Project Report
On
EXPLORING ARBITRAGE OPPORTUNITY IN SELECTED NSE STOCK OPTIONS USING PUT-CALL PARITY

Submitted By:

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CANDIDATE'S DECLARATION

I, **Nikhil Kumar**, student of MBA(E) 2015-2017 batch of Delhi School of Management, Delhi Technological University, India do hereby declare that the project entitled **"Exploring Arbitrage Opportunity in selected NSE Stock Options using Put-Call Parity"** is an original work, carried out as partial fulfilment of the requirement of the degree of Executive MBA in Delhi School of Management, Delhi Technological University, Delhi.

The information and data given in the report is authentic to the best of my knowledge.

This Report is not being submitted to any other University for award of any other Degree, Award and Fellowship.

Name: - Nikhil Kumar

Sign: -

Place: New Delhi

Date: 08/05/2017

CERTIFICATE

It is to hereby certify that the project titled **"Exploring Arbitrage Opportunity in selected NSE Stock Options using Put-Call Parity"** submitted by **Nikhil Kumar** in partial fulfilment of the requirements of the degree of Executive MBA in Delhi School of Management, Delhi Technological University, Delhi is a record of original work carried out by him under my guidance and supervision. I further certify that the work is original and is not based, derived or reproduced from existing work and has not been submitted elsewhere for the award of any degree or diploma.

Signature
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Visiting Faculty, DSM, DTU.

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ABSTRACT

The put and call prices have a deterministic relationship, irrespective of the investor demand for the option, if both options are purchased on the same underlying asset and have the same exercise price and expiration date. The theoretical put-call relationship can be developed to determine a put (call) price for a given call (put) price and other relevant information (for example, current price of the asset, exercise price, risk-free rate and time to maturity). If the actual call or put price is different from the theoretical price, there exists an arbitrage opportunity and an arbitrageur can set up a risk- less position and earn more than the risk-free rate of return.

The extant project has been undertaken with an objective to identify if the put-call parity relationship exists in case of selected NSE stock options. If there is a violation of this relationship what are factors responsible for this violation.

Various factors that were studied to determine the quantum of arbitrage profits were:

i. the extent to which options are in the money or out of the money,
ii. if arbitrage profits occurred in the case of in the money options or out of the money options,
iii. time to maturity of the options, and
iv. The number of contracts traded.

It was found that violation of put-call parity relationship did take place for many options of selected NSE Stock options. It was also found that arbitrage profits are more in case of deeply in the money or deeply out of the money options. Arbitrage profit increase by increase in time to maturity. As expected the quantum of arbitrage profit reduced significantly with increase in liquidity. Out of the money put options led to more arbitrage profits where there were less liquid options. Out of the money put options created more arbitrage profits for not so near the month and far month contracts. Number of contracts traded were positive and significant for high liquid options. Number of contracts traded were negative and significant for deeply in the money or out of the money option contracts. The gap between Spot price of Stock and the Strike price of the NSE stock option is directly proportional to the arbitrage profit.

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1. INTRODUCTION

1.1 Overview

Since derivatives trading began in June 2000, they have now become the most important segment of the Indian securities market. In June 2000, Securities and Exchange Board of India (SEBI) allowed the National Stock Exchange (NSE) and Bombay Stock Exchange (BSE), and their clearing houses to begin derivatives trading. This was done by introducing index futures contracts based on S&P NSE Nifty index and BSE-30 (Sensex) index. Subsequently, trading in options based on these two indices, options on individual securities and futures on individual securities was introduced. Trading in index options began in June 2001, and trading in options and futures on individual securities started in July 2001 and November 2001 respectively. Interest rate futures was introduced in the Indian stock market in June 2003.

In just about the five years since derivatives trading was started in the Indian stock market, the Indian derivatives market has seen phenomenal growth. The futures and options (F&O) segment of NSE saw a total turnover of Rs. 21,30,612.00 crores during 2003-04 whereas it was Rs. 4,39,863.00 crores during 2002-03, Rs. 1,01,925 crores during 2001-02 and only Rs. 2,365.00 crores in 2000-01. Despite the fact that futures are more popular than options and contracts on individual securities, there has been massive growth in the turnover of stock options. The F&O segment of NSE saw the stock options turnover of Rs. 2,17,207 crores during 2003-04 as against Rs. 1,00,131.00 crores and only Rs. 25,163.00 crores during 2002-03 and 2001-02 respectively.

In 2016-17 the futures and options (F&O) segment of NSE saw a total turnover of Rs. 9,43,70,301.61 crores which is nearly 1183 % increase over a decade. Similarly the turnover of the NSE stock options has grown exponentially to Rs. 61,07,485.87 crore in 2016-17.

Option contract is one of the variants of derivative contracts. They give its holder the right, but not the obligation, to buy or sell a specified amount of the underlying asset for a certain agreed price (exercise/strike price) on or before some specified future date (expiration date). The underlying asset could be individual stock, stock market index, foreign currency, commodities, gold, silver, or fixed-income securities.

A call option gives its holder the right to buy whereas put option gives its holder the right to sell. The call option holder (the person who has purchased the call) exercises the option only if the value of the underlying asset on the maturity of the option is more than the exercise price, otherwise the option is not utilised. The put option holder exercises the option if the value of the underlying asset on the maturity is less than the exercise price, otherwise the option is not utilised. To purchase the right to buy or sell the underlying asset, the option holder must pay a certain price for purchasing the right. This is called option premium.

The holder of the Call option purchases the right to purchase the underlying asset and pays call premium as the purchase price of the right to buy. Put option holder purchase the right to sell and pays put premium as the purchase price of the right to sell the underlying asset. The person who sells the option to give the buyer the right to buy or sell the underlying asset is known as writer or seller of the option. The option premium is received by the option writer for selling the option. The payoff of option holder on expiration is positive or zero whereas payoff of option writer on expiration is always negative or zero. The option holder makes a profit if the payoff of option holder on expiration is more than the option premium that he pays to purchase the option. The option writer makes a profit if the premium that he receives for selling the option is more than the amount (negative payoff) that he pays to the option holder on expiration. The option holder's profit is the value of the option at expiration minus price originally paid for the right to buy or sell the underlying asset at the exercise price. The option writer's profit is the value of the option at expiration plus price he receives for selling the right.

The underlying assets in the Indian stock market are stock market indices and 54 individual securities. For the purpose of this project, the underlying asset is NSE individual securities. The option could be either of American style or of European style. An American option allows its holder the right to purchase (if a call) or sell (if a put) the underlying asset on or before the expiration date. In the case of the European option, it can be exercised only on the maturity date. In the Indian stock market, index options and individual stock options are of European style. Since this project deals only with individual stock option, a European option is only relevant to us as far as this project is concerned.

The put and call prices have a deterministic relationship, irrespective of the investor demand for the option, if both options are purchased on the same underlying asset and have the same exercise price and expiration date. The theoretical put-call relationship can be developed to determine a put (call) price for a given call (put) price and other relevant information (for example, current price of the asset, exercise price, risk-free rate and time to maturity). If the actual call or put price is different from the theoretical price, there exists an arbitrage opportunity and an arbitrageur can set up a risk- less position and earn more than the risk-free rate of return.

The put-call parity relationship was first developed by Stoll (1969) and later extended and modified by Merton (1973). Several different studies have empirically tested the put-call parity theorem. Some of these studies are: Stoll (1969); Klemkosky and Resnick (1979); Gray (1989); Garay, Ordonez and Gonzalez (2003); Broughton, Chance and Smith (1998); Mittnick and Rieken (2000); Taylor (1990); Evnine and Rudd (1985); Finucane (1991); Francfurter and Leung (1991); Brown and Easton (1992); Easton (1994); Kamara and Miller (1995); Wagner, Ellis and Dubofsky (1996); Gould and Galai (1974); Bharadwaj and Wiggins (2001).

However, there is a mixed response to the empirical verification of put-call parity relationship. Some studies support the put-call parity relationship while others don't support the put-call parity theorem.

1.2 Derivative Trading mechanism at NSE

1.2.1 Equity Derivatives at NSE

The National Stock Exchange of India Limited (NSE) commenced trading in derivatives with the launch of index futures on June 12, 2000. The futures contracts are based on the popular benchmark Nifty 50 Index.

The Exchange introduced trading in Index Options (also based on Nifty 50) on June 4, 2001. NSE also became the first exchange to launch trading in options on individual securities from July 2, 2001. Futures on individual securities were introduced on November 9, 2001. Futures and Options on individual securities are available on 175 securities stipulated by SEBI.

The Exchange has also introduced trading in Futures and Options contracts based on Nifty IT, Nifty Bank, and Nifty Midcap 50, Nifty Infrastructure, Nifty PSE, Nifty CPSE indices.

This section provides an insight into the derivatives segment of NSE. Real-time quotes and information regarding derivative products, trading systems & processes, clearing and settlement, risk management, statistics etc. are available here.

1.2.2 Instrument wise Volume and Turnover

As on May 09, 2017 15:30:29 IST		
Product	**No. of contracts**	**Traded Value (Rs crores)**
Index Futures	1,23,408	9,683.56
Stock Futures	6,44,598	48,239.23
Index Options	29,26,464	2,44,145.72
Stock Options	3,65,456	28,569.21
F&O Total	**40,59,926**	**3,30,637.72**

Options Value calculated as (Premium + Strike price) x Quantity

1.2.3 Products

Since the launch of the Index Derivatives on the popular benchmark Nifty 50 Index in 2000, the National Stock Exchange of India Limited (NSE) today have moved ahead with a varied product offering in equity derivatives. The Exchange currently provides trading in Futures and Options contracts on 9 major indices and more than 100 securities.

Derivatives on the following Products

- Nifty 50 Index
- Nifty IT Index
- Nifty Bank Index
- Nifty Midcap 50 Index
- Nifty Infrastructure Index
- Nifty PSE Index
- Individual Securities
- Nifty CPSE

NSE became the first exchange to launch trading in options on individual securities. Trading in options on individual securities commenced from July 2, 2001. Option contracts are European style and cash settled and are available on 175 securities stipulated by the Securities & Exchange Board of India (SEBI).

1.2.4 Contract Specifications

Security descriptor

The security descriptor for the options contracts is:

- Market type : N
- Instrument Type : OPTSTK
- Underlying : Symbol of underlying security
- Expiry date : Date of contract expiry
- Option Type : CE/ PE
- Strike Price: Strike price for the contract
- Instrument type represents the instrument i.e. Options on individual securities.
- Underlying symbol denotes the underlying security in the Capital Market (equities) segment of the Exchange
- Expiry date identifies the date of expiry of the contract

- Option type identifies whether it is a call or a put option, CE - Call European, PE - Put European.

Underlying Instrument

Option contracts are available on 175 securities stipulated by the Securities & Exchange Board of India (SEBI). These securities are traded in the Capital Market segment of the Exchange.

Trading cycle

Options contracts have a maximum of 3-month trading cycle - the near month (one), the next month (two) and the far month (three). On expiry of the near month contract, new contracts are introduced at new strike prices for both call and put options, on the trading day following the expiry of the near month contract. The new contracts are introduced for three month duration.

Expiry day

Options contracts expire on the last Thursday of the expiry month. If the last Thursday is a trading holiday, the contracts expire on the previous trading day.

1.2.5 Strike Price Intervals

The strike scheme for options contracts on all individual securities is based on the volatility of the underlying stock. Exchange shall review it and revise if necessary, on a quarterly basis. The Exchange, at its discretion, may enable additional strikes as specified in the direction of the price movement, intraday, if required. The additional strikes may be enabled during the day at regular intervals and message for the same shall be broadcast to all trading terminals.

New contracts with new strike prices for existing expiration date are introduced for trading on the next working day based on the previous day's underlying close values, as and when required. In order to decide upon the at-the-money strike price, the underlying closing value is rounded off to the nearest strike price interval.

The in-the-money strike price and the out-of-the-money strike price are based on the at-the-money strike price interval.

Symbol	Applicable Step value	No. of Strikes Provided In the money - At the money - Out of the money	No of additional strikes which may be enabled intraday
LT	20	10 -1- 10	10
MARUTI	50	10 -1- 10	10
RELIANCE	20	10 -1- 10	10
SBIN	5	10 -1- 10	10
VEDL	5	10 -1- 10	10

1.2.6 Trading Parameters

Contract size

The value of the option contracts on individual securities may not be less than Rs. 5 lakhs at the time of introduction for the first time at any exchange. The permitted lot size for futures contracts & options contracts shall be the same for a given underlying or such lot size as may be stipulated by the Exchange from time to time.

Price steps

The price step in respect of the options contracts is Re.0.05.

Base Prices

Base price of the options contracts, on introduction of new contracts, would be the theoretical value of the options contract arrived at based on Black-Scholes model of calculation of options premiums.

The options price for a Call, computed as per the following Black Scholes formula: $C = S * N(d_1) - X * e^{-rt} * N(d_2)$

And the price for a Put is: $P = X * e^{-rt} * N(-d_2) - S * N(-d_1)$

Where:

$d_1 = [\ln(S/X) + (r + \sigma^2 / 2) * t] / \sigma * \text{sqrt}(t)$

$d_2 = [\ln(S/X) + (r - \sigma^2 /2) * t] / \sigma * \text{sqrt}(t) = d_1 - \sigma * \text{sqrt}(t)$

C = price of a call option

P = price of a put option

S = price of the underlying asset

X = Strike price of the option

r = rate of interest

t = time to expiration

σ = volatility of the underlying

N represents a standard normal distribution with mean = 0 and standard deviation = 1 ln represents the natural logarithm of a number. Natural logarithms are based on the constant e (2.71828182845904).

Rate of interest may be the relevant MIBOR rate or such other rate as may be specified.

The base price of the contracts on subsequent trading days, will be the daily close price of the options contracts. The closing price shall be calculated as follows:

- If the contract is traded in the last half an hour, the closing price shall be the last half an hour weighted average price.
- If the contract is not traded in the last half an hour, but traded during any time of the day, then the closing price will be the last traded price (LTP) of the contract.

If the contract is not traded for the day, the base price of the contract for the next trading day shall be the theoretical price of the options contract arrived at based on Black-Scholes model of calculation of options premiums.

1.2.7 Quantity freeze

Orders which may come to the exchange as a quantity freeze shall be based on the notional value of the contract of around Rs.5 crores. Quantity freeze is calculated for each underlying on the last trading day of each calendar month and is applicable through the next calendar month.

Derivatives on Individual Securities	Symbol	May-17	Jun-17	Jul-17
Larsen & Toubro Ltd.	LT	500	500	500
Maruti Suzuki India Ltd.	MARUTI	150	150	150
Reliance Industries Ltd	RELIANCE	500	500	500
State Bank Of India	SBIN	3000	3000	3000
Vedanta Limited	VEDL	3500	3500	3500

1.2.8 Order type/Order book/Order attributes

- Regular lot order
- Stop loss order

- Immediate or cancel
- Spread order

1.2.9 Trading

NSE introduced for the first time in India, fully automated screen based trading. It uses a modern, fully computerized trading system designed to offer investors across the length and breadth of the country a safe and easy way to invest.

NSE's automated screen based trading, modern, fully computerized trading system designed to offer investors across the length and breadth of the country a safe and easy way to invest. The NSE trading system called 'National Exchange for Automated Trading' (NEAT) is a fully automated screen based trading system, which adopts the principle of an order driven market

1.2.10 Clearing and Settlement

National Securities Clearing Corporation Limited (NSCCL) is the clearing and settlement agency for all deals executed on the Derivatives (Futures & Options) segment. NSCCL acts as legal counter-party to all deals on NSE's F&O segment and guarantees settlement.

A Clearing Member (CM) of NSCCL has the responsibility of clearing and settlement of all deals executed by Trading Members (TM) on NSE, who clear and settle such deals through them.

1.2.11 Risk Management

A sound risk management system is integral to an efficient clearing and settlement system. NSE introduced for the first time in India, risk containment measures that were common internationally but were absent from the Indian securities markets.

Risk containment measures include capital adequacy requirements of members, monitoring of member performance and track record, stringent margin requirements, position limits based on capital, online monitoring of member positions and automatic disablement from trading when limits are breached, etc.

Risk Management for Derivative products is managed with Standard Portfolio Analysis of Risk (SPAN)® is a highly sophisticated, value-at-risk methodology that calculates performance bond/margin requirements by analyzing the "what-if's" of virtually any market scenario.

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1.3 Objective of the Study

This project aims to study whether the put-call parity relationship holds in case of NSE stock options in the Indian stock market. The individual securities selected for stock options are Larson & Tubro, Maruti Suzuki, Reliance, SBI, Vedanta Ltd. This project also seeks to find out different factors responsible for the violation of put-call parity relationship, if any.

This project analysis is divided into five sections. Section 2 deals with the theoretical framework. Sections 3 literature review, section 4 deals with Research Methodology, section 5 discusses analysis of data, conclusion, limitations of the research and scope of further research.

2. THEORETICAL FRAMEWORK

In option contract, there are two parties involved – the writer (seller) of the contract and the buyer (option holder) of the contract. The buyer of the contract pays the premium to the writer of the contract. The buyer of call option and writer of put option believe that the asset prices will increase in the future. The writer of call and buyer of put believe that the asset prices will decline in the future. The option buyer may earn unlimited profits but will incur only limited losses. That is why they pay premium.

The option writers can earn only limited profits but may incur unlimited losses. That is why they receive premium. Option contract gives its holder the right, but not the obligation, to buy or sell a specified quantity of the underlying asset for a certain agreed price on or before some specified future date. A call option provides its holder the right to buy whereas the put option provides the right to sell. In the following discussion, stock has been assumed as the underlying asset. The payoff and profits of the options writers and buyers are as follows:

Payoff to call holder = Max (S_T – X, 0)
Payoff to call writer = Min (X - S_T, 0)
Payoff to put holder = Max (X - S_T, 0)
Payoff to put writer = Min (S_T – X, 0)
Profit to call holder = Max (S_T – X, 0) – C
Profit to call writer = Min (X - S_T, 0) + C
Profit to put holder = Max (X - S_T, 0) – P
Profit to put writer = Min (S_T – X, 0) + P

Where:
X: exercise price of the option
S_T: the market price of the underlying asset on the maturity of the option
C: current market price of European call option (call premium)
P: current market price of European put option (put premium)

There is a theoretical relationship between call premium, put premium and other relevant variables such as current asset price, exercise price, risk- free rate and time to maturity. If current asset price, exercise price, risk-free rate, dividend and time to maturity are known to us, for a given call (put) premium, there will be a unique theoretical put (call) premium. If actual put (call) premium is different from theoretical put (call) premium, there will be a pure arbitrage opportunity and the investor will be able to earn the cash flow that will bring him more than the risk- free rate of return.

For example, a portfolio consisting of buying a call option with an exercise price of X and time to maturity of T and investment of $(X+D)e^{-rT}$ in the risk-free asset with time to maturity the same as that of expiration date of the option.

The value of this portfolio at time T, when the option expires and investment in risk-free asset matures is:

	S_T < X	**S_T > X**
Value of put option	0	S_T - X
Value of stock	X + D	X + D
Total	X + D	S_T + D

Where r is the risk-free rate with continuous compounding and D is the dividend per share (if any) the stock is expected to pay on or before the maturity.

Let us take another example which involves buying a put option with an exercise price of X and time to maturity of T and investment in the underlying asset (stock) in the spot market (protective put).

The value of this portfolio at time T when the option expires is:

	S_T < X	**S_T > X**
Value of call option	X - S_T	0
Value of risk-free asset	S_T + D	S_T + D
Total	X + D	S_T + D

The above two portfolios have the same payoff. If that is the case, they must have the same cost to establish.

Cost of establishing the first portfolio (call plus risk-free asset) = $C + (X+D)e^{-rT}$

Cost of establishing the second portfolio (put plus stock) = $P + S_0$

$$C + (X+D)e^{-rT} = P + S_0$$

If the stock (underlying asset) is not expected to pay any dividend before the maturity of the option (i.e. D = 0), the above relationship can be written as:

$$C + Xe^{-rT} = P + S_0$$

The above relationship is called as put-call parity theorem because it represents the proper relationship between call and put premiums. If this relationship is ever violated, an arbitrage opportunity will arise. If the above relationship is violated it indicates mispricing.

To exploit mispricing, one should buy the relatively cheap portfolio and sell the relatively expensive portfolio to earn arbitrage profits. If cost of establishing call plus risk- free asset is greater than cost of establishing put plus stock ($C + Xe^{-rT} > P + S_0$), one can earn arbitrage profits by writing call, buying put, borrowing from the risk-free market and buying the stock. The present value of profit from this is:

$C – P – S_0 + Xe^{-rT} = á$

If cost of establishing put plus stock is more than cost of establishing call plus risk-free asset ($C + Xe^{-rT} < P + S_0$), one can earn arbitrage profits by buying call, writing put, lending in risk-free market and acquiring a short position in the stock. The present value of profit from this position is:

$P - C + S_0 - Xe^{-rT} = â$

There will not be any arbitrage opportunity if á = â = 0

The above put-call parity relationship was first developed by Stoll (1969). Stoll's original model assumed $X = S_0$ (at the money option) and further assumed that the stock is not expected to pay any dividend before the maturity of the option. He did not differentiate between the American and European options. He implicitly stated that his model can be applied both in case of American and European options. Later, Stoll's model was modified by Merton (1973) who argued that for a non-dividend paying stock, Stoll's model is applicable only if the options are of European style. According to Merton, Stoll's model cannot be applied for a non-dividend paying stock if the options are of American style because although it not optimal for a non-dividend paying stock to exercise the call option before maturity, it may be optimal to exercise the put option before the maturity. Stoll (1973) conceded the point mentioned by Merton with certain conditions.

This project deals with the stock options. Since stock options on NSE are of European style and the underlying asset is the individual securities, we avoid problems arising out of dividend estimation and the early exercise effect, which are encountered in the model given by Merton (1973) and other existing studies [Klemkosky and Resnick (1979); Gould and Galai (1974)]. Thus, for this project, the put call parity model developed by Stoll (1969) can be applied to find out if an arbitrage profit exists due to violation of put call pricing theorem. Stoll's model can be extended to include in-the-money and out-of-the money options.

Another problem associated with exploitation of arbitrage profits is the short selling restrictions associated with spot market. To overcome this problem, we can use NSE stock futures for acquiring a short or long position with the same time to maturity as that of options. The expiration date of NSE Stock futures is the same as that of NSE Stock options, the problem of acquiring a short or long position can easily be resolved.

Consider the portfolio of buying a European put option on NSE Stock options with an exercise price of X and time to maturity of T and acquiring a long position in NSE Stock futures with time to maturity of T (same as that of option). The payoff of this portfolio on expiration date is:

	$\mathbf{S_T < X}$	$\mathbf{S_T > X}$
Payoff of put purchased	$X - S_T$	0
Payoff of long futures	$S_T - F_0$	$S_T - F_0$
Total	$X - F_0$	$S_T - F_0$

Consider another portfolio consisting of buying a call option with an exercise price of X and time to maturity of T and an investment of $(X - F_0)e^{-rT}$ in the risk-free asset with time to maturity of T (same as that of option).

The payoff of this portfolio on expiration date is:

	$S_T < X$	**$S_T > X$**
Payoff of call purchased	0	$S_T - X$
Payoff of risk-free assets	$X - F_0$	$X - F_0$
Total	$X - F_0$	$S_T - F_0$

Thus, the two portfolios have the same payoff. If that is the case, they must have the same cost to establish. The cost of establishing put plus long futures is P whereas the cost of establishing call plus risk- free asset is $C + (X - F_0)e^{-rT}$.

Thus:

$P = C + (X - F_0)e^{-rT}$

If there is a violation of the above relationship, the arbitrage opportunity will arise. If $P > (X - F_0)e^{-rT}$, one should buy call, write put, short futures and invest in the risk-free market. The present value of profit of this position is:

$P - C - (X - F_0)e^{-rT} = ã$

If $P < (X - F_0)e^{-rT}$, one should write call , buy put, long futures and borrow from the risk-free market. The present value of profit of this position is:

$C – P + (X – F_0)e^{-rT} = ä$

For no arbitrage condition, ã = ä = 0.

Thus Stoll’s model (with slight modifications) can be applied in case of NSE Stock options to exploit arbitrage profit arising out of violation of put-call parity theorem. This project tries to find out if an arbitrage profit exists due to violation of put-call parity theorem in case of NSE Stock options and if there is a violation, the factors responsible for the violation of this relationship. The different factors taken into account are: the extent to which options are in the money or out of the money; if the violation is more in case of in-the money option or out of the money option; time to maturity; and number of contracts traded. This is described in the following sections.

3. LITERATURE REVIEW

Before the review of the empirical literature on Put Call parity, the effects of the use of non-synchronous data in tests of the Put Call Parity relation is discussed below:

3.1 Effects of the use of non-synchronous data in previous empirical studies of the PCP relation

Various empirical studies on the PCP relation have suggested that apparent mispricing of options lead to real opportunities for arbitrage in markets. Very often, the transaction costs are not given and this leads to the mispricing. Sometimes, options and the price of underlying assets do not match and this leads to a violation of the PCP relation. To correct this apparent non-synchronicity, a suitable form of sampling should be selected, depending on the liquidity of the options and underlying assets that are used in the empirical study, to remove the effect of non-synchronous trading.

Brown and Easton[8] (1992) propose that for liquid options and stock markets, the following recommendations should be considered in the sampling process when only the closing price of options and stocks is known:

- The sample should only be used if the spread is within the bid-ask spread and then the closing stock price should be used. If the spread is not within the bid-ask spread, the sample must be discarded.
- Only those put and call options that fulfill the following characteristics should be considered:
    - Their volume of transactions is different from zero on the sampled day;
    - That the date and time of closing of the market should be the same as that for the stock; and
    - That the closing price of put and call options should be within the closing bid-ask spread.

A large amount of empirical literature on the Put Call Parity relation in the European, American, and Australian markets is available. Given below is a short review of this literature.

3.2 Previous studies of the PCP relation in Europe

Nisbet[13] (1992) has done an empirical study based on negotiated American options traded on the London Traded Options Market (LTOM). For this, he has used the intra-daily data, including transaction costs and dividend payments. In this study, Nisbet has found that a large number of violations of the PCP relation are present when the only transaction cost taken into consideration is the bid-ask spread.

In another model, Nisbet found that when the costs of commission and the effect of dividends were taken into consideration, in addition to the bid-ask spread, the volume and frequency of the violations in relation to the PCP were so low that there are very low possibilities of potential arbitrage gains.

In a paper on study of PCP in European bourses, Capelle-Blancard and Chaudhury[14] (2001) find support for the PCP relation in France and presents a review of the literature on the PCP relation in different European countries.

3.3 Previous studies of the PCP relation in the USA

The PCP relation has been tested very extensively in the US markets. Stoll[1] (1969) as well as Gould and Galai.[9] (1974) who conducted the initial studies, established support for the PCP theory Gould and Galai found that depending on the magnitude of assumed transaction costs, the PCP relation held.

Evnine and Rudd,[10] (1985) Klemkosky and Resnick,[3,4,5] (1979, 1980, 1992) and Chance[11] (1987) have also tested the PCP relation in the formal US markets (for example, Chicago Board Options Exchange (CBOE), Chicago Board of Trade (CBOT)). They found possible inefficiencies for options in these formal markets.

These early studies had the following three important factors, which may have caused the possible inefficiencies:

- These studies did not use intra-daily or daily closing data. The samples mostly used weekly or monthly closing prices, which increase the probability of errors caused by non-synchronicity in data;

- These studies did not take into account the transaction costs. Since all studies were made on American options, it was not possible to isolate the effect of the value of the early exercise of options in most cases;
- The registration of over-the-counter (OTC) transactions is not very precise because these transactions take place directly between financial institutions and corporations, and not through a formal market.. An empirical study of the PCP relation on European options on the S&P 500, which is negotiated on the CBOE was done by Kamara and Miller[12] (1995).

By using European type options contracts, the authors eliminated the problem caused by the value of the early exercise of a US option. Kamara and Miller found that the number of PCP violations was much smaller than what was found in earlier studies which had used only American options. The authors also reached the conclusion that the PCP relation violations pattern is associated with a 'premium' value that results from liquidity risk. This is the risk that an investor incurs when he is trying to carry out arbitrage transactions and is unable to complete one of the transactions at the correct price.

Authors Kamara and Miller also found that the number of violations and their frequency is related to moneyness. This means that the options which are farther from being at-the-money present a greater number of violations to the PCP relation than those that are closer to being at-the-money.

3.4 Previous studies of the PCP relation in Australia

The prominent studies in Australia were done by Loudon[15] (1988), Gray[16] (1989) Taylor[17] (1990), Easton[18] (1994), Brown and Easton[8] (1992) and Cusack[7] (1997).

Both Loudon and Taylor independently made empirical tests of the PCP relation in the Australian Options Market (AOM). Although they used the same model and the same source of information, they reached diametrically opposite conclusions. A study conducted by Brown and Easton tried to reconcile the results obtained by Loudon and Taylor.

The authors then present the model employed by Loudon and Taylor, and later by Brown and Easton, in addition to a comparative table of the results obtained in each study.

$C\text{-}S+Ke^{-rT}<=P<=C\text{-}S+K+Vp(D)$

Brown and Easton got results which are similar to those of Loudon. From this, they conclude that the main reason for the different result obtained by Taylor was the use of non-synchronous data. About 60 per cent of their samples were invalid. On the other hand, Taylor used only monthly closing data and included closing data for days for which the volume of put or call transactions was zero. In addition, Brown and Easton found some computational errors in the procedure used to calculate the put-call values.

The studies of Loudon and Brown and Easton show the existence of apparent inefficiencies in the AOM. These inefficiencies come from an underestimation of the price of puts (lower boundary), in most cases. This is the reason why apparent arbitrage opportunities were present.

In his study on the AOM, Gray[16] (1989) used a model that included transaction costs, the value of early exercise of option contracts and the effects of dividends. He also used closing prices for options and stocks that were traded during the day. Gray found major violations of the PCP relation, even when commission costs were included. However, the frequency and volume of violations was much less when transaction costs include the bid-ask spread.

An empirical study on the AOM for American options was conducted by Cusack[7] (1997). He included transaction costs and excluded the bid-ask spread. He did not include the effect of dividends and used intra-daily data for time intervals between five and 15 minutes. He verified that their results were consistent with those obtained by Loudon, Brown and Easton and Gray. These results were found to be consistent with the existence of inefficiencies in the Australian market, even when transaction costs were included in the analysis. It was also found that the use of intra-daily data versus the use of closing daily data did not make any difference to the results obtained.

Comparison of empirical studies of the PCP relation in Australia: Loudon[15] (1988), Taylor[17] (1990), Brown & Easton[8] (1992).

	Loudon	**Taylor**	**Brown and Easton**
Non-violation (%)	60	83.8	70.8
Lower Boundary Violation (%)	38.5	0	26.3
Upper Boundary violations (%)	1.5	16.2	3

4. RESEARCH METHODOLOGY

4.1 Research Type and General Goal

The proposed research is descriptive and causal. The proposed research is developed from quantitative point of view.

4.2 Data Population

For the purpose of the project put and call prices on the selected stock Options in the time period of 1st January 2016 till 31st December 2016 will be taken. The selected stock options are Larsen & Toubro Limited (NSE Symbol: LT), Maruti Suzuki India Limited (NSE Symbol: MARUTI), Reliance Industries Limited (NSE Symbol: RELIANCE), State Bank of India (SBIN), and Vedanta Limited (VEDL). The selected stock options are most active in their respective category. Further, in order to enhance the efficacy of the research, only those options will be shortlisted for the study for which at least one transaction has taken place. This has been done as transactions indicate sanctity of price at least to some extent. Further, with the increase in the number of transactions the process of price discovery also improves. For the shortlisted data the theoretical value of the put option will be calculated. The difference between the actual value and the theoretical value of the put call is the possible monetary profit that can be achieved through arbitrage.

The Data thus collected will be analysed on following three broad categories:

i. Number of Contracts
ii. Time to Maturity
iii. Moneyness

For the analysis based on the number of contracts, the data is grouped in following categories:

i. 1-100
ii. 100-500
iii. 5000-1000
iv. >1000

For the analysis based on the time to maturity, the data is grouped in following categories:

i. <30 days
ii. 30 to 60 days
iii. > 60 days

For the analysis based on the moneyness, the data is grouped in following categories:

Strike price is

i. < 0.90 * Spot Price
ii. 0.90 * Spot Price to less 0.95 * Spot Price
iii. 0.95 * Spot Price to less than Spot Price
iv. Spot Price to less than 1.05 * Spot Price
v. 1.05 * Spot Price to less than 1.10 * Spot Price
vi. > 1.10 * Spot Price

4.3 Methods and Techniques

Descriptive Statistics (count, maximum, minimum, mean and standard deviation) will be generated on the data in the categories listed above to discern any apparent characteristic or pattern.

4.4 Developing a Model for Causal Research on factors responsible for violation of PCP in NSE Stock options.

The objective of this study is to find out if put-call parity theorem holds in case of NSE Stock options and if it does not hold, the factors responsible for this violation. To verify the put-call relationship, theoretical put price is computed for a given call price, exercise price, value of NSE Nifty, risk-free rate and time to maturity. For the purpose of this project, the risk- free rate has been taken as 7.2% with continuous compounding. (7.2% was the yield on the 10 year Government of India treasury bonds during 2016). The theoretical put price has been computed as follows:

$P_{Th,\,t} = C_{A,\,t} + S_{A,\,t} – Xe^{-rT}$

Where:

$C_{A,\,t}$: actual call premium for NSE Stock call option with an exercise price of X and time to maturity of T on day t.

$P_{Th,\,t}$: theoretical put premium for NSE Stock put option with an exercise price of X and time to maturity of T on day t.

$S_{A,\,t}$: Spot price of Stock on day t.

r: risk- free rate per annum with continuous compounding.

T: time to maturity of the option on day t.

After computing the theoretical put premium of day t for a given call price, exercise price, risk-free rate and time to maturity, this theoretical put premium is compared with actual put premium of day t with the same exercise price and time to maturity. This is done by subtracting theoretical put premium from actual put premium with the same exercise price and same time to maturity.

That is,

$A = P_{A,\,t} - P_{Th,\,t}$

$P_{A,\,t}$: actual put premium for NSE Stock put option with the exercise price of X and time to maturity of T.

|A| : arbitrage Profit.

If A is significant and greater than zero, it means that put price is too high relative to call price and an arbitrageur can exploit this situation by earning arbitrage profit. In this case, he should write put option, buy call option, short NSE Stock and lend in the risk- free market. By acquiring this position, he will be able to generate sufficient cash flow that will yield him more than the risk- free rate of return.

If A is significant and less than zero, it means put price is too low relative to call and an arbitrageur can exploit this situation by buying put option, writing call option, acquiring long position in NSE Stock and borrowing from the risk- free market.

That is, if the value of A comes out to be significant (either positive or negative), arbitrageur can set up a position where he will be able to generate good amount of arbitrage profit.

5. DATA ANALYSIS

The basic data for this project have been collected from **www.nseindia.com**, an official website of National Stock Exchange. The put-call parity relationship has been verified using daily data on exercise prices available for trading; value of underlying stock; call premium for different exercise prices; put premium for different exercise prices; time to maturity for different exercise prices available for trading; and number of contracts traded for different exercise prices.

To verify the put-call parity relationship, the sample carrying one year time period from 1st January 2016 to 31st December 2016 was chosen. From 1st January 2016 to 31st December 2016, there were total 247 days available for trading. The number of observations for which trading was available with different exercise prices and/or time to maturity were:

Derivatives on Individual Securities	**Symbol**	**Total Observations**	**Average Observation per day**
Larsen & Toubro Ltd.	LT	45362	184
Maruti Suzuki India Ltd.	MARUTI	59884	242
Reliance Industries Ltd	RELIANCE	51826	210
State Bank Of India	SBIN	49156	199
Vedanta Limited	VEDL	33098	134

At any given time, there were only three contracts available with 1 month, 2 months and 3 months to expiry. The expiry date for these contracts is last Thursday of expiry month and these contracts have a maximum of three months expiration cycle. A new contract is introduced on the next trading day following the expiry of the near month contract. On the date of the start of the new option contract, there are minimum of seven exercise prices available for trading – three 'in the money', one 'at the money' and three 'out of the money' for every call and put option. The new exercise prices can be added in between for each contract. The minimum increment in exercise prices in case of selected NSE Stock options are as follows:

Derivatives on Individual Securities	Symbol	Minimum increment in Exercise Price
Larsen & Toubro Ltd.	LT	20 or in multiples of 20 thereof
Maruti Suzuki India Ltd.	MARUTI	50 or in multiples of 50 thereof
Reliance Industries Ltd	RELIANCE	20 or in multiples of 20 thereof
State Bank Of India	SBIN	5 or in multiples of 5 thereof
Vedanta Limited	VEDL	5 or in multiples of 5 thereof

Out of the total observations of 45,362 for Larsen & Toubro, there were 35,896 observations for which there was no trading with different exercise prices and/or time to maturity. These observations were not considered for this project and also only those exercise prices are taken into consideration for which we have both Put as well as Call option. So, for this project 3190 observations were used to verify the put-call parity relationship for Larsen & Toubro.
Similarly, for Maruti Suzuki India Ltd, Reliance Industries Ltd., State Bank of India, and Vedanta Ltd., the number of observations used to verify the put-call parity relationship were 3675, 3758, 4881, and 2402 respectively.

5.1 Empirical Results

5.1.1. Descriptive Statistics

The model described above has been tested for the selected NSE Stock options which are of European style. At any given time, there are three contracts available for trading with one month, two months and three months to expiry. If today is 15th January 2017, three contracts are available for trading: January option, February option and March option. January option will expire on last Thursday of January. A new contact (April option) will be introduced on the next trading day following the expiry of January option (near month contract). For each expiry date, NSE Nifty option trading is available with different exercise prices. Some are in the money, some are out of the money and some are at the money. The objective of this project is to find out whether there is a violation of put-call parity theorem in case of selected NSE Stock options and if there is a violation what amount of arbitrage can be earned due to this violation. Three main factors identified as the main cause of violation are: number of contracts traded, the extent to which option is in the money or out of the money and time to maturity of the option.

In this project, arbitrage profits have been computed for different ranges of number of contracts traded, for different ranges of gap between Spot Price and Exercise Price and for different ranges of time to maturity.

The arbitrage profits for different ranges of number of contracts and for different ranges of time to maturity have been shown in tables 5.1 and 5.2 respectively. The arbitrage profits for different ranges of gap between Spot Price and Exercise Price have been shown in table 5.3.

For L&T

Table 5.1: Arbitrage Profits and Number of Contracts Traded

Number of contracts traded		**Arbitrage Profits Per Contract (in Rupees)**			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
1-100	1641	6.37	55.53	0.00	13.48
100-500	677	4.41	51.3	0.00	10.97
500-1000	360	4.02	47.4	0.00	10.54
>1000	512	3.9	42.35	0.00	9.4

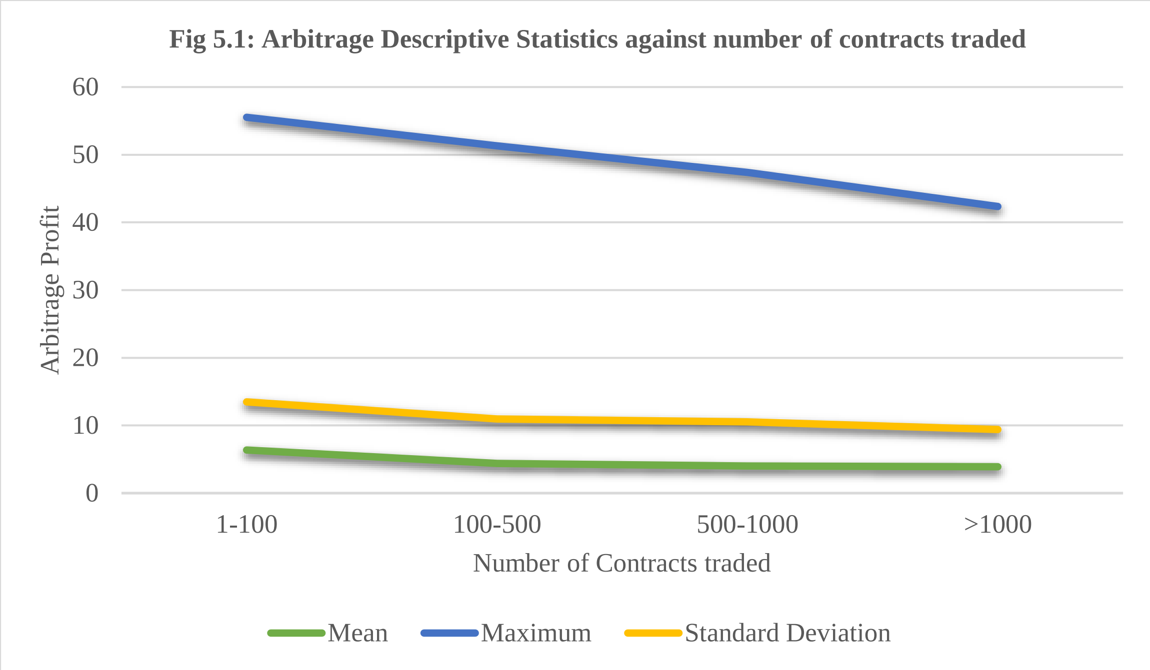


Table 5.2: Arbitrage Profits and Time to Maturity

Time to Maturity		Arbitrage Profits Per Contract (in Rupees)			
Range	Count	Mean	Maximum	Minimum	Standard Deviation
< 30 days	2502	5.07	55.53	0.00	12.34
30 to 60 days	676	6.08	35.36	0.00	12.06
> 60 days	12	11.55	23.79	0.00	10.76

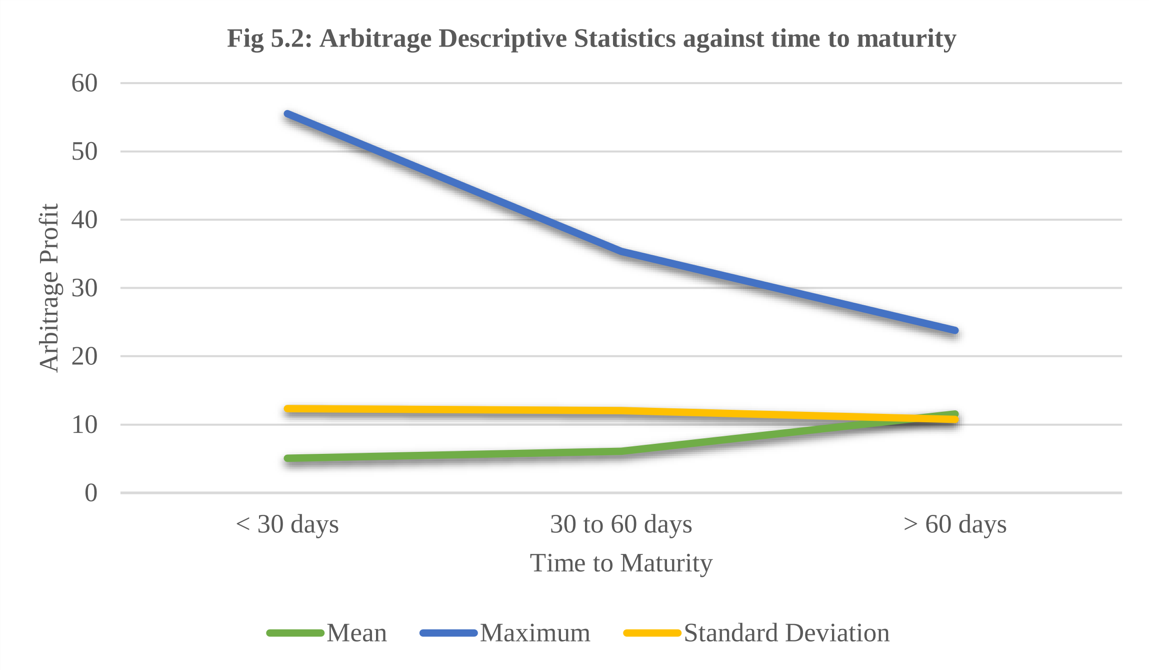
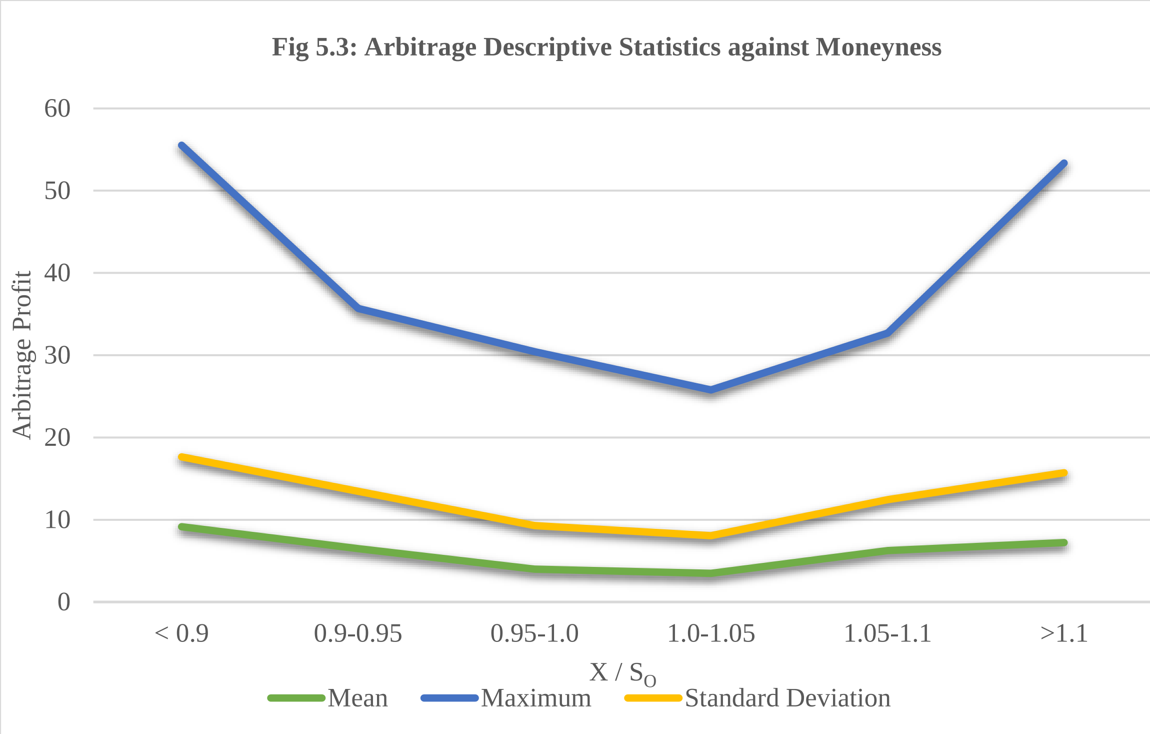


Table 5.3: Arbitrage Profits and Gap between NSE Nifty Value and Exercise Price

If Exercise price is:		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 0.90 S_O	207	9.15	55.53	0.00	17.64
0.90 S_O – 0.95 S_O	380	6.47	35.68	0.00	13.45
0.95 S_O – 1.0 S_O	800	3.98	30.43	0.00	9.3
1.0 S_O – 1.05 S_O	845	3.48	25.78	0.00	8.06
1.05 S_O – 1.10 S_O	517	6.23	32.69	0.00	12.43
>1.10 S_O	441	7.22	53.35	0.00	15.72



<u>For Maruti</u>

Table 5.4: Arbitrage Profits and Number of Contracts Traded

Number of contracts traded		**Arbitrage Profits Per Contract (in Rupees)**			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
1-100	1935	19.33	326.22	0.00	45.66
100-500	773	14.31	182.92	0.00	38.08
500-1000	421	13.33	94.55	0.00	30.92
>1000	546	10.66	87.24	0.00	26.06

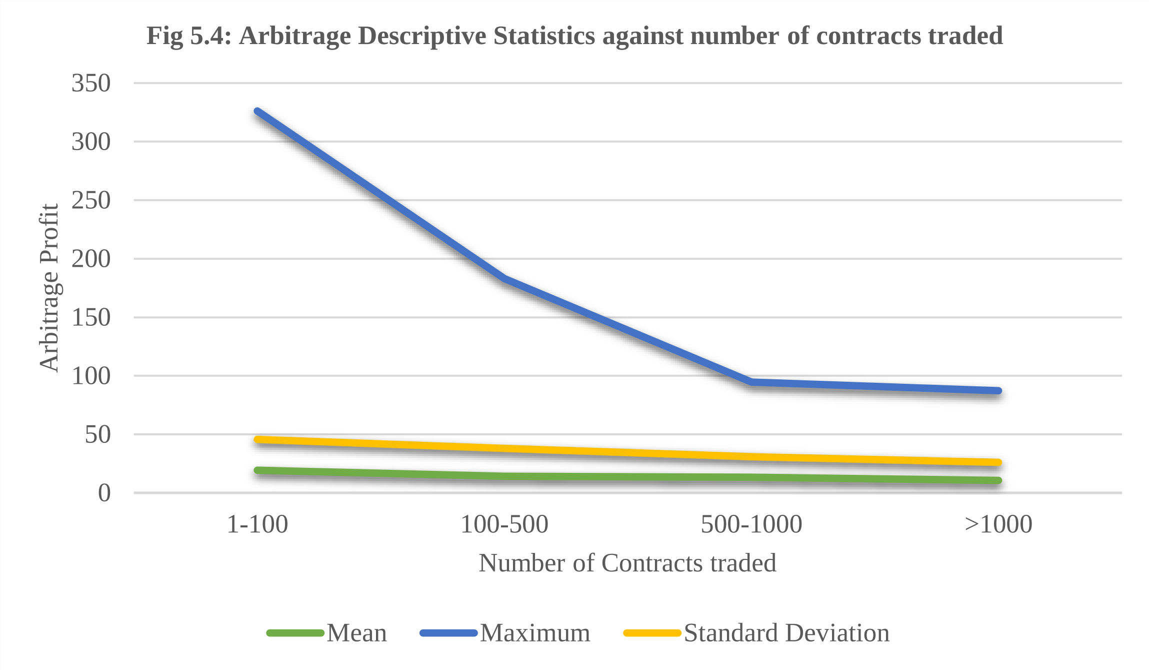


Table 5.5: Arbitrage Profits and Time to Maturity

Time to Maturity		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 30 days	3059	15.31	326.22	0.00	38.76
30 to 60 days	601	21.23	205.7	0.00	30.36
> 60 days	17	33.23	115.79	0.00	24.76

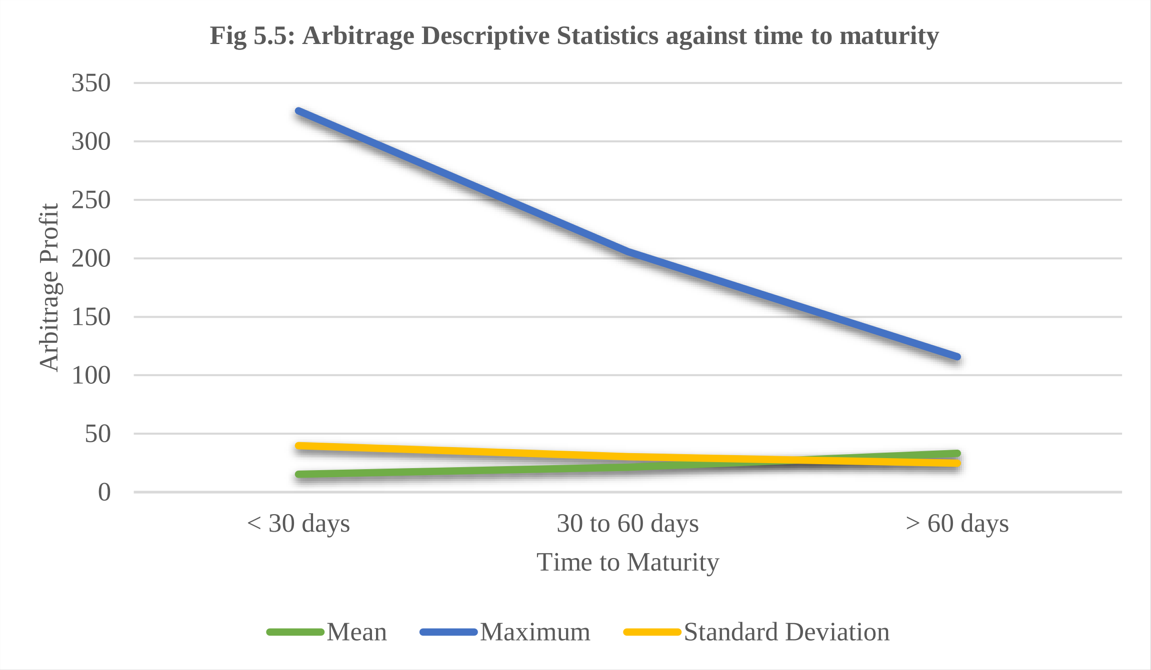
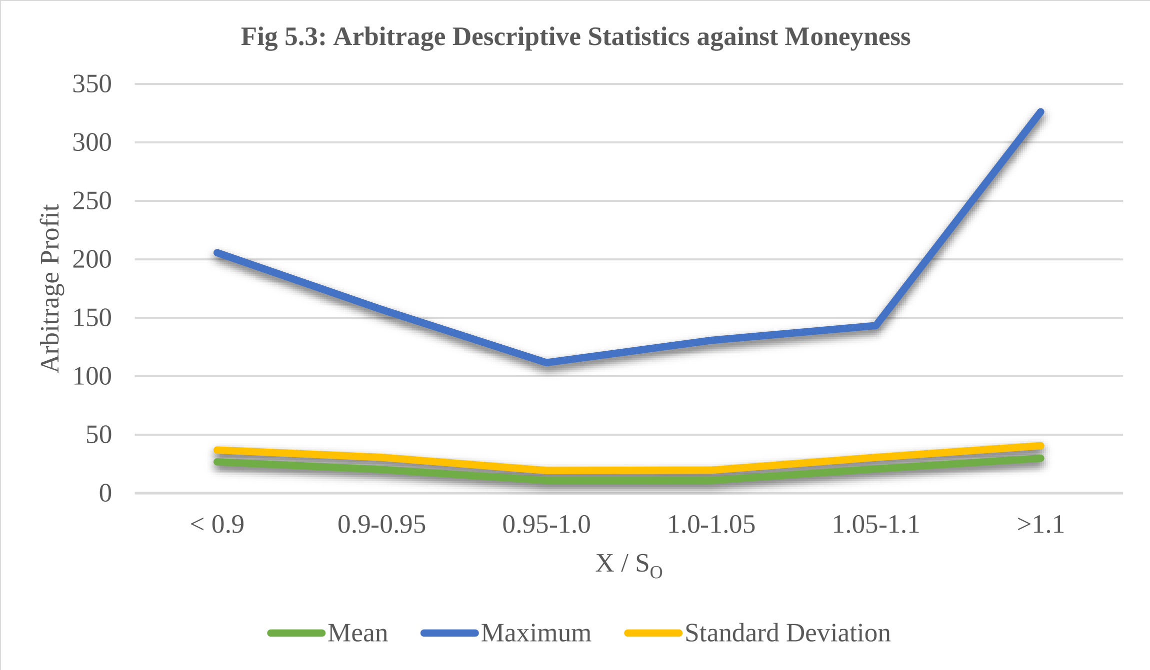


Table 5.6: Arbitrage Profits and Gap between NSE Nifty Value and Exercise Price

If Exercise price is:		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 0.90 S_O	240	26.8	205.7	0.00	36.9
0.90 S_O – 0.95 S_O	516	20.33	157.06	0.00	30.72
0.95 S_O – 1.0 S_O	1083	10.87	111.6	0.00	19.35
1.0 S_O – 1.05 S_O	1031	10.99	130.7	0.00	19.67
1.05 S_O – 1.10 S_O	450	20.63	143.26	0.00	30.7
>1.10 S_O	355	29.84	326.22	0.00	40.59



For Reliance

Table 5.7: Arbitrage Profits and Number of Contracts Traded

Number of contracts traded		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
1-100	1735	3.8	51.58	0.00	11.06
100-500	710	3.64	48.7	0.00	10.2
500-1000	397	3.21	48.2	0.00	8.72
>1000	916	2.64	45.37	0.00	7.94

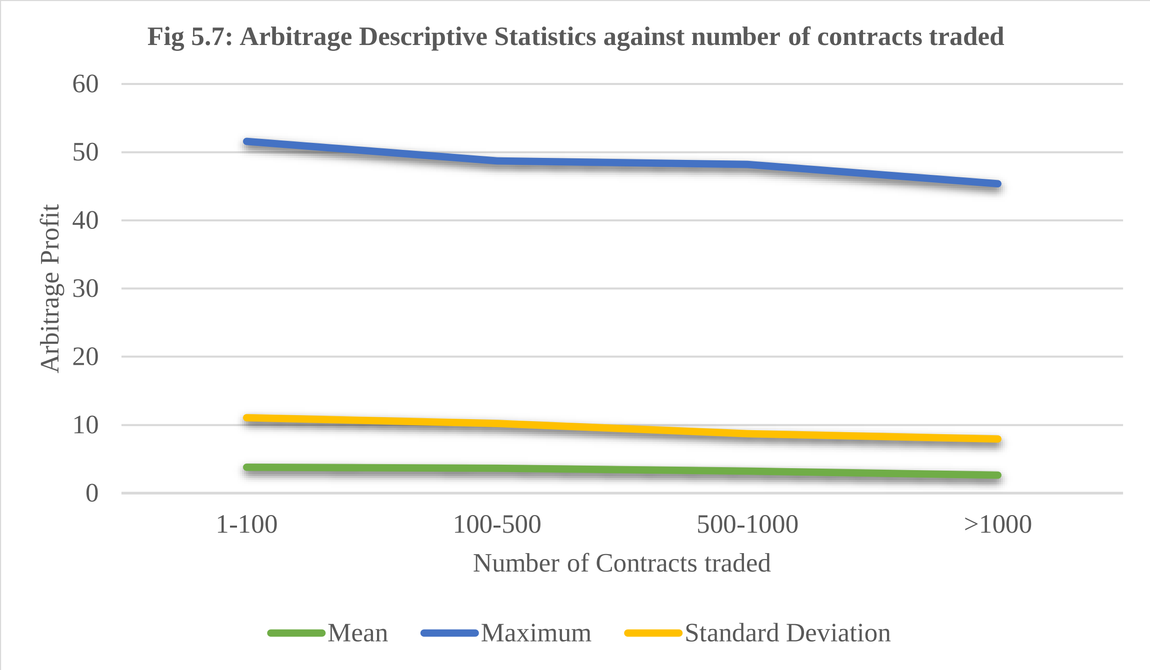


Table 5.8: Arbitrage Profits and Time to Maturity

Time to Maturity		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 30 days	2750	3.19	51.58	0.00	8.46
30 to 60 days	996	3.35	45.37	0.00	7.96
> 60 days	14	4.69	30.63	0.00	5.46

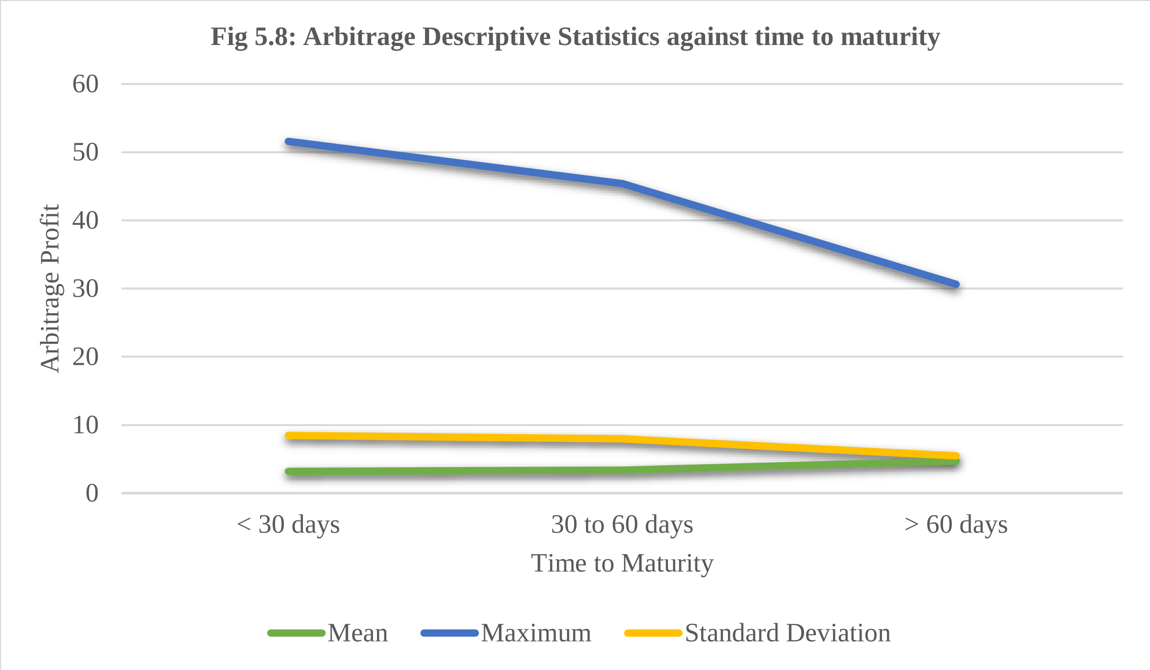
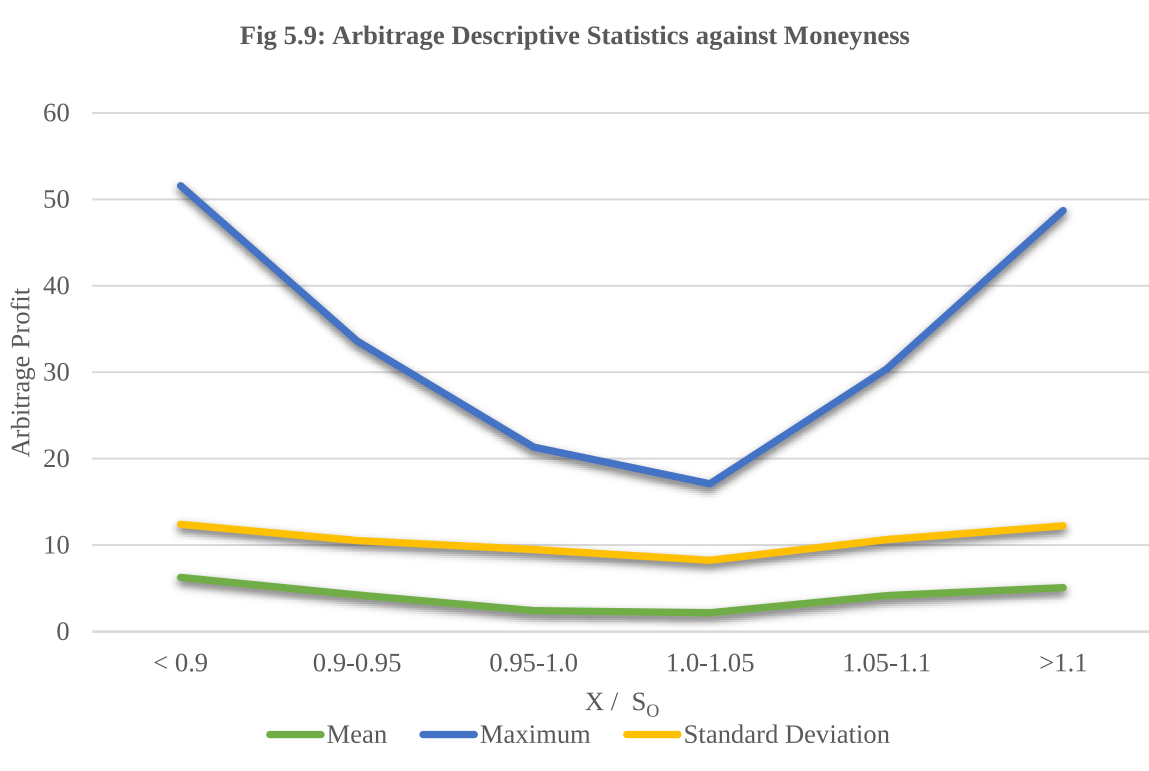


Table 5.9: Arbitrage Profits and Gap between NSE Nifty Value and Exercise Price

If Exercise price is:		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 0.90 S_O	142	6.27	51.58	0.00	12.41
0.90 S_O – 0.95 S_O	524	4.23	33.59	0.00	10.55
0.95 S_O – 1.0 S_O	1107	2.44	21.33	0.00	9.50
1.0 S_O – 1.05 S_O	1109	2.18	17.1	0.00	8.25
1.05 S_O – 1.10 S_O	572	4.18	30.37	0.00	10.64
>1.10 S_O	304	5.10	48.7	0.00	12.22



<u>For SBI</u>

Table 5.10: Arbitrage Profits and Number of Contracts Traded

Number of contracts traded		**Arbitrage Profits Per Contract (in Rupees)**			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
1-100	2506	1.33	17.37	0.00	2.92
100-500	873	1.01	17.01	0.00	2.24
500-1000	441	0.92	15.6	0.00	2.24
>1000	1061	0.73	14.34	0.00	2.24

Fig 5.10: Arbitrage Descriptive Statistics against number of contracts traded

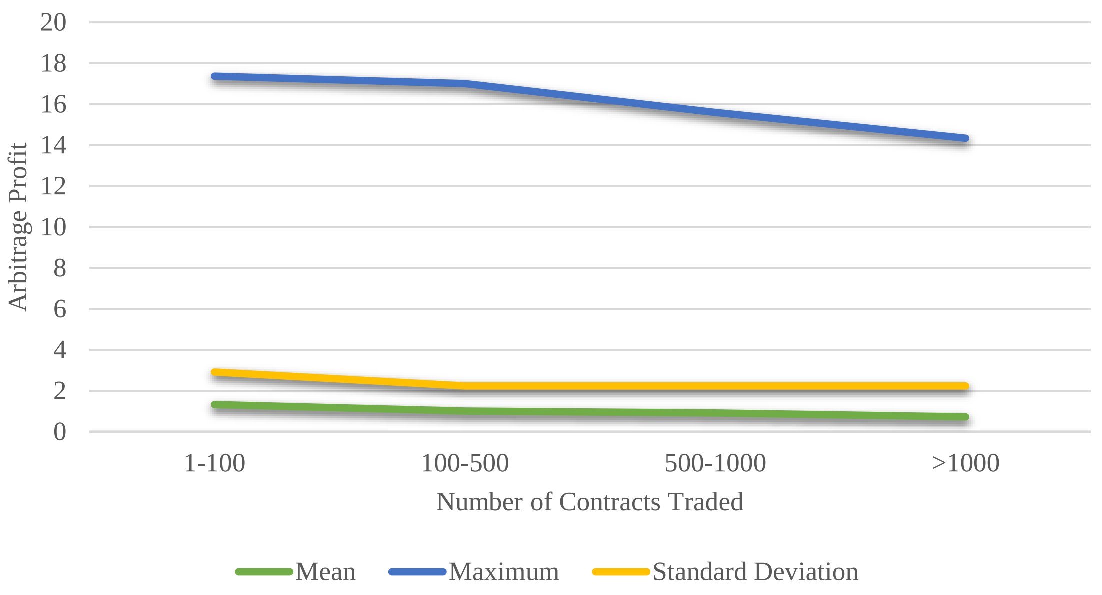


Table 5.11: Arbitrage Profits and Time to Maturity

Time to Maturity		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 30 days	3428	0.96	17.37	0.00	4.52
30 to 60 days	1447	1.44	14.62	0.00	3.92
> 60 days	7	3.09	5.78	0.00	3.68

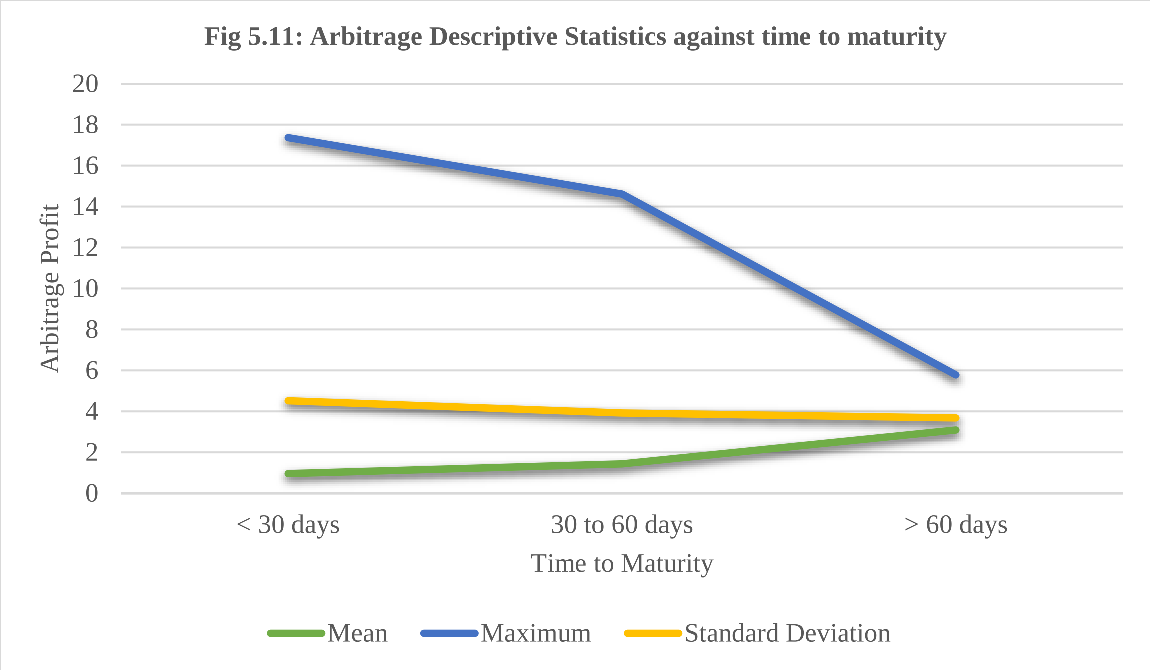
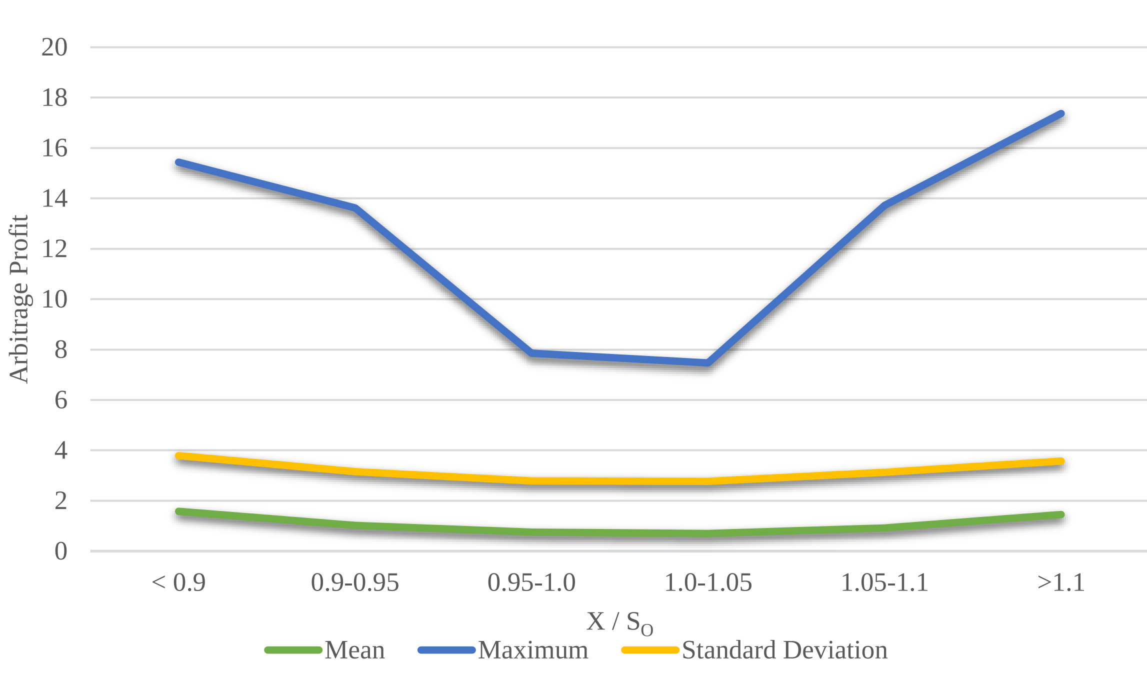


Table 5.12: Arbitrage Profits and Gap between NSE Nifty Value and Exercise Price

If Exercise price is:		**Arbitrage Profits Per Contract (in Rupees)**			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 0.90 S_O	860	1.58	15.44	0.00	3.79
0.90 S_O – 0.95 S_O	651	1.02	13.62	0.00	3.15
0.95 S_O – 1.0 S_O	807	0.75	7.86	0.00	2.79
1.0 S_O – 1.05 S_O	831	0.7	7.47	0.00	2.77
1.05 S_O – 1.10 S_O	611	0.92	13.72	0.00	3.13
>1.10 S_O	1122	1.45	17.37	0.00	3.58

Fig 5.12: Arbitrage Descriptive Statistics against Moneyness



For Vedanta

Table 5.13: Arbitrage Profits and Number of Contracts Traded

Number of contracts traded		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
1-100	1314	1.13	18.13	0.00	3.64
100-500	481	0.72	16.38	0.00	2.92
500-1000	292	0.67	15.43	0.00	2.4
>1000	315	0.66	12.79	0.00	1.96

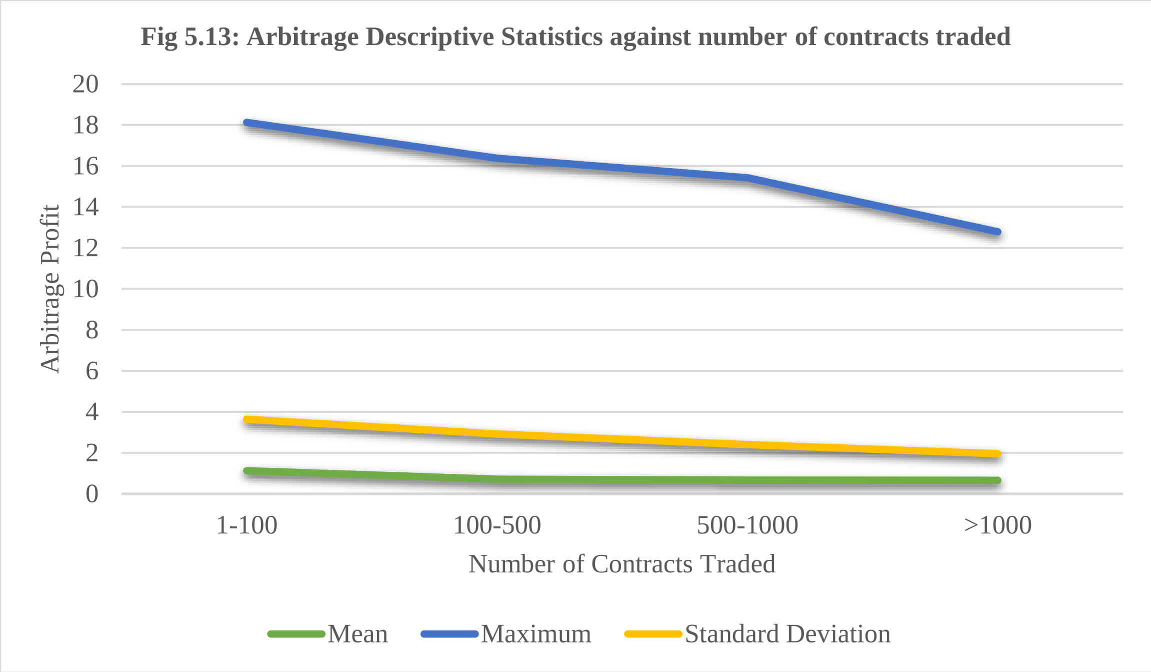


Table 5.14: Arbitrage Profits and Time to Maturity

Time to Maturity		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 30 days	1907	0.88	18.13	0.00	4.7
30 to 60 days	489	1.13	9.1	0.00	3.56
> 60 days	6	2.6	6.6	0.00	3.10

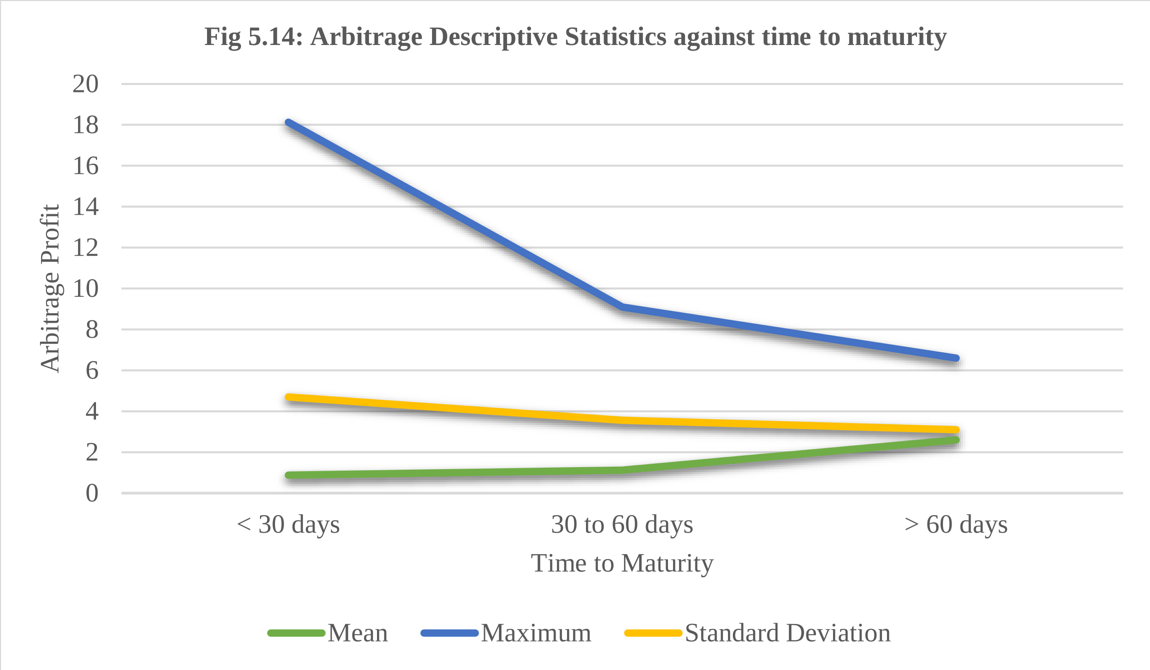


Table 5.15: Arbitrage Profits and Gap between NSE Nifty Value and Exercise Price

If Exercise price is:		Arbitrage Profits Per Contract (in Rupees)			
Range	**Count**	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
< 0.90 S_O	528	1.44	16.38	0.00	3.69
0.90 S_O – 0.95 S_O	381	0.86	10.29	0.00	3.2
0.95 S_O – 1.0 S_O	424	0.61	6.49	0.00	2.78
1.0 S_O – 1.05 S_O	448	0.54	8.08	0.00	2.74
1.05 S_O – 1.10 S_O	290	0.88	12.28	0.00	3.19
>1.10 S_O	331	1.2	18.13	0.00	3.78

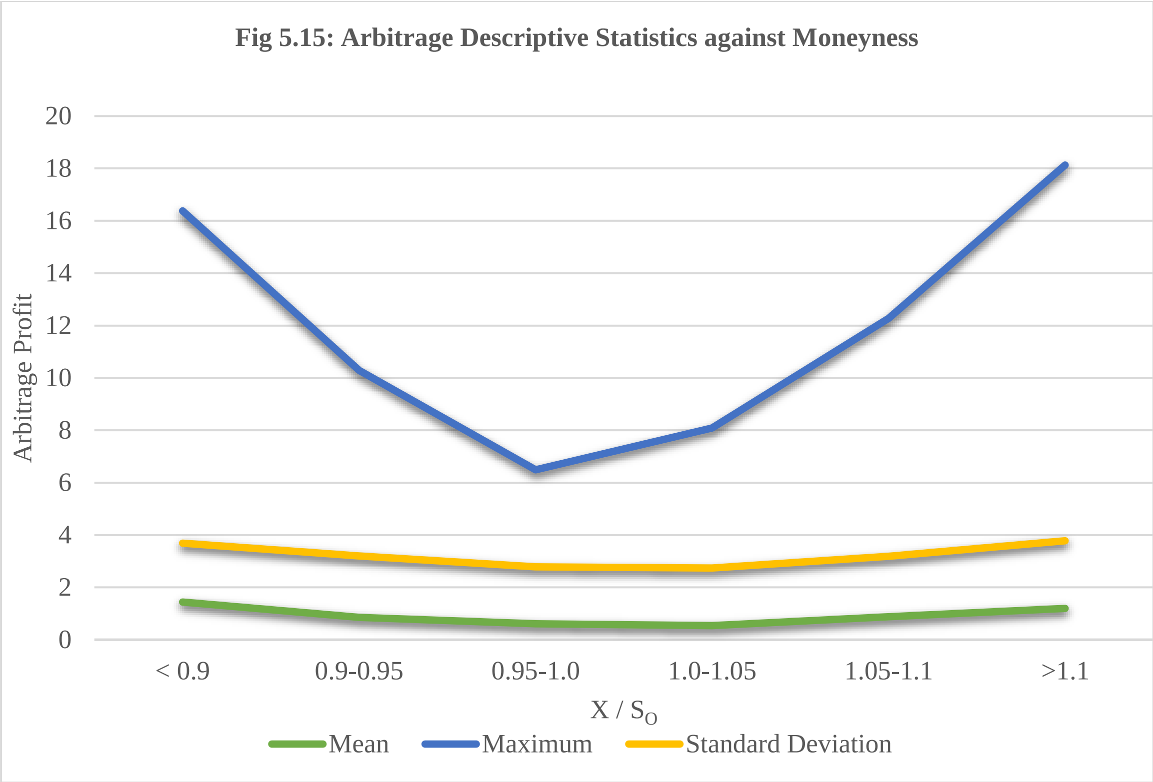


Fig 5.15: Arbitrage Descriptive Statistics against Moneyness
20
18
16
14
12
10
8
6
4
2
0
Arbitrage Profit
< 0.9
0.9-0.95
0.95-1.0
1.0-1.05
1.05-1.1
>1.1
X / S_O
Mean
Maximum
Standard Deviation

6. CONCLUSION

Options have been an important segment of the Indian derivatives market. In the Indian securities market, trading in index option began in June 2001.The index options trading was introduced in the Indian stock market less than four years ago. Yet, there has been spectacular growth in the turnover of index options. The NSE stock options turnover increased from Rs. 25163.00 crores during 2001-02 to Rs. 61,07,485.87 crores during the financial year 2016-17. There are three kinds of participants in the index option market: speculator, hedger and arbitrageur. Hedgers use index options to eliminate the price risk associated with an underlying asset. Speculators use index options to bet on future movement in the price of the underlying asset. Arbitrageurs use index options to take advantage of mispricing. There is a deterministic relationship between call and put prices if both the options are purchased on the same underlying asset and have the same exercise price and expiration date. If the actual call price differs from the theoretical call price (for a given put price) or actual put price differs from the theoretical put price (for a given call price) , there is an arbitrage opportunity and an arbitrageur can set up a risk- less position and earn more than the risk-free rate of return.

The objective of this study is to identify if the put-call parity relationship exists in case of NSE stock options. If there is a violation of this relationship what are factors responsible for this violation. The results show that there is a violation of put-call parity relationship for many NSE stock options.

The most obvious observation from the data is the fact that the quantum of arbitrage profit decreases with increase in the number of contracts traded i.e. increase in liquidity. The arbitrage profits for different ranges of number contracts traded have been shown in Table 5.1, Table 5.4, Table 5.7, Table 5.10, and Table 5.13 for L&T, Maruti, Reliance, SBI, and Vedanta respectively. The results for L&T show that arbitrage profits are more for less liquid options. For number of contracts traded between 1 to 100, the mean arbitrage profit is Rs. 6.37 per stock in a contract as against Rs. 4.41, Rs. 4.02 and Rs. 3.9 for number of contracts traded between 100-500, 500-1000 and greater than 1000 respectively. The results further show that there is the largest variation in the arbitrage profits for the number of contracts traded between 1 to 100. The standard deviation of the arbitrage profits for the number of contracts traded between 1-100 is Rs. 13.48 as against around Rs. 1800 for the number of contracts traded more than 100. Similarly the results for other companies shows that the maximum arbitrage profit, mean arbitrage profit and standard deviation decreases with increase in liquidity except in case of SBI standard deviation is constant for contracts traded between 100-500, 500-1000 and greater than 1000.

These findings are similar to those of Kamara and Miller (1995)[12], Ackert and Tian (1999)[39], and Draper and Fung (2002)[40] for the US and UK markets that mispricing increases with less liquid options.

Table 5.2, Table 5.5, Table 5.8, Table 5.11, and Table 5.14 for L&T, Maruti, Reliance, SBI, and Vedanta respectively shows the arbitrage profit earned for different time to maturity. The results indicate that larger the time to maturity, higher the mean arbitrage profit. The maximum profit earned for different ranges of time to maturity is the highest in case of number of contracts traded less than or equal to 30. It means although the mean profit is low in case of short maturity options, even then there are some options with less time to maturity can earn high amount of arbitrage profits.

Kamara and Miller (1995)[12] for S&P 500 and Draper and Fung (2002)[40] for FTSE-100 found that the Put-Call parity violations to increase with time to expiry.

Further Arbitrage profits earned for different ranges of gap between value of NSE Stock options and exercise price have been shown in Table 5.3, Table 5.6, Table 5.9, Table 5.12, and Table 5.15 for L&T, Maruti, Reliance, SBI, and Vedanta respectively. The results indicate that the arbitrage profits are more when options are deeply in the money or deeply out of the money. The same results hold even for the standard deviation of arbitrage profits.

This implies that arbitrageur can earn higher profits when the strike prices of the options are farther from the current spot price. These results are similar to those of Kamara and Miller (1995)[12], Ackert and Tian (1999)[39], and Draper and Fung (2002)[40] for the US and UK markets.

7.1. LIMITATIONS OF THE STUDY

- The time period for selection Nifty Index option contracts is arbitrary. There may be different outcomes in different time periods.
- In the selected time period there was a major event (i.e. demonetisation of Indian currency) which had a very negative impact on the stock markets. The FII component in the Indian stock market went up considerably which may have had an impact on the prices of the derivatives in the Stock Markets. This study does not take into account these factors.
- The study is limited to one company from five sectors only and therefore the results cannot be generalised for other companies and other sectors.
- The financial statements contain historical information. This information is useful; but an investor should be concerned more about the present and future.

7.2. SCOPE FOR FURTHER STUDIES

The extant study presents a picture of arbitrage opportunity and its factors for a period of time. A study may be conducted to judge the significance of the factors over different time periods in the history of options trading in the Indian stock market and also for companies from different sectors.

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9. ANNEXURE

Sample data for L&T

Symbol	Date	Expiry	Option Type	Strike Price	Call Price	Put Price	No. of contracts	Underlying Value	time to expiry	$C+Xe^{-rt}$	$P+S_O$	Δ	Moneyness
LT	01-Jan-16	28-Jan-16	CE	1200	99.95	6.15	2	1289.2	27	1293.575757	1295.35	1.774243112	0.930809805
LT	01-Jan-16	28-Jan-16	CE	1250	60.15	16.1	56	1289.2	27	1303.510163	1305.3	1.789836575	0.969593546
LT	01-Jan-16	28-Jan-16	CE	1300	31.3	35.85	1248	1289.2	27	1324.39457	1325.05	0.655430038	1.008377288
LT	01-Jan-16	28-Jan-16	CE	1350	14.45	71.7	774	1289.2	27	1357.278976	1360.9	3.621023501	1.04716103
LT	01-Jan-16	28-Jan-16	CE	1400	6.7	110	424	1289.2	27	1399.263383	1399.2	0.063383036	1.085944772
LT	01-Jan-16	28-Jan-16	CE	1500	1.8	205	56	1289.2	27	1493.832196	1494.2	0.36780389	1.163512256
LT	04-Jan-16	28-Jan-16	CE	1200	71.85	13.75	21	1255.95	24	1266.182331	1269.7	3.517669233	0.955452048
LT	04-Jan-16	28-Jan-16	CE	1240	51.5	26.25	2	1255.95	24	1285.643408	1282.2	3.443408459	0.98730045
LT	04-Jan-16	28-Jan-16	CE	1250	39.65	30.3	185	1255.95	24	1283.746178	1286.25	2.503822117	0.99526255

Sample data for Maruti

Symbol	Date	Expiry	Option Type	Strike Price	Call Price	Put Price	No. of contracts	Underlying Value	time to expiry	$C+Xe^{-rt}$	$P+S_O$	Δ	Moneyness
MARUTI	01-Jan-16	28-Jan-16	CE	4500	184	38.9	1	4638.5	27	4660.096588	4677.4	17.3034	0.970141209
MARUTI	01-Jan-16	28-Jan-16	CE	4550	168.65	53.15	1	4638.5	27	4694.480995	4691.65	2.83099	0.980920556
MARUTI	01-Jan-16	28-Jan-16	CE	4600	119.3	70.05	219	4638.5	27	4694.865401	4708.55	13.6846	0.991699903
MARUTI	01-Jan-16	28-Jan-16	CE	4650	91.25	90.4	392	4638.5	27	4716.549808	4728.9	12.3502	1.00247925
MARUTI	01-Jan-16	28-Jan-16	CE	4700	70.45	106.95	922	4638.5	27	4745.484214	4745.45	0.03421	1.013258597
MARUTI	01-Jan-16	28-Jan-16	CE	4800	37.75	205.25	847	4638.5	27	4812.253028	4843.75	31.497	1.03481729
MARUTI	01-Jan-16	28-Jan-16	CE	4950	12.45	327.7	7	4638.5	27	4936.156247	4966.2	30.0438	1.06715533
MARUTI	04-Jan-16	28-Jan-16	CE	4100	480	1	1	4580.65	24	4560.635463	4581.65	21.0145	0.895069477
MARUTI	04-Jan-16	28-Jan-16	CE	4400	212.5	29.95	2	4580.65	24	4591.718546	4610.6	18.8815	0.960562366

Sample data for Reliance

Symbol	Date	Expiry	Option Type	Strike Price	Call Price	Put Price	No. of contracts	Underlying Value	time to expiry	$C+Xe^{-rt}$	$P+S_O$	Δ	Moneyness
RELIANCE	01-Jan-16	28-Jan-16	CE	920	101.25	1.5	1	1015.35	27	1016.36308	1016.85	0.486919719	0.906091496
RELIANCE	01-Jan-16	28-Jan-16	CE	940	83.6	3.05	7	1015.35	27	1018.606843	1018.4	0.206842896	0.925789137
RELIANCE	01-Jan-16	28-Jan-16	CE	960	67.5	5.25	14	1015.35	27	1022.400606	1020.6	1.80060551	0.945486778
RELIANCE	01-Jan-16	28-Jan-16	CE	980	49	8.95	47	1015.35	27	1023.794368	1024.3	0.505631875	0.965184419
RELIANCE	01-Jan-16	28-Jan-16	CE	1000	34.4	14.9	155	1015.35	27	1029.088131	1030.25	1.16186926	0.98488206
RELIANCE	01-Jan-16	28-Jan-16	CE	1020	24.45	23.05	912	1015.35	27	1039.031893	1038.4	0.631893355	1.004579702
RELIANCE	01-Jan-16	28-Jan-16	CE	1040	15.45	33.95	678	1015.35	27	1049.925656	1049.3	0.62565597	1.024277343
RELIANCE	01-Jan-16	28-Jan-16	CE	1060	9.9	46	490	1015.35	27	1064.269419	1061.35	2.919418584	1.043974984
RELIANCE	01-Jan-16	28-Jan-16	CE	1100	3.6	82.3	318	1015.35	27	1097.756944	1097.65	0.106943814	1.083370266

Sample data for SBI

Symbol	Date	Expiry	Option Type	Strike Price	Call Price	Put price	No. of contracts	Underlying Value	$C+Xe^{-rt}$	$P+S_O$	Δ	Moneyness	time to expiry
SBIN	01-Jan-16	28-Jan-16	CE	200	28.5	0.4	2	227.8	227.4376261	228.2	0.762373852	0.877963126	27
SBIN	01-Jan-16	28-Jan-16	CE	205	22.6	0.6	2	227.8	226.5110668	228.4	1.888933198	0.899912204	27
SBIN	01-Jan-16	28-Jan-16	CE	210	17.6	1.05	1	227.8	226.4845075	228.85	2.365492545	0.921861282	27
SBIN	01-Jan-16	28-Jan-16	CE	215	15.5	1.75	3	227.8	229.3579481	229.55	0.192051891	0.94381036	27
SBIN	01-Jan-16	28-Jan-16	CE	220	11.7	2.95	100	227.8	230.5313888	230.75	0.218611237	0.965759438	27
SBIN	01-Jan-16	28-Jan-16	CE	225	8.3	4.6	427	227.8	232.1048294	232.4	0.295170584	0.987708516	27
SBIN	01-Jan-16	28-Jan-16	CE	230	5.85	6.95	2392	227.8	234.6282701	234.75	0.12172993	1.009657594	27
SBIN	01-Jan-16	28-Jan-16	CE	235	3.95	9.75	693	227.8	237.7017107	237.55	0.151710724	1.031606673	27
SBIN	01-Jan-16	28-Jan-16	CE	240	2.65	13.8	1372	227.8	241.3751514	241.6	0.224848622	1.053555751	27

Sample data for Vedanta

Symbol	Date	Expiry	Option Type	Strike Price	Call Price	Put Price	No. of contracts	Underlying Value	time to expiry	$C+Xe^{-rt}$	$P+S_O$	Δ	Moneyness
VEDL	01-Jan-16	28-Jan-16	CE	85	7.05	1.45	2	91.65	27	91.59849111	93.1	1.501508887	0.927441353
VEDL	01-Jan-16	28-Jan-16	CE	90	5.4	3.1	102	91.65	27	94.92193177	94.75	0.171931767	0.981996727
VEDL	01-Jan-16	28-Jan-16	CE	95	3	5.9	259	91.65	27	97.49537242	97.55	0.05462758	1.0365521
VEDL	04-Jan-16	28-Jan-16	CE	85	6.75	2.7	10	88.95	24	91.3485401	91.65	0.301459904	0.95559303
VEDL	04-Jan-16	28-Jan-16	CE	90	4.15	4.95	404	88.95	24	93.72492481	93.9	0.175075192	1.011804384
VEDL	04-Jan-16	28-Jan-16	CE	95	2.3	8	892	88.95	24	96.85130952	96.95	0.098690481	1.068015739
VEDL	04-Jan-16	28-Jan-16	CE	105	0.65	13.35	172	88.95	24	105.1540789	102.3	2.854078942	1.180438449
VEDL	04-Jan-16	28-Jan-16	CE	120	0.15	27.4	7	88.95	24	119.5832331	116.35	3.233233077	1.349072513
VEDL	05-Jan-16	28-Jan-16	CE	85	9.3	1.6	10	92.4	23	93.91522967	94	0.084770327	0.91991342

10. ADHERENCE SHEET

S.No.	Date	Things to be Completed	Mentor's Signature
1	15-02-2017	Title Finalization	
2	01-03-2017	Literature Review & Questionnaire finalization	
3	26-03-2017	Data Collection	
4	13-04-2017	Data Analysis and first draft	
5	24-04-2017	Second Draft	
6	02-05-2017	Final Report	`