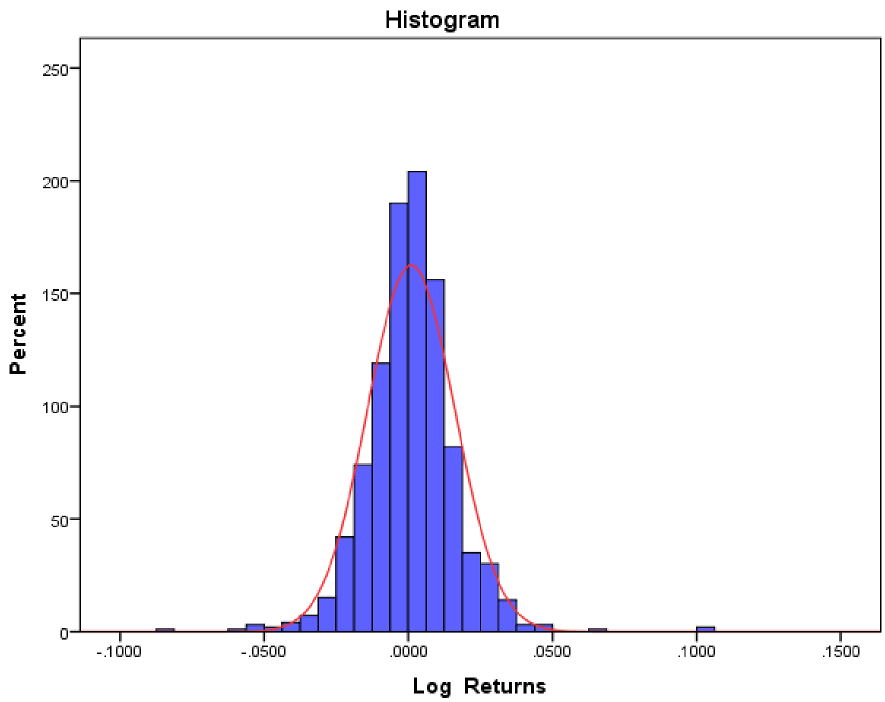


**Chart 4.13**

Distribution of Log Returns

ITC

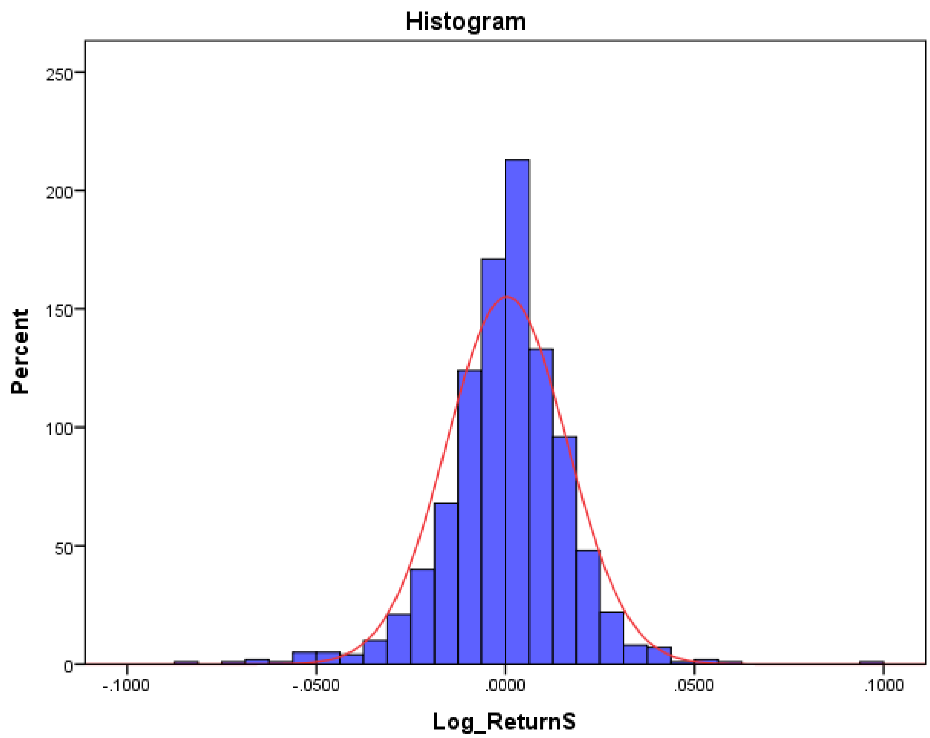


**Chart 4.14**

Distribution of Log Returns

JPASSOCIATE

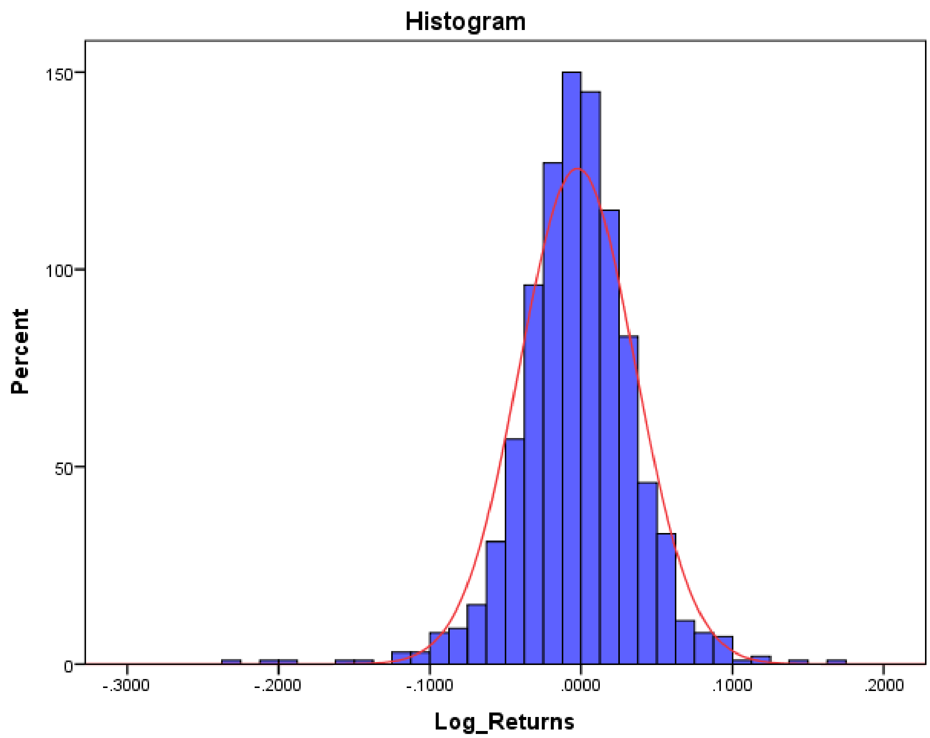


**Chart 4.15**

Distribution of Log Returns

LT

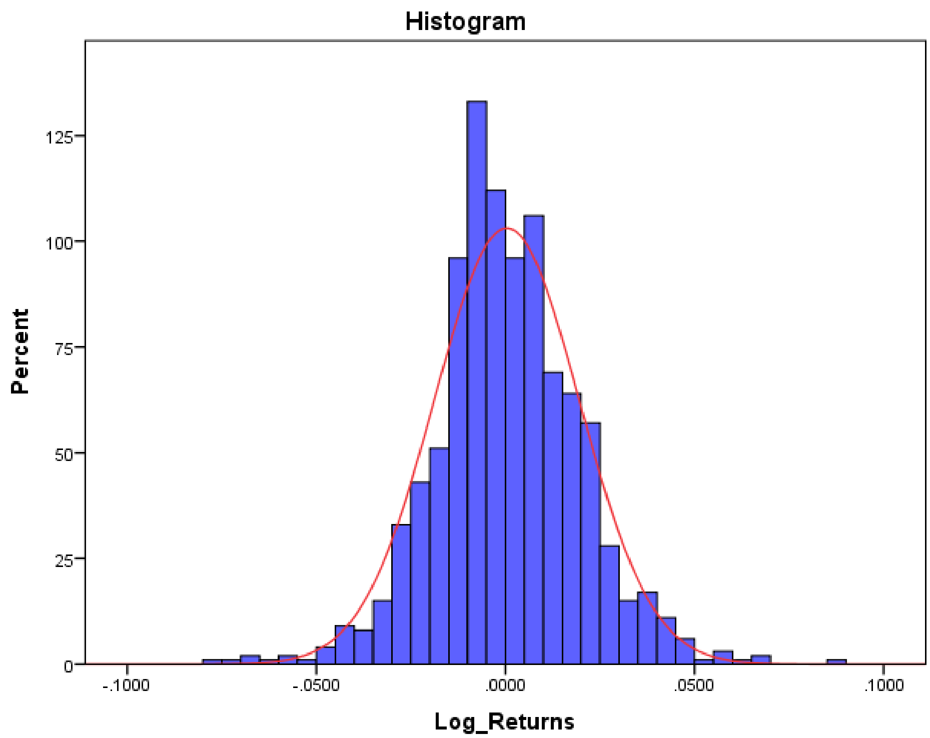


**Chart 4.16**

Distribution of Log Returns

M&M

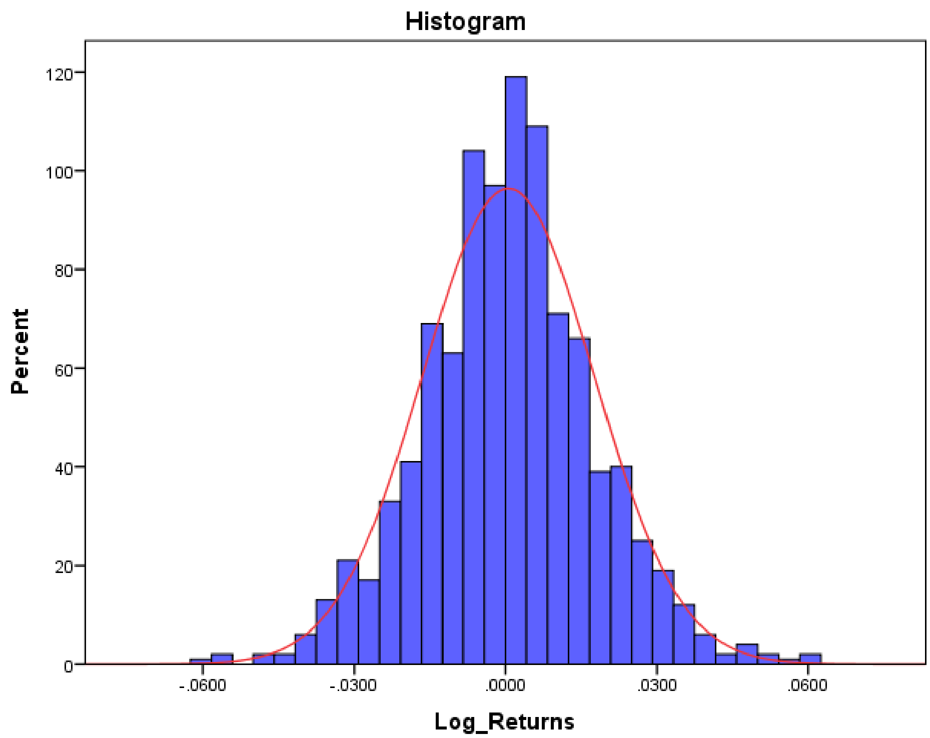


**Chart 4.17**

Distribution of Log Returns

RELIANCE

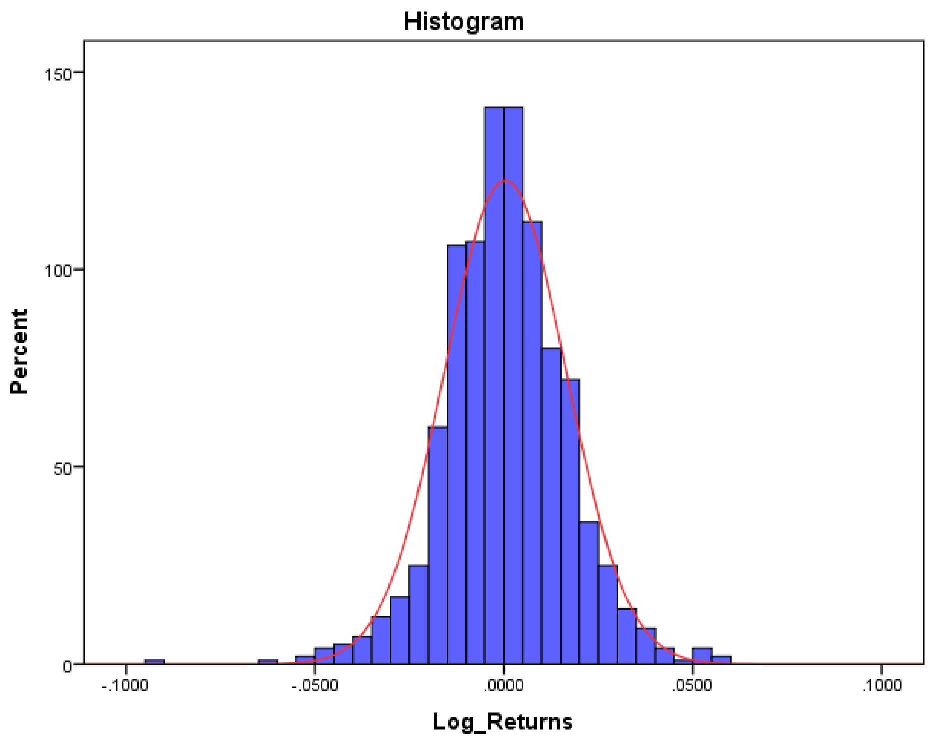


**Chart 4.18**

Distribution of Log Returns

RELINFRA

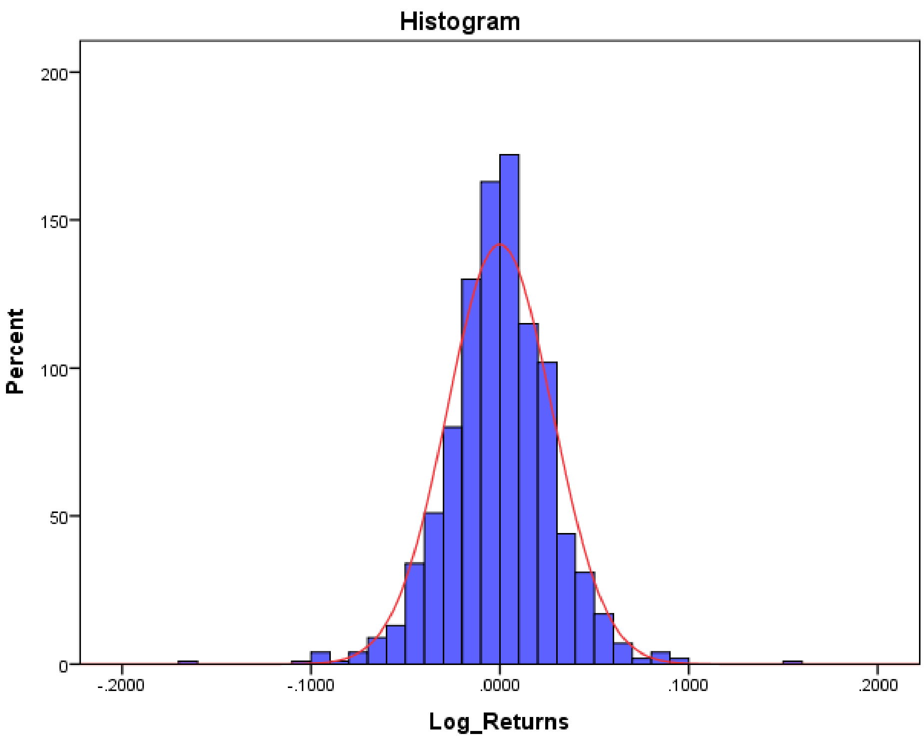


**Chart 4.19**

Distribution of Log Returns

SBIN

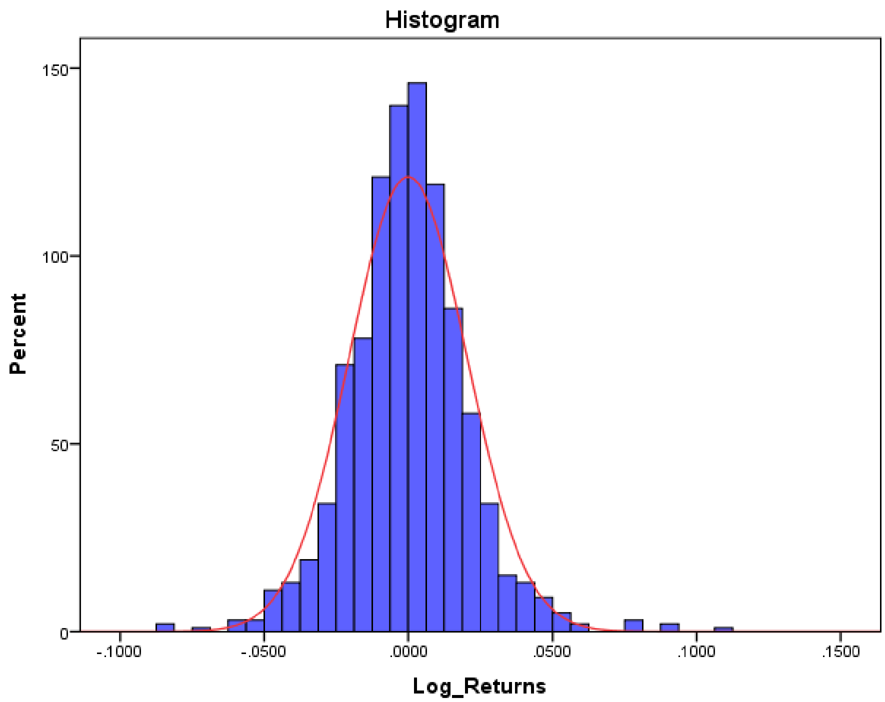


**Chart 4.20**

Distribution of Log Returns

TATASTEEL

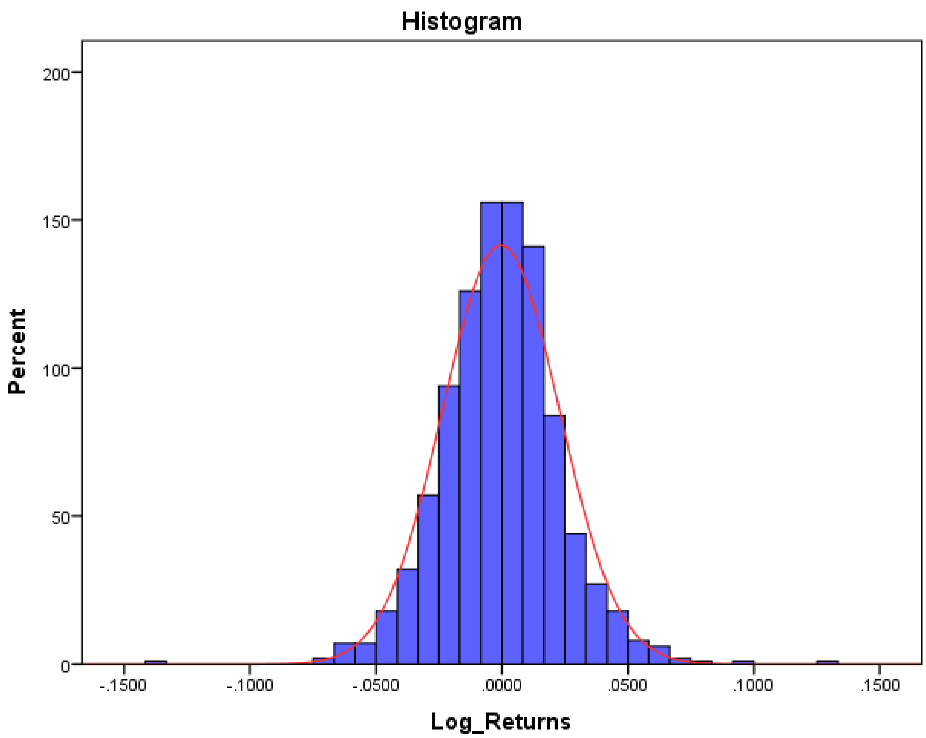


**Chart 4.21**

Distribution of Log Returns

TATAMOTORS

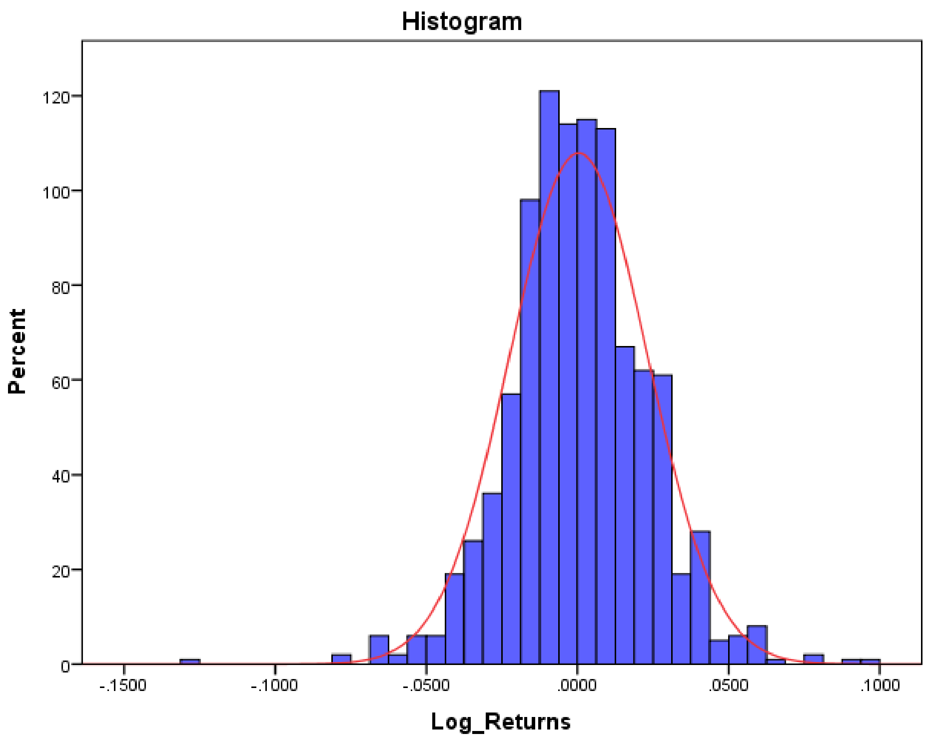


**Chart 4.22**

Distribution of Log Returns

TCS

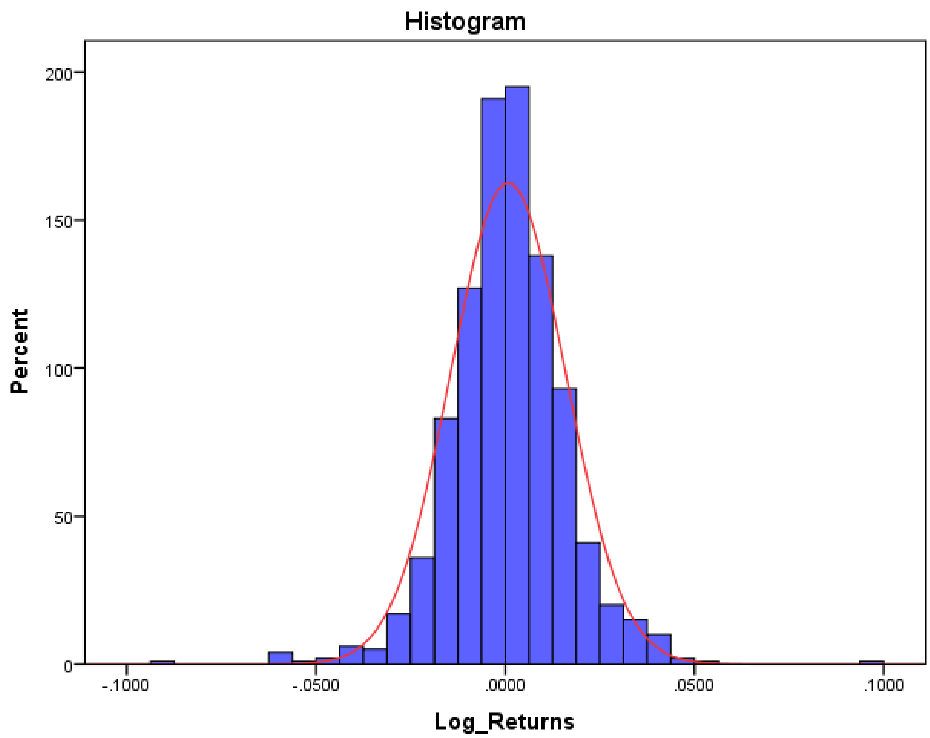
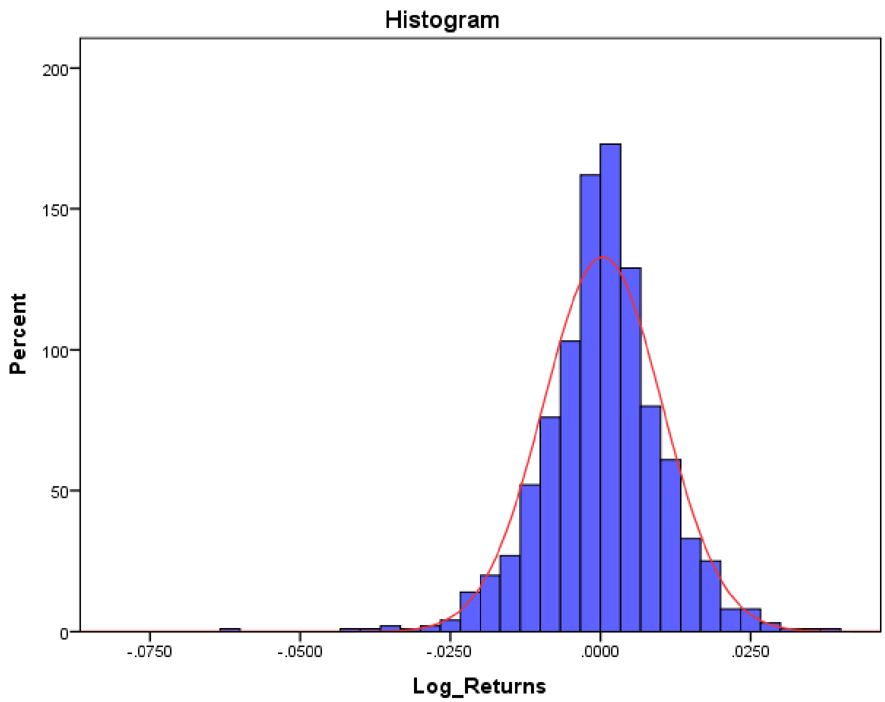


**Chart 4.23**

Distribution of Log Returns

Index NIFTY 50



## BRIEF PROFILE OF THE RESEARCH SCHOLAR

Rajesh Kumar is working as an Assistant professor with Department of Management Studies, Satya College of Engineering & Technology, Affiliated to YMCA University of Science and Technology, Faridabad. His qualification is B A (Eco. Hons), MBA (Finance) from the Centre of Management Studies, Jamia Millia Islamia, Delhi and he is registered with YMCA University for pursuing Ph.D. He did NCFM certification in NCFM-Capital Market (Dealer) Module, NCFM-Derivative Market (Dealer) Module, NCFM- Option Trading Strategies Module and NCFM- NSDL-Depository Operations Module from NSE. He also did short term course on Introductory Financial Mathematics from the Department of Mathematics, IIT, Delhi. He is having total 11 years of experience in education sector. His area of interest includes financial derivative, capital market and project management and infrastructure finance. The researcher has published five papers in national/international journals. The researcher has also presented papers in national/international conferences.

## LIST OF PUBLUCATIONS

| Sr. No. | Title of the paper | Name of the Journal | Volume and Issue | Year |
|---|---|---|---|---|
| 1 | An Empirical Investigation of the Black-scholes Call Option Pricing Model with Reference to NSE | International Journal of BRIC Business Research (IJBBR) | Vol. 6, No. 2 | May 2017 |
| **2** | Determining the efficiency of the Black and Scholes Model in Pricing of Nifty Stock call options after Replacing the Spot Price by the Discounting Value of Future Price | Asian Journal of Management (AJM) | Vol. 8, Issue 3 | Jul-Sep. 2017 |
| **3** | Determining the Efficiency of the Black and Scholes Model in Pricing of INDEX Nifty50 Call options after replacing the Spot Price by the Discounting Value of Future Price | Journal of Banking, Finance and Insurance Management | Vol. 1, Issue 2 | Dec. 2017 |
| **4** | A Close Look into Black-Scholes INDEX Nifty50 Put Option Pricing Model: Evidence from Indian National Stock Exchange | Asian Journal of Management (AJM) | Vol. 9, Issue 1 | Jan-Mar 2018 |

**LIST OF PAPERS IN CONFERENCE**

| Sr. No. | Title of the paper | National/ International | Name of Conference | Institute |
|---|---|---|---|---|
| 5 | An Empirical Investigation of the B&S Stock Option Pricing Model with Reference to NSE, 2016 | International | SDREM | YMCA UST, Faridabad |
| 6 | Efficiency of Black-Scholes Model for Pricing NSE INDEX Nifty50 Put Options and Observed Negative Cost of Carry Problem, 2017 | International | RISAEM | Guru Kashi University, Bhathinda, Punjab |