Behaviour of Implied Volatility in Indian Market: An Empirical Study

Narain[1], Narander Kumar Nigam[2,*], Piyush Pandey[3]

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1. Assistant Professor, Faculty of Management Studies (FMS), Delhi University, Delhi ,India
2. Assistant Professor, Shaheed Sukhdev College of Business Studies, Delhi University, Delhi ,India
*Corresponding Author Email Address: narandernigam@gmail.com
3. Research Scholar, Department of Financial Studies, Delhi University, Delhi, India

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Abstract

If Black Scholes option pricing model (BSM) hold, then options with same maturity and on the same underlying should have same Implied Volatility **(IV)**, irrespective of strike prices. Empirical researches have shown otherwise and attribute this to the violation of the constant volatility assumption of BSM. In this paper, we estimate **IV** using option prices with different strike prices and examine the relationship between **IV** and moneyness, known as volatility smile and study the potential determinants of **IV.** For this, we use daily data of call and put CNX Nifty Index Options from April 2004 to March 2014. Our results suggest asymmetric volatility across time and strike price using alternative measures of moneyness. We suggest that this is result of the Perceptual Risk Hypotheses developed in the study. Further, it was found that **IV** of lower strike price is significantly higher (lower) than that of higher strike price for call (put) options which we may attribute to the Market Over-reaction Hypotheses. Put **IV** was observed to be higher than call **IV** irrespective of any attributes. Our results further show that current month contracts have significantly higher **IV** than those of next month followed by far month contracts. Nifty futures' volumes and momentum were found to be significant determinants of IV using Vector Autoregression. This study will be helpful to traders, market regulators and investors concerning these markets.

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1. Introduction

It is widely known that the implied volatility derived from the options contracts traded on stock market indices using Black, Scholes and Merton (BSM) option pricing formula is not accurate to fully reflect the option prices traded on the exchanges. Theoretically, investors should not be trading with heterogeneous expectations of the volatility of the underlying, across strike prices or maturity. In other words, given the assumptions of the BSM model, two identical option contracts having different strike prices must exhibit same implied volatility.

However, it has been empirically found across markets that implied volatilities have shown asymmetry with respect to the strikes away from the spot prices. Implied volatilities at the strikes nearest to spot prices (at-the-money) are generally found to be lower than for the strikes away from the spot prices; resulting into so-called “volatility smile” or “smirk”. For US stock market, Rubinstein (1994), Jackwerth and Rubinstein (1996), Dumas et al. (1998) have shown that the implied volatility monotonically decreases as the strike price increases with respect to the current level of the underlying S&P500 index. European stock markets have also shown similar tendencies (Tompkins (1999) for German markets, Pena et al. (1999) for Spanish markets, Beber (2001) for Italian markets, among others. The initial studies done in this area with respect to Indian stock market are exhibiting similar patterns within their limited scope.

Finance theory tries to investigate this behaviour and seek alternative explanation other than represented under the BSM framework. There are two broad categories of such explanations which exist in the theory. Firstly, the assumptions of the BSM model are not valid in practice and hence attributed to implied volatility to explain the difference between theoretical and empirical option prices. Secondly, BSM formula is not complete and hence, should account for some other relevant factors to accommodate smile patterns. As a result, various option pricing approaches have been devised which account for anyone, or both, of these explanations, for example, Stochastic volatility models (Hull & White (1987) and Heston

(1993)), Implied binomial tree or lattice approach (Derman & Kani (1994) and Rubinstein (1994)), Random jump model (Bates (1996)), Non-parametric kernel regression approach (Ait-Sahalia & Lo (1998)), Multifactor model (Bates (2000)), among others. Besides, Dennis (1996) attributes the cause of volatility smile to the presence of transaction costs.

This study focuses on the Index option market in India on its major stock exchange i.e. National Stock Exchange of India (NSE) the largest stock exchange in world in terms of number of index options traded in the calendar year 2013 (World Federation of Exchanges, www.world-exchanges.org). NSE started on its derivatives segment CNX Nifty option contract from June 4, 2001 and has emerged as a market leader with more than 99% of the volume in this segment. The underlying index of the option contract is the primary index of the NSE, CNX Nifty index, comprising of the largest and most liquid 50 stocks listed on the exchange, representing 22 sectors of the Indian economy with 70% of the free float market capitalisation as on March 31, 2014. The Nifty option is a cash settled European option with 3 month trading cycle - the near month (one), the next month (two) and the far month (three). There are quarterly expiry for the long term index option contract which are not been considered in this study due to data insufficiency.

This study examines the relation between implied volatility and moneyness referred to as volatility smile for the Indian option market. The study also explores the potential determinants of the characteristics of the volatility smile. Irrespective of the variants of the implied volatility skewness patterns, “smirk”, “sneer”, etc., this paper uses the common nomenclature of volatility smile.

This paper is organised into following sections, including this introduction segment. Section 2 covers the review of literature. Section 3 discusses the data description and methodology in detail. Section 4 describes the empirical results. The final section provides summary and conclusions.

2. Review of Literature

Many early studies have found a U-shape smile pattern for implied volatility in many options markets prior to the 1987 stock market crash. Macbeth and Mervilli (1979) found in-the-money stock option with a short remaining time to expiration tend to have higher implied volatilities than corresponding options with a longer time to expiration. Sheikh (1991) argued that a U-shaped pattern occurred for the S&P 100 options during various sub-periods between 1983 and 1985. Duque and Paxson (1994) gave evidence of smile pattern in equity call options on LIFFE and relatively high implied volatility for in-the-money options. Bakshi et al. (1997) exhibit a clear U-shaped pattern across moneyness, with the smile pattern evident for options near expiration. Brown and Taylor (1997) used Asay Model on the SPI futures option and found that the model tends to overprice call options and underprice put options. Peña et al. (1999) analyze the determinants of the smile pattern in IV on the Spanish IBEX-35 index from January 1994 to April 1996. The results suggest a bidirectional Granger causality between implied volatility and transaction costs (proxied by the bid-ask spread). Beber (2001) analyzed the potential determinants of the volatility smile using call and put options on the Mib30 Italian stock index from November 1995 to March 1998. Results suggested a causal relationship between implied volatility and time to expiration, the number of transacted option contracts and historical volatility. Malin Engstrom (2002) provides evidence for U-shaped smile pattern from 27 individual stock options traded in the Stockholm Stock Exchange (StSE) during the period from July 1, 1995 to February 1, 1996. Bollen and Whaley (2004) documents a sneer pattern for S&P 500 index options and U-shaped smile pattern from 20 individual stock options traded in the Chicago Board Options Exchange (CBOE) over the period from June 1995 to December 2000.

Studies in the Indian context also have documented the existence of the volatility smile in the Indian options market. Varma (2002) observes mispricing in the Indian index options market and estimates the volatility smile for call & put options and found that is different across option types. Misra, et al. (2006) found that deeply in-the- money and deeply out-of-the-money options have higher implied volatility than at the money options, as well as it is higher for far the month option contracts than for near the month option contracts. Vijaykumar & Sehgal (2008) found evidence of positive smile asymmetry profile after working on daily data for S&P CNX Nifty call and put options for years 2004 and 2005. They further documented that historical volatility and time to expiration are the potential determinants of smile asymmetry in India.

The existing studies fail to provide a conclusive evidence of the smile asymmetry pattern in India because of small sample periods and immaturity of market structure in the initial periods that the studies cover. Also the existing research didn't explicitly study the smile asymmetry pattern across tenure of options and different market conditions. Now that the derivatives segments of the Indian markets has matured, we undertake a decadal study which provides an extensive analysis of examining smile asymmetry patterns across different set of options, tenure of options, measures of moneyness and market conditions.

3. Data and Methodology

The closing prices of call and put options on the CNX Nifty Index traded daily on NSE during the period April 1, 2004 to March 31, 2014 was collected from NSE website: www.nseindia.com. The daily yields on 91-day T-bill rates and the daily data of CNX Nifty Index Futures were collected from Bloomberg. The data for 91 day T-bill was available from 27 November 2003; hence the study period was chosen to start from the next financial year i.e. April 1 2004.

This dataset was also refined as follows to make it fit for further analysis. Firstly, trading days on which no transactions took place were deleted from the sample. Also, options with less than 5 trading days to maturity were excluded in order to avoid extremely large trading activities during last four days of the maturity of the contract. Similarly options with more than 90 trading days to maturity were also excluded to avoid data insufficiency as they were introduced much later on the exchange. A further filtering was also been done to include call contracts where identical put contracts also exists to facilitate comparisons. The final dataset is so chosen to have common sample with risk-free rates data. Therefore, from over 1 million initial observations, we were finally left with 2,417 trading sessions with 63,394 observations each for Call as well as Put contracts, with an average of 26 liquid prices per day.

The Implied Volatility (IV) is inferred from the market data using Black-Scholes (1973) formula, shown below, for each observed European call and put option closing prices. It is the measure of the variation in Index return in either direction and indicates the expensiveness of the option contract for the traders.

$$C = S\,N(d_1) - K\,e^{-rT}\,N(d_2)$$

$$P = K\,e^{-rT}\,N(-d_2) - S\,N(-d_1)$$

wherein

$$d_1 = \frac{\ln(S/K) + (r + 0.5\sigma^2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

Also, S is the stock index closing price, K is the strike price, r is 91 day T-bill yield rate p.a., T is the time to expiration of the option and N(x) represents the normal cumulative density function.

This computed implied volatility was further studied on univariate basis with respect to their contract specification constructs. The level of implied volatility was studied across type of contract (Put, Call) and tenure of the contract expiry (Near month, Next month & Far month). Further implied volatility level was also been studied across different market phases (Upward, Downward and Normalcy). For this purpose (See Chart 1), an upward market phase is defined as a period starting from April 1, 2004 to January 1, 2008 wherein CNX Nifty experienced a constant rise in its level before the advent of global financial crisis. A downward market phase is defined as a period starting from January 2, 2008 to February 27, 2009 wherein CNX Nifty experienced a constant decline in its level before any recovery could start. The third normal market phase is defined as a period starting from February 28, 2009 to March 31, 2014 wherein CNX Nifty has remained more or less stable.

In order to have deeper understanding of the volatility smile in Indian stock index option market, the moneyness of the option contract has been defined in three different ways. First, moneyness of the contract is estimated as the relative value of the difference between Index value and strike price to the Index value (referred as M1 hereafter), i.e. M1 = |(S-K)/S| (Misra et al., 2006). This measure is simple, but it doesn't consider the volatility of the underlying asset and the option's time to expiration. Hence, second measure of moneyness is estimated as the natural logarithm of the ratio of the strike price to the underlying Index value and then further divided by the product of at-the-money implied volatility and the square root of the time to expiration (referred as M2 hereafter, Natenberg,1994; Dumas et al., 1998; Tompkins, 1999; Beber, 2001) i.e.

$$M2 = \frac{\ln(K/S)}{\sigma_{atm}\sqrt{T}}$$

At-the-money implied volatility, σ_{atm}, is computed as the average of implied volatility of a call and a put option with a strike price K* a close as possible to the index value, such that, for each trading session

$$K^* = \arg_k \min(S/K - 1)$$

The third measure of moneyness is estimated as the option's Delta (referred as M3 hereafter), i.e. M3 = $N(d_1)$. This measure is coherent with the Black & Scholes model and reflects both time-to-expiration and volatility. Based on these measures of moneyness, univariate analysis of the level of implied volatility is studied across the moneyness for each of the option contract type.

But, to understand the nature of implied volatility relation with these measures of moneyness, shape of implied volatility function (volatility smile) is estimated using following parsimonious models (Shimko (1993))

$$\text{Model 1:} \qquad Y = \alpha + \beta_1 X + \varepsilon$$

$$\text{Model 2:} \qquad Y = \alpha + \beta_1 X + \beta_2 X^2 + \varepsilon$$

Where Y represents the implied volatility and X represents the moneyness of the options of each type. With such huge database spanning over one full decade covering periods of boom, recession and normalcy, implied volatility was found to be stationary to gain better estimates' which were stable over the decade. The intercept of the models (α) represents a general level of volatility that resides in the implied volatility function. Whereas, slope coefficient β_1 represents the asymmetry in the risk neutral probability density function and slope coefficient β_2 represents the degree of curvature in the implied volatility function.

However, to account for time varying nature of the volatility in the short run, the first model is also estimated on every trading session with sufficient observation; implicitly assuming the stationarity of the volatility during the trading session. These daily regression results were further been averaged to compute the combined parameters for the entire period. However, t-statistic was not directly averaged but computed using the average value of the daily parameter and average standard error (Beber (2001)).

Subsequently the level of implied volatility of the option contracts focuses to explain options' mispricings with the various market related variables. Any deviation of the market price of the option contract from its BSM price solely attributed to the phenomenon of implied volatility might be very much confounding. Hence, there is a need to study the decomposition of the level of implied volatility or at least the factors affecting the level of implied volatility. For the purpose of this study, these factors have been classified into three categories: Firstly, factors relating to market liquidity; Secondly, factors related to characteristics of underlying asset; and Lastly, factors related to investors behaviour.

In the first category of explanatory variables, options' market liquidity related variables are considered. These measures reflect the extent of market frictions to provide any potential explanation for the mispricings. As a measure of market liquidity of index based contracts traded for the trading session, two variables considered are value of options traded (VOPT) and number of futures traded (NFUT). VOPT is defined as the value of CNX Nifty index options traded in a trading session for all strikes of particular option type. Similarly, NFUT is defined as the number of CNX Nifty index futures contracts traded in a trading session. Unlike index futures market, value based liquidity measure of option market was found to be better than number based liquidity measure.

The second category of explanatory variables represents the dynamics of underlying asset. These measures reflect the extent of investor assessments of the underlying stochastic process, as opposed to BSM model, in order to provide any potential explanation for the mispricings. The description of the underlying stochastic process is explained by the expected return from the underlying (RETF), realized volatility in the returns from the underlying (HVOL), the extent of variation in this volatility (VVOL), and the market trends in terms of short term momentum (MOM) & long term market phases (upward or downward, D1 and D2). These variables are been defined as follows. RETF is defined as the logarithmic return from CNX Nifty index futures data series. In contrast to the methodology adopted by few authors (Jackwerth & Rubinstein (1996), Beber (2001)) to derive implied volatility from index futures prices, this variable is considered as a part of explanatory variables to explain the mispricings. For the CNX Nifty index futures price at time t, RETF is computed as:

$$RETF_t = ln\frac{F_t}{F_{t-1}}$$

HVOL is defined as the annualised standard deviation of logarithmic returns on CNX Nifty index closing during previous 20 trading sessions (Assuming 20 trading sessions in a month). This variable tries to contribute towards the relaxation of the assumption of constant volatility assumed in the theoretical option pricing model.

$$HVOL_t = [\sigma(r_t, \ldots\ldots\ r_{t-19})]\sqrt{252}$$

VVOL is defined as the standard deviation of HVOL of the CNX Nifty index closing during previous 20 trading sessions. This variable tries to contribute for the *Vega* risk in hedging activity as an explanation for the mispricings of certain type of options.

$$VVOL_t = \sigma(HVOL_t, \ldots\ldots\ HVOL_{t-19})$$

Short term market trend, MOM, is defined as the natural logarithm of the ratio between the CNX Nifty index value and its 50-day simple moving average. This ratio is positive (negative) in a bullish (bearish) market movement.

$$MOM_t = ln\frac{S_t}{{}^1/_{50}\sum_{i=t-49}^{t} S_i}$$

Whereas, long term market trends are defined in terms of the dummy variable D1 for upward market phase already defined earlier, dummy variable D2 for downward market phase also defined earlier and rest of the period designated as the period of normalcy.

The third category of explanatory variables represents the investor behaviour and practices. This measures reflect the extent of relative demand for out of the money put options which, as argued by market practitioners, drives up prices; thus, providing potential explanation for the option mispricings. The only variable considered under this category is the proportion of the out-of-the-money put contracts (VPUT). VPUT is defined as the value of contracts written on out-of-the-money put options as a percentage of total reported out-of-the-money call and put transactions for the day. This variable also acts as the proxy for the portfolio insurance activity of the fund managers leading to accentuated volatilities (Platen & Schweitzer (1998)) as an explanation of the option mispricings.

$$VPUT_t = \frac{\sum_{i=1}^{k} VP_i}{\sum_{i=1}^{m} VT_i}$$

where VP_i is the value of the out-of-the-money put options contracts traded on day t and VT_i is the value of the out-of-the-money options contracts traded on day t such that k of the total m out-of-the-money options are puts.

All the potential determinants of the implied volatility as well as the at-the-money implied volatility for every trading session were tested for the stationarity of the time series as per Augmented Dickey Fuller Test (ADF) test and were found to be stationary at I(0)[1]. The directions of relationship of implied volatility with its potential determinants were tested with Granger Causality[1]. The measures of market liquidity, value of options traded (VOPT) and number of futures traded (NFUT), were found to be bilaterally causing at-the-money implied volatility. Historical volatility (HVOL) as well as (VVOL) were also been found with bilateral relationship with at-the-money implied volatility. However, short term market trends (MOM) as well as futures' returns (RETF) were found to have Granger caused at-the-money implied volatility unilaterally. These causalities were uniform across the type of option contracts. However, the measure of investor behaviour and practices (VPUT) was found to be in bilateral relationship with at-the-money implied volatility of call options; whereas, it was found to have Granger caused at-the-money implied volatility of put options. This behaviour of the potential determinants has warranted the application of Vector Auto-Regression (VAR) analysis of the level of implied volatilities. The mathematical representation of a VAR is:

$$\mathbf{Y_t = a_1 Y_{t-1}} + \ldots\ldots \mathbf{a_P Y_{t-p}} + \mathbf{bX_t} + \mathbf{e_t}$$

where Y_t is a vector of endogenous variables, X_t is a vector of exogenous variables, a_1, $a_2 \ldots\ldots a_p$ and b are matrices of coefficients to be estimated, and e_t is a vector of innovations that may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables.

The lag lengths for such analysis were selected based on Schwarz Information Criteria. In general, the aforesaid relations were found with one lags with respect to put option contracts as opposed to two lags for the call option contracts. It reflects the extra sensitivity of investors towards downside movement of prices.

4. Empirical Results

4.1 Description of implied volatility

A graphical plot of the implied volatility of the both types of option contracts confirms the existence of the volatility smile for Indian option markets as well (see Chart 2). The pattern of average level of implied volatility at the respective level of moneyness makes the formation of the smile curve somewhat more explicit (see Chart 3). However, it is evident that the smile pattern exists for first as well as second measures of moneyness but the graph is much more flat for the third measure; thereby leading to an impression that the formation of the smile is dependent on the measure of moneyness used in the computations. Hence, a thorough statistical testing of the asymmetry in the smile is warranted.

As the volatility of the underlying asset is generally assumed to be constant, given an information set, but observed to be conditionally time-varying across the trading days, a paired sample test is employed to check whether the out-of-the-money (OTM) average implied volatility for the trading session statistically differs from in-the-money (ITM) average implied volatility for that trading session. This test will also reveal that the smile pattern exhibits the asymmetry across the level of moneyness. As evident form Table 1, implied volatility of the call option contracts are higher for ITM contracts as opposed to OTM contracts at 5 percent level of significance. A reverse pattern is shown for the put contracts. The differences in the degrees of freedom are mainly due to the removal of extreme values out of 2,417 observations (trading sessions).

The pattern of volatility smile is also analyzed from the perspective of contract tenures: short, medium and long. Chart 4 presents the average implied volatility against first measure of moneyness (M1) for both types of option contracts with respect to contracts expiring in the present month (Near month or 30 days), then for contracts expiring in the next month (Next month or 30-60 days) and then for contracts expiring in next to next month (Far month or 60-90 days). As is clear from the chart, the smile pattern exists across different contract tenures. However, the band of volatility smile gets shorter as the tenure lengthens which may be due to the illiquidity bias prevailing for long tenure contracts[2]. Average implied volatility based line charts were so chosen to gauge smile patterns in clear contrasts. Similarly, such graphs were also been prepared with other two measures of moneyness (*viz.* M2 and M3) and again smile patterns were found to be more contrasting with former case. Table 2 presents the same conclusions in statistical terms. Due to non-equality of the variances of implied volatility across contract tenures (see Levene's statistics), a non-parametric comparison of the level of implied volatility across tenures is tested through Kruskal-Wallis test. The test results clearly shows that the level of implied volatility of the Near month contract is highest, followed by that of Next month contracts and further followed by Far month contracts, irrespective of the fact that whether the contracts are call options or put options. Separate test results with only two different contract tenures, although not reported here, also confirm these results.

Another relook at the pattern of volatility smile is made from the perspective of market phases: upward, downward and normal. Chart 5 presents the average implied volatility against first measure of moneyness (M1) for both types of option contracts with respect to contracts existing during rising market (Upward phase), then for contracts existing during falling market (Downward phase) and then for contracts existing during the period of normalcy (Normal phase). As is evident from the chart, the smile pattern exists across different market phases[2]. However, the smile pattern is more skewed to the left during the downward market contributing to the asymmetry of the volatility pattern. Average implied volatility based line charts were so chosen to gauge smile patterns in clear contrasts. Similarly, such graphs were also been prepared with other two measures of moneyness (*viz.* M2 and M3) and again smile patterns were found to be more contrasting with former case. Table 3 presents the same conclusions in statistical terms. Again due to the non-equality of the variances of average implied volatility across market phases (see Levene's statistics), a non-parametric comparison of average implied volatility across market phases is tested through Kruskal-Wallis test. The test results clearly shows that the average implied volatility is highest during the downward phase of the market, irrespective of the fact that whether the contracts are call options or put options. Bilateral test results, although not reported here, also confirms this result and further supports the order of average implied volatility within each type of the option contracts. Hence, lower average implied volatility is observed during upward (normal) phase of the market for the call (put) contracts as opposed to normal (upward) market phase.

Another interesting results with respect to Indian index options market is that the implied volatility of put option contract is statistically higher than that of an identical call option contract. A paired sampled t-test shows that the implied volatility of an average put contract is 4.98 percent higher than that of an identical but call option contract (t-statistic of 29.590 with degree of freedom 63393). Similar results are obtained with other parametric and non-parametric tests subscribing to different test assumptions. This phenomenon exists irrespective of the tenure of the contract (Near, Next and Far month contract) or the phases of the market (Upward, Downward and Normal market)[2].

4.2 Model's estimation

As discussed in the previous section, the typical linear and quadratic models suggested in the literature are used to assess the shape of implied volatility function. Table 4 presents the extent of asymmetry (β_1) as well as amount of curvature (β_2) observed for the volatility smile prevailing in India. As evident from the reported results, volatility smile exists for Indian market as the β_1 coefficients of model 1 is found to be statistically significant for almost all different definitions of moneyness for both put and call option contracts. This certainly indicates that the level of volatility is not constant across different strike prices, resulting in different measures of moneyness. For call option contracts, the level of implied volatility is observed to be higher as the strike price lowered according to first measure of moneyness used for model 1 as well as model 2. This result for second measure of moneyness is the same but that for third measure of moneyness is still in congruence except for model 2. However, for put option contracts, due to general validity of adjusted $\overline{R}^2$ of model 2 for interpretation purposes, it is clear that the level of implied volatility is observed to be higher as the strike price increases. The significance level of the asymmetry coefficient increases drastically when suggestive improvement in the functional relationship, model 2, is carried out. This fact is also been manifested in terms of the improvement in the measure of adjusted $\overline{R}^2$. The positive coefficient of the curvature measured by β_2 clearly signifies a U-shaped smile relationship between implied volatility and moneyness exists for Indian stock market and the relationship is certainly non-linear, if not quadratic. This further signifies that the rate of asymmetry is not constant across moneyness but varies with the level of moneyness observed for the contract.

Given the fact that the implied volatility series was found to be stationary, unlike some studies with shorter periods (Beber (2001)), these results of the asymmetric volatility behaviour across strike prices are fairly stable over the long term. If there are no reason to believe in the stationarity of implied volatility across days, except intra-day, then the daily assessment of implied volatility relationship averaged over the sample period is also been reported in Table 5. The averaged measure of asymmetry in daily implied volatility is not found to be significant. It might be due to either the problem of micronumerocity or validity of the assumption of intra-day stationarity of implied volatility. Hence, these results cannot be considered for further analysis, and also, extension of the analysis has not been done using model 2.

4.3 Potential determinants of implied volatility

In the previous section it was already discussed that the average implied volatility function suffers from the problem of endogeneity. Having determined the lag length structure using Schwarz Information Criterion (SIC), suitable Vector Auto-Regression (VAR) models are designed for each of call contract and put contract respectively. The results are presented in Table 6 and Table 7. In order to understand the determinants of implied volatility, so obtained using strike price, spot price, risk-free rate of return, contract tenure and option premium, VAR regression is run with respect to three categories of factors representing nine variables. Table 6 presents the result of such regression for call option contract with appropriate lagged variables. As is evident from the table, at-the-money implied volatility of the call option can be explained, besides its own lagged terms, by the historical volatility representing the market microstructure related aspects of margin requirements. The measure of market liquidity, NFUT, which acts as proxy for the transaction costs of option trading also explains the at-the-money implied volatility behaviour. This variable also helps in completing the market for derivative traders forming strategies based on options & futures contracts. The validity of the assumptions of Black & Scholes model relating to the distributional attributes of underlying asset is also very important to explain the at-the-money implied volatility. Hence, the attributes of the underlying asset, HVOL, VVOL, RETF and MOM have been found statistically significant. The measure of investor behaviour and varied market microstructure practices has not been found to be effective in explaining the at-the-money implied volatility of call option contracts.

For the put option contracts, as already noted in the previous section, the potential determinants were found to be exerting their influences the next day itself. These exertions are swifter than that for call option contracts reflecting the extra sensitivity of investors towards downside movement of prices. Table 7 presents the result output of VAR regression for put option contract with appropriate shorter lagged variables. As is evident from the table, at-the-money implied volatility of the put option can be explained, besides its own lagged terms, by the historical volatility representing the market microstructure related aspects of margin requirements. The measure of market liquidity (NFUT and VOPT), which acts as proxy for the transaction costs of option trading also explains the at-the-money implied volatility behaviour. These transaction costs contribute to the cost of providing portfolio insurance service of fund managers as well. The distributional attributes of the underlying assets as well as investor behaviour & practices are not so much effective in explaining the at-the-money implied volatility behaviour of the put contracts except market momentum, MOM, factor which may again contribute to the margin requirements during falling markets.

These results contribute to the incompleteness of the Black & Scholes models in fully reflecting the option pricing in actual market conditions.

5. Summary and Conclusions

An underlying asset must exhibit same implied volatility (IV) irrespective of strike prices under standard Black Scholes assumptions. However, empirical researches have shown it otherwise and have attributed this behaviour to the fact that the Black Scholes constant volatility assumption is violated. In this study, world's top index options market *i.e.* National Stock Exchange of India's CNX Nifty index has been studied over the last decade (daily files ranging from April 2004 to March 2014) with respect to the behaviour of IV across contract type, tenure and market phases. Implied volatilities were estimated using option prices with different strike prices and two important dimensions about IV were studied: (1) the relationship between IV and moneyness under three definitions of moneyness, referred to as volatility smile, and (2) the potential determinants of IV. Our results suggest an asymmetric volatility profile across time and strike price using alternative measures of moneyness, thus confirming the consistency of our findings with earlier works globally. Further, it was found that IV of lower strike price is significantly higher (lower) than that of higher strike price for call (put) options. This could be attributed to higher exposure of traders when the markets are low. Secondly, lower strike put options are used as insurance. A third explanation attributed to this finding is the Market Over-reaction Hypothesis implying that a falling market is perceived by the investors as comparatively more risky than an equivalent rise in the market from its current level. In general, we may attribute this to a "*Perceptual Risk Hypothesis*" which we deduced from our empirical analysis and further confirmed from interaction with the industry experts. This perceptual risk refers to an investor's perception of attaining a given strike from the current level of the underlying during the tenure of the contract. Given the spot price of the underlying, the perceptual risk component is locussed around each and every strike available in the market for the underlying. Every trader perceives this risk component for a particular strike price entirely different from every other strike available in the market. This perceptual risk component of the trader accelerates as we go farther from the current level of the underlying, which helps in explaining the formation of smile in the options market. However, as stated earlier, this rate of acceleration is faster during the market downturn as proclaimed by the Market Over-Reaction hypothesis. Thus, there exists a perceived risk component to the IV of the underlying not necessarily included in the volatility of the underlying at the range beyond the at-the-money levels. It was also observed that during recession, underlying asset has relatively higher implied volatility. Our results further show that current month contracts have significantly higher IV than those of next month followed by far month contracts. Put IVs were observed to be higher than call IVs irrespective of any attributes. Due to smile asymmetry, the linear model of IV across moneyness was found to be inadequate. Nonlinearity and endogeneity problems were faced while identifying determinants of IV. Granger causality test was used to ascertain the direction of relationship between at the money (ATM) implied volatility and its various determinants. Vector Auto Regression (VAR) model indicated that historical volatility, Nifty volumes and momentum are significant determinants for both call and put options with high explanatory power. In this way, this study provides useful insights for traders, market regulators and investors.

Notes:

1. For the paucity of space, ADF and Granger Causality results have not been reproduced here. They can be accessed on request.

2. Although, the scatter plots of all such contracts were also been prepared, but due to paucity of space, these graphs have not been reproduced here. They can be accessed on request.

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Chart 1: Level of CNX Nifty during sample period

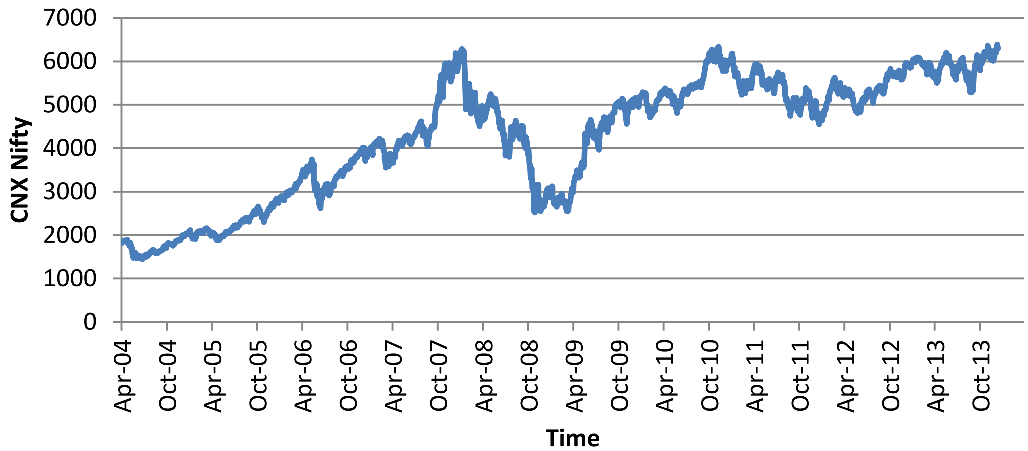


Chart 2: Implied Volatility (IV) of option contracts with their moneyness (M)

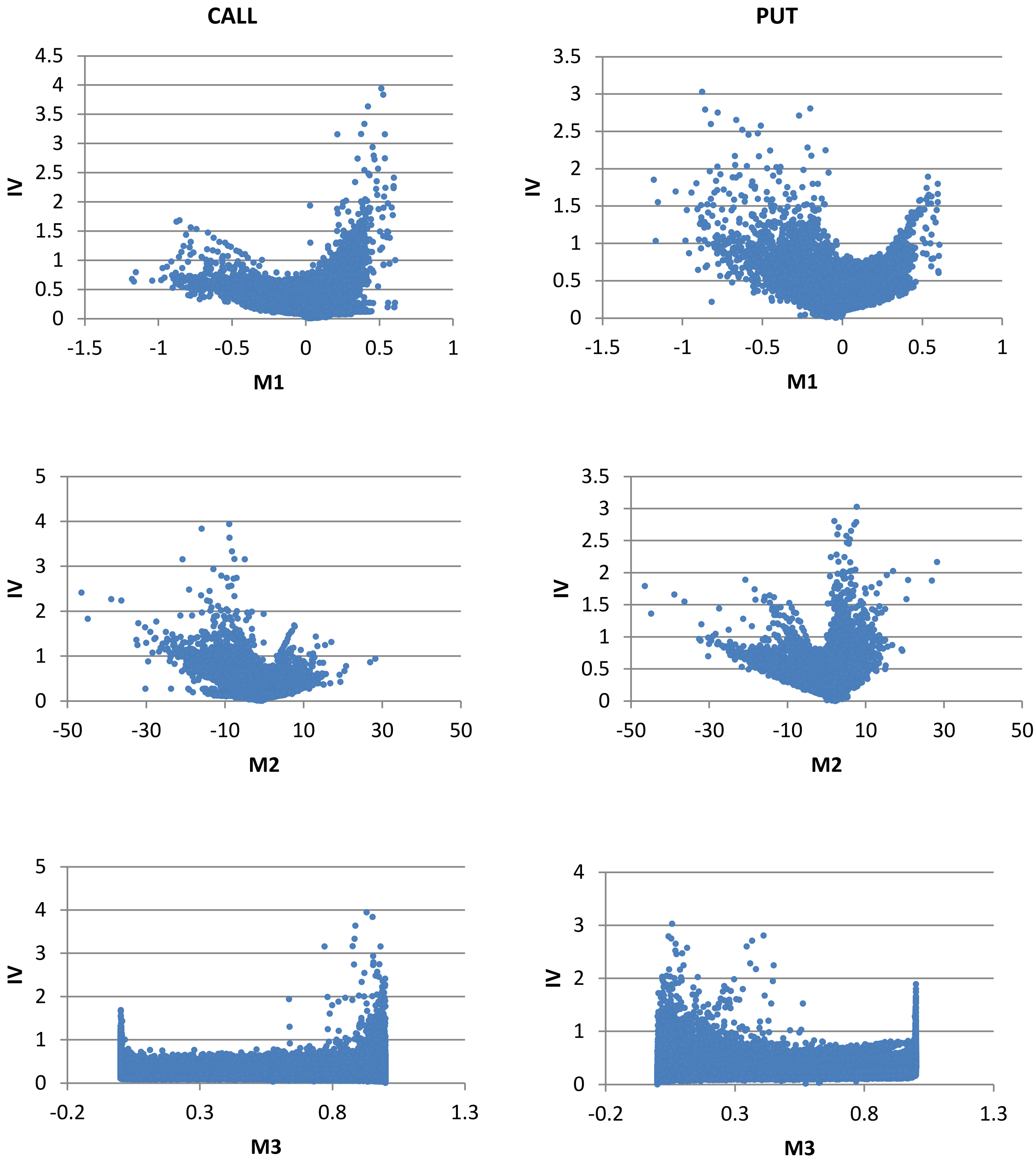
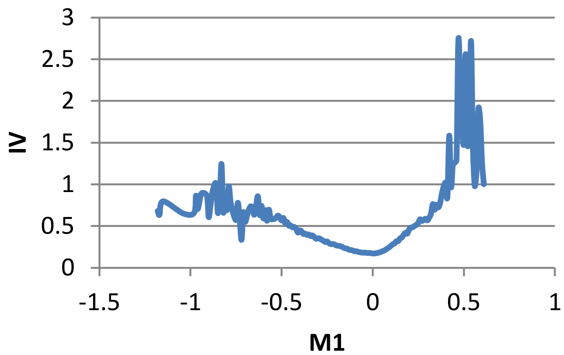
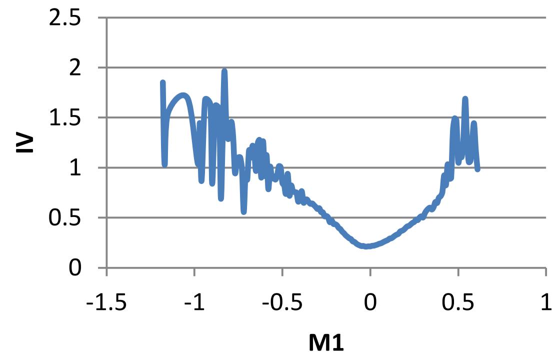


Chart 3: Average Implied Volatility (IV) of option contracts with their moneyness (M)

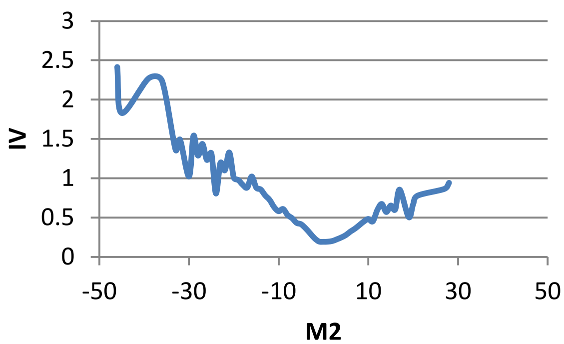
CALL **PUT**

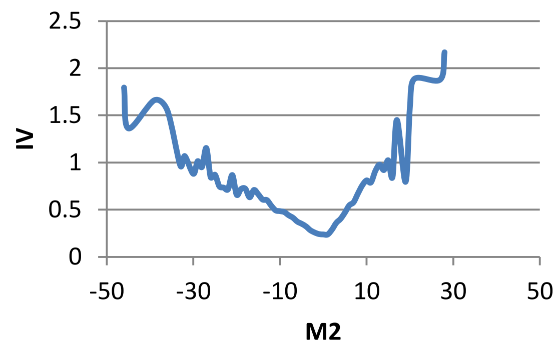
Moneyness 1



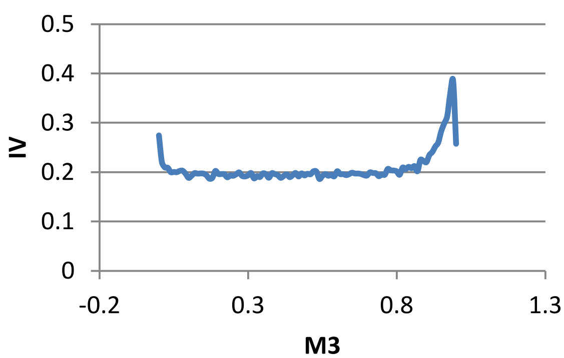


Moneyness 2





Moneyness 3



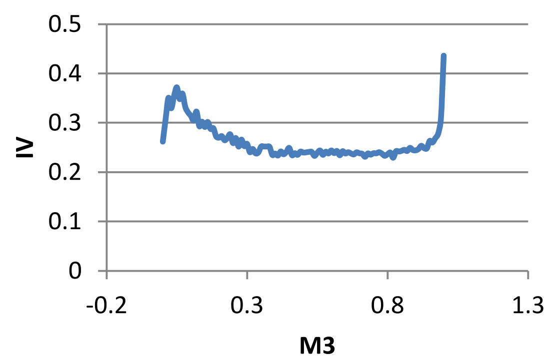
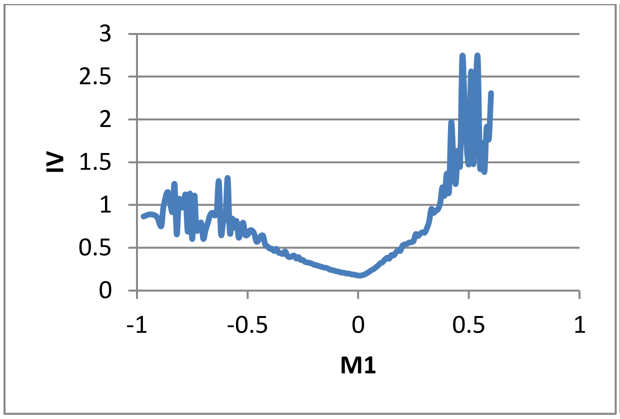
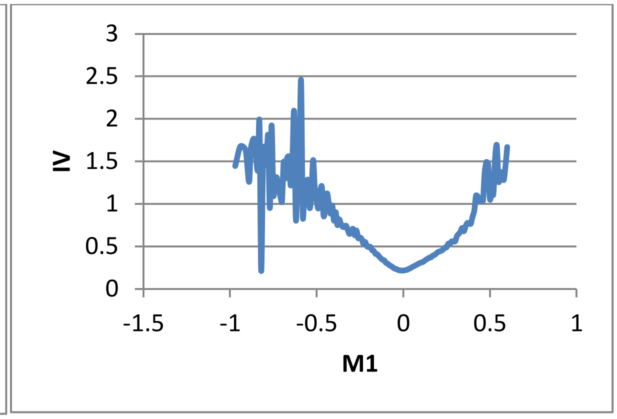


Chart 4: Average Implied Volatility (IV) of option contracts of different tenures

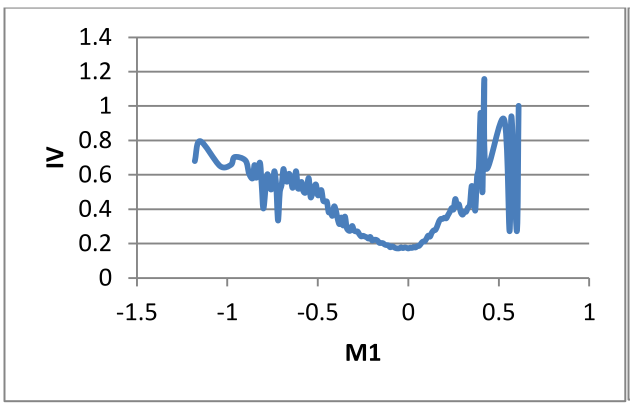
CALL **PUT**

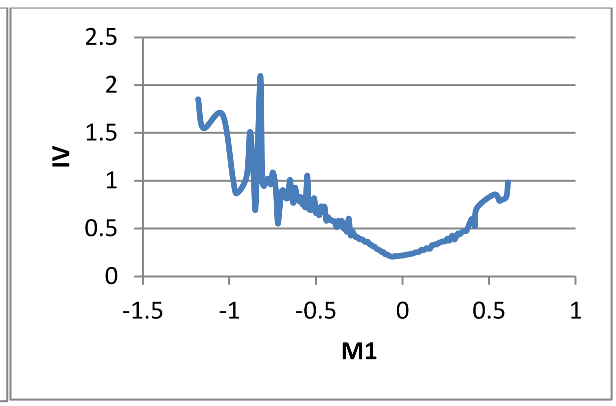
Near month



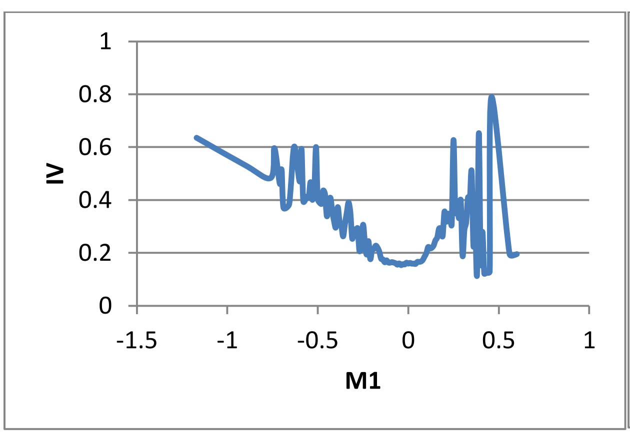


Next month





Far month



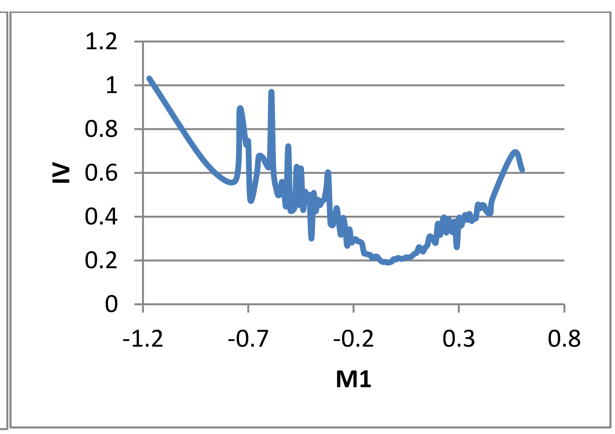
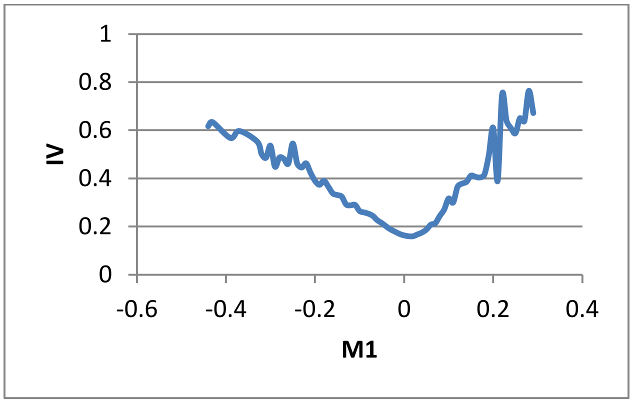
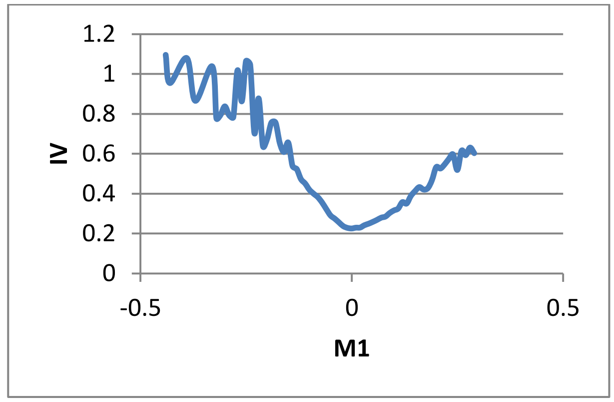


Chart 5: Average Implied Volatility of option contracts under different market phases

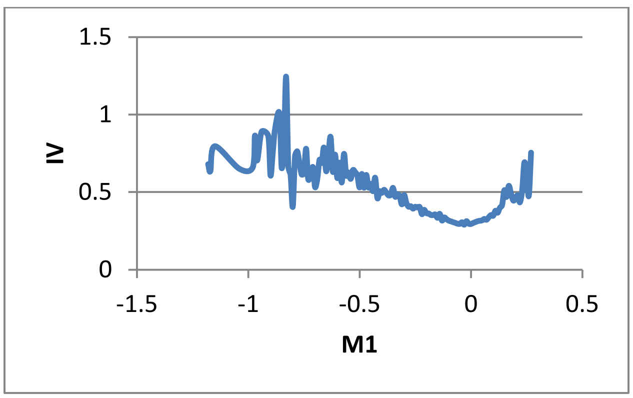
CALL **PUT**

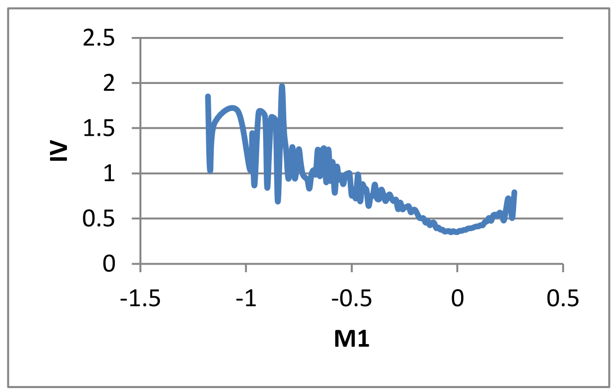
Upward phase



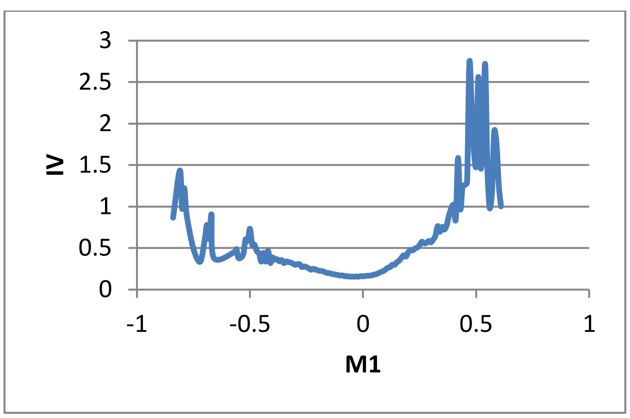


Downward phase





Normal phase



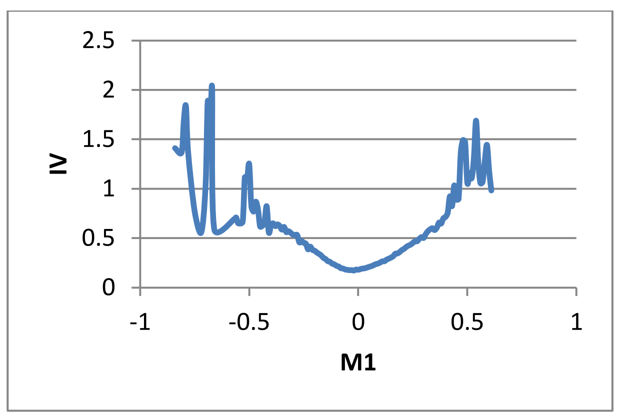


Table 1: Paired sample statistics of the option contracts across their moneyness

Implied volatility of in-the-money option minus implied volatility of out-of-the-money option							
CALL				**PUT**			
Mean	t-statistic	d.o.f	Sig. (2-tailed)	Mean	t-statistic	d.o.f	Sig. (2-tailed)
M1							
0.0256	17.378	2367	.000	-0.0083	4.383	2367	.000
M2							
0.0256	17.378	2367	.000	-0.0083	4.383	2367	.000
M3							
0.0223	16.231	2356	.000	-0.0103	1.843	2345	.066

The table summarises the paired t-test of each of the type of the contract, i.e. Call & Put contracts, compared with averaged implied volatility of the options contracts where are in-the-money with that of the out-of-the-money contracts averaged for the same day. To determine the contract as in-the-money, at-the-money or out-of-the-money three definition of the level of moneyness is used as described in the text, i.e. M1, M2 and M3.

Table 2: Tests of implied volatility of the option contracts across their tenures

	CALL			PUT		
	Near month	Next month	Far month	Near month	Next month	Far month
Test of Homogeneity of Variances of implied volatility						
Levene Statistics	2091.249			132.314		
p-value	.000			.000		
Kruskal-Wallis test of equality of implied volatility across contract tenures						
Mean Rank	35391.51	29713.39	23803.55	35480	30028.86	24411.27
No. of observations	29987	23139	10268	29987	23139	10268
Kruskal-Wallis test statistics	3787.667			3101.117		
p-value	.000			.000		

The first panel of this table describes the test of homogeneity of variance fundamental to conduct the test of equality of Mean implied volatility of contracts with three different tenures viz. Near, Next and Far month. This testing is done for both the types of option contracts, i.e. Call and Put. The second panel describes the result of the non-parametric test equivalent to the F-test to test the equality of implied volatility across such tenures.

Table 3: Tests of Average implied volatility of the option contracts across market phases

	CALL			PUT		
	Upward	Downward	Normal	Upward	Downward	Normal
Test of Homogeneity of Variances of average implied volatility						
Levene Statistics	29.376			56.907		
p-value	.000			.000		
Kruskal-Wallis test of equality of average implied volatility across market phases						
Mean Rank	970.85	2043.69	1197.27	1176.56	2083.31	1034.79
No. of observations	914	278	1225	914	278	1225
Kruskal-Wallis test statistics	504.479			514.652		
p-value	.000			.000		

The first panel of this table describes the test of homogeneity of variance fundamental to conduct the test of equality of Mean implied volatility of contracts under three different market conditions viz. Near, Next and Far month. This testing is done for both the types of option contracts, i.e. Call and Put. The second panel describes the result of the non-parametric test equivalent to the F-test to test the equality of implied volatility across such tenures.

Table 4: Relationship between implied volatility and moneyness across options

(based on HAC consistent Newey-West method for Linear (model1) and Quadratic (model2) models)

Option Type	Model	No. of observations	α (*t*-statistics)	β_1 (*t*-statistics)	β_2 (*t*-statistics)	Adj. $\bar{R}^2$
Moneyness measure M1						
Call						
	Model 1	63394	0.2260 (123.0867)	0.2167 (6.4191)	---	0.0269
	Model 2	63394	0.1965 (104.0376)	0.4756 (18.3826)	2.3520 (18.4592)	0.3496
Put						
	Model 1	63394	-0.0388 (-0.5540)	0.3104 (4.3530)	---	0.0067
	Model 2	63394	2.9191 (13.6430)	-5.3765 (-11.6777)	2.6951 (10.9924)	0.0578

Moneyness measure M2						
Call						
	Model 1	63394	0.2220 (131.0617)	-0.0211 (-17.7973)	---	0.1376
	Model 2	63394	0.2091 (113.0292)	-0.0099 (-10.2251)	0.0019 (11.9485)	0.2697
Put						
	Model 1	63394	0.2740 (99.9879)	-0.0006 (-0.4688)	---	-0.000003
	Model 2	63394	0.2593 (95.2420)	0.0122 (10.1395)	0.0022 (12.8773)	0.0210

Moneyness measure M3						
Call						
	Model 1	63394	0.1972 (73.3955)	0.0520 (10.7334)	---	0.0138
	Model 2	63394	0.2433 (81.6697)	-0.3187 (-25.8818)	0.3762 (26.6187)	0.0641
Put						
	Model 1	63394	0.2859 (61.5645)	-0.0225 (-2.4349)	---	0.0002
	Model 2	63394	0.3618 (60.7848)	-0.5155 (-17.3538)	0.4872 (13.9699)	0.0092

The table presents the Heteroscedasticity and Autocorrelation Consistent (HAC) regression results of implied volatility with moneyess in three different panels each with the three different measures of moneyness. Each panel reports separate results of Call and Put option contracts with two models, linear (Model 1) and quadratic (Model 2).

Table 5: Average daily relationship between implied volatility and moneyness across options

Option Type	No. of estimated OLS models	Average observations	$\bar{\alpha}$ (t-statistics)	$\overline{\beta_1}$ (t-statistics)
Moneyness measure M1				
Call	2414	20.69	0.2029 (17.1105)	0.2029 (1.3195)
Put	2414	26.26	0.2615 (1.6126)	-0.0175 (-0.1106)
Moneyness measure M2				
Call	2414	26.26	0.1906 (20.1472)	-0.0057 (-0.8679)
Put	2414	26.26	0.2422 (19.8966)	0.0054 (0.6120)
Moneyness measure M3				
Call	2414	26.26	0.1822 (6.7115)	0.0362 (0.8737)
Put	2414	26.26	0.2487 (8.3799)	0.0159 (0.2906)

The table presents the simple OLS regression results of implied volatility of Call and Put option contracts with respect to moneyness in three different panels each with the three different measures of moneyness. Such regressions are run on daily data and then the intercept and slope coefficients are averaged across the entire sample period.

Table 6: VAR Regression results for call options

Vector Autoregression Estimates
Included observations: 2412
Standard errors in ( ) & t-statistics in [ ]

	ATM_IV	HVOL	NFUT	VPUT	VOPT	VVOL
ATM_IV(-1)	0.622932	0.062423	1.16E+08	-0.247241	2442385.	0.010224
	(0.02122)	(0.01489)	(3.0E+07)	(0.14323)	(871542.)	(0.00342)
	[29.3524]	[4.19309]	[3.84653]	[-1.72622]	[2.80237]	[2.98601]
ATM_IV(-2)	0.219260	0.023639	2433789.	0.108389	-884537.4	-0.005109
	(0.02141)	(0.01502)	(3.0E+07)	(0.14449)	(879248.)	(0.00345)
	[10.2409]	[1.57396]	[0.07987]	[0.75013]	[-1.00602]	[-1.47914]
HVOL(-1)	0.221673	1.024351	2.07E+08	-0.357564	-48070.28	-0.003452
	(0.02879)	(0.02020)	(4.1E+07)	(0.19431)	(1182415)	(0.00465)
	[7.69901]	[50.7176]	[5.05961]	[-1.84013]	[-0.04065]	[-0.74324]
HVOL(-2)	-0.162726	-0.099518	-1.94E+08	0.318592	105863.8	0.006885
	(0.02778)	(0.01949)	(4.0E+07)	(0.18750)	(1140951)	(0.00448)
	[-5.85707]	[-5.10637]	[-4.91677]	[1.69915]	[0.09279]	[1.53594]
NFUT(-1)	-2.42E-12	2.28E-11	0.502388	1.43E-10	-0.006210	-2.76E-12
	(1.5E-11)	(1.1E-11)	(0.02150)	(1.0E-10)	(0.00062)	(2.4E-12)
	[-0.15993]	[2.15105]	[23.3625]	[1.40171]	[-10.0081]	[-1.13094]
NFUT(-2)	3.86E-11	-9.09E-12	0.198947	6.00E-11	0.001225	3.56E-12
	(1.6E-11)	(1.1E-11)	(0.02209)	(1.0E-10)	(0.00064)	(2.5E-12)
	[2.48936]	[-0.83446]	[9.00477]	[0.57229]	[1.92101]	[1.42247]
VPUT(-1)	-0.000537	-0.002596	9773670.	0.268128	134149.6	-0.000814
	(0.00348)	(0.00244)	(4957941)	(0.02351)	(143056.)	(0.00056)
	[-0.15415]	[-1.06242]	[1.97132]	[11.4051]	[0.93774]	[-1.44806]
VPUT(-2)	0.003737	-0.004167	1255327.	0.136804	-66050.59	-0.000243
	(0.00320)	(0.00224)	(4548487)	(0.02157)	(131242.)	(0.00052)
	[1.16938]	[-1.85860]	[0.27599]	[6.34292]	[-0.50327]	[-0.47075]
VOPT(-1)	-8.87E-10	-5.75E-10	1.530580	5.77E-10	0.551220	4.22E-11
	(5.2E-10)	(3.7E-10)	(0.74646)	(3.5E-09)	(0.02154)	(8.5E-11)
	[-1.69113]	[-1.56281]	[2.05046]	[0.16304]	[25.5926]	[0.49827]
VOPT(-2)	6.35E-12	6.38E-10	-3.821672	-5.83E-09	0.176325	-7.92E-11
	(5.1E-10)	(3.6E-10)	(0.73082)	(3.5E-09)	(0.02109)	(8.3E-11)
	[0.01237]	[1.77176]	[-5.22932]	[-1.68346]	[8.36182]	[-0.95620]
VVOL(-1)	0.210734	0.573167	4.14E+08	-0.550156	-1852295.	1.586195
	(0.09926)	(0.06963)	(1.4E+08)	(0.66987)	(4076180)	(0.01601)
	[2.12311]	[8.23204]	[2.92903]	[-0.82129]	[-0.45442]	[99.0538]
VVOL(-2)	-0.233271	-0.532331	-3.64E+08	0.414402	1618976.	-0.627735
	(0.09936)	(0.06970)	(1.4E+08)	(0.67058)	(4080494)	(0.01603)
	[-2.34768]	[-7.63746]	[-2.57451]	[0.61798]	[0.39676]	[-39.1590]
C	0.011038	-0.000291	32654301	0.292345	1660084.	-0.000115

	(0.00322)	(0.00226)	(4584301)	(0.02174)	(132275.)	(0.00052)
	[3.42682]	[-0.12885]	[7.12307]	[13.4487]	[12.5502]	[-0.22161]
D1	-0.000322	0.003418	-39903980	0.056466	-1507502.	0.000384
	(0.00226)	(0.00159)	(3220252)	(0.01527)	(92917.1)	(0.00037)
	[-0.14246]	[2.15378]	[-12.3916]	[3.69789]	[-16.2242]	[1.05262]
D2	0.010762	-0.000526	-23301910	0.030553	-1111398.	-0.000102
	(0.00259)	(0.00182)	(3688772)	(0.01749)	(106436.)	(0.00042)
	[4.15237]	[-0.28939]	[-6.31698]	[1.74674]	[-10.4420]	[-0.24474]
MOM(-2)	0.020601	-0.025713	71121124	0.224290	213695.0	-0.000446
	(0.01045)	(0.00733)	(1.5E+07)	(0.07054)	(429218.)	(0.00169)
	[1.97103]	[-3.50708]	[4.78109]	[3.17977]	[0.49787]	[-0.26432]
RETF(-1)	-0.268839	-0.039673	1.17E+08	0.502193	-3408590.	-0.003216
	(0.03680)	(0.02581)	(5.2E+07)	(0.24834)	(1511132)	(0.00594)
	[-7.30603]	[-1.53699]	[2.23552]	[2.02224]	[-2.25565]	[-0.54176]
R-squared	0.909945	0.980471	0.778237	0.242277	0.808933	0.983595
Adj. R-squared	0.909343	0.980340	0.776756	0.237215	0.807656	0.983485
F-statistic	1512.491	7515.175	525.3015	47.86170	633.7412	8974.792
Schwarz SC	-4.469154	-5.178296	37.68328	-0.650422	30.59227	-8.117724
Schwarz criterion		49.66381				

The table presents the Vector Auto-Regression results for the Call option contracts with respect to potential determinants of at-the-money implied volatility (ATM_IV). The other variables considered are historical volatility (HVOL), volume of Nifty futures traded (NFUT), value of out-of-the-money put contracts (VPUT), value of options traded (VOPT), variation in the historical volatility (VVOL), momentum (MOM) and return on futures series (RETF). Besides, two dummy variables representing bullish market (D1) and bearish market (D2) were also considered. The last four variables, including dummy variables, were exclusively considered as independent variables. The number in parenthesis along the variables represents the lag term.

Table 7: VAR Regression results for put options

Vector Autoregression Estimates
Included observations: 2414
Standard errors in ( ) & t-statistics in [ ]

	ATM_IV	HVOL	NFUT	VOPT	VVOL
ATM_IV(-1)	0.719244	0.085576	1.43E+08	-19037.17	0.015695
	(0.01657)	(0.00896)	(1.8E+07)	(479024.)	(0.00258)
	[43.3947]	[9.55525]	[7.91823]	[-0.03974]	[6.07309]
HVOL(-1)	0.102177	0.921527	18206429	-220397.3	-0.004136
	(0.01150)	(0.00622)	(1.2E+07)	(332477.)	(0.00179)
	[8.88194]	[148.250]	[1.45721]	[-0.66290]	[-2.30563]
NFUT(-1)	8.29E-11	2.00E-11	0.640377	-0.001988	-3.41E-12
	(1.4E-11)	(7.7E-12)	(0.01545)	(0.00041)	(2.2E-12)
	[5.83020]	[2.60420]	[41.4553]	[-4.83657]	[-1.53603]
VOPT(-1)	-1.60E-09	5.37E-10	-4.268237	0.637361	3.94E-11
	(5.5E-10)	(3.0E-10)	(0.60006)	(0.01597)	(8.6E-11)
	[-2.89306]	[1.79777]	[-7.11307]	[39.9150]	[0.45686]
VVOL(-1)	0.022187	0.043577	37307608	-317516.8	0.973768
	(0.02979)	(0.01610)	(3.2E+07)	(861055.)	(0.00465)
	[0.74469]	[2.70690]	[1.15299]	[-0.36875]	[209.618]
C	0.018559	-0.004594	38528382	1639340.	-0.000227
	(0.00383)	(0.00207)	(4155018)	(110569.)	(0.00060)
	[4.85120]	[-2.22234]	[9.27274]	[14.8265]	[-0.38087]
D1	0.015826	0.001058	-56620219	-1174333.	-0.000492
	(0.00276)	(0.00149)	(2997345)	(79761.9)	(0.00043)
	[5.73458]	[0.70951]	[-18.8901]	[-14.7230]	[-1.14423]
D2	0.021044	-0.000362	-32482826	-898371.4	-0.000543
	(0.00321)	(0.00173)	(3483171)	(92690.1)	(0.00050)
	[6.56148]	[-0.20918]	[-9.32565]	[-9.69220]	[-1.08559]
MOM(-2)	-0.061925	-0.016641	1.09E+08	-529973.6	0.002962
	(0.01360)	(0.00735)	(1.5E+07)	(393001.)	(0.00212)
	[-4.55398]	[-2.26477]	[7.38454]	[-1.34853]	[1.39709]
VPUT(-1)	0.007725	-0.004680	13666369	-315067.9	-0.001883
	(0.00433)	(0.00234)	(4700196)	(125076.)	(0.00067)
	[1.78497]	[-2.00116]	[2.90762]	[-2.51901]	[-2.79038]
RETF(-1)	-0.058326	0.011371	1.61E+08	1016986.	0.011058
	(0.04673)	(0.02525)	(5.1E+07)	(1350676)	(0.00729)
	[-1.24804]	[0.45029]	[3.16869]	[0.75295]	[1.51753]
R-squared	0.877152	0.979560	0.772289	0.744116	0.972957
Adj. R-squared	0.876640	0.979475	0.771341	0.743051	0.972844
F-statistic	1715.769	11516.21	814.9839	698.7983	8645.456
Schwarz SC	-3.921327	-5.152430	37.69034	30.43746	-7.638100
Schwarz criterion		51.30556			

The table presents the Vector Auto-Regression results for the Put option contracts with respect to potential determinants of at-the-money implied volatility (ATM_IV). The other variables considered are historical volatility (HVOL), volume of Nifty futures traded (NFUT), value of options traded (VOPT), variation in the historical volatility (VVOL), value of out-of-the-money put contracts (VPUT), momentum (MOM) and return on futures series (RETF). Besides, two dummy variables representing bullish market (D1) and bearish market (D2) were also considered. The last five variables, including dummy variables, were exclusively considered as independent variables. The number in parenthesis along the variables represents the lag term.