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# IMPLIED VOLATILITY SMILE PATTERNS: EVIDENCE FROM NIFTY 50 INDEX OPTIONS

Dr. V. Srividya, Ms. D. Susana

PSG Institute of Management, PSG College of Technology, Coimbatore- 641004

## 1. INTRODUCTION

Volatility in financial markets has garnered the attention of researchers, practitioners, academicians and policy regulators. The reason for this widespread interest in stock market volatility can be attributed to the fact that changes in market volatility can have important effect on capital investment, consumption and other business cyclic variables (Schwert, 1989). Volatility serves as an indicator for the vulnerability of financial markets and the economy. Hence policy makers often rely on market estimates of volatility for policy framework. (Poon and Granger, 2003). In stock markets traders, investors and portfolio managers are apprehensive about the aberrant volatility in assets prices and expect for certainty in prices in order to anticipate future price movements before making investment decisions to realize possible gains. Volatility over a future period can be considered as risk and hence estimation of volatility is needed as a measure at present times (Engle, 2004). In order to express uncertainty in an economically meaningful way, the conventional mode of interpretation of uncertainty is in terms of volatility or the variance in historical returns of the assets (Koutmos, 2011).

Derivatives, a phenomenal financial innovation during the past decades have been an effective solution to hedge risks or uncertainty in the financial markets. Derivatives are basically financial contracts that derive their value from the performance of underlying assets, i.e. equities or bonds, over a period of time. Derivatives are aimed to mitigate risk by providing commitment to prices at future dates and giving protection against adverse movement of future prices. Traders can benefit by taking highly leveraged positions of the underlying assets at low transaction costs in the stock markets by entering into the derivatives contracts. Apart from hedging benefit, derivatives offer a wide spectrum of other advantages for traders, investors and practitioners inclusive of price discovery, enhancement of liquidity (Acharya et al., 2012) and speculation on future direction of the market. Apparently, derivatives are cited as the innovation in the era of financial deregulation (Turbeville, 2013), the ultimate financial innovation (Acharya et al., 2012). As noted by Tripathy et al. (2009) derivatives has brought in substantial gains in terms of trading

  

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volumes and market capitalization by drawing in greater participation of risk averse investors. The types of derivative contracts vary from options, swaps, swaptions, forwards and futures. Amidst the diverse class of financial derivatives, options has emerged as one of the most traded security due to its unique feature of providing the right to the investor to take decision on executing the contract depending on the prevailing market price. Options are widely preferred by traders, speculators and hedgers due to the reasons of hedging risk, limited loss to traders and possibility of higher returns for a given premium (Mitra, 2009).

The growth of financial derivatives after mid 1970s was fuelled by the rise of instability in the global financial markets and has significantly increased during the last two decades. In particular, the total number of futures and options traded on exchanges worldwide rose to 24.78 billion contracts in 2015, up 13.5% from 2014, giving the industry its highest rate of growth since 2010. (WFE, Annual statistics Guide, 2016).

In India, introduction and growth of derivatives in India was recent development, with the institution of stock index futures in the year 2000, followed by index options in 2001, and options and futures on individual securities in 2001, respectively, by Bombay Stock Exchange (BSE) and National Stock Exchange (NSE), the two leading stock Exchanges in India. The market for financial derivatives has grown tremendously in terms of available instruments, their complexity and turnover, and in the class of equity derivatives, futures and options on stock indices have gained more popularity relative to individual stocks. In fact, empirical evidence by Tripathy et al. (2009) has shown that Indian stock market has become more efficient after the introduction of derivatives. Index options trading in India has witnessed an immense growth and presently, NSE has the distinction of being the largest index option traded globally in terms of volume (DNA INDIA, 22 Apr. 2015).

Understanding the pricing of options in the markets is pivotal for traders and analysts for their investments, and option pricing depends on the price movement of the underlying assets and several other parameters. One of the most significant advancements in options pricing was the Black-Scholes option pricing model (1973), the widely studied model by several researchers across different markets. The model uses parameters such as underlying stock price, volatility of the stock price, strike price or purchase price of the option, time to expiration of the option contract and risk-free interest rate to compute the market price of the option. Black Scholes option pricing model (1973) primarily assumes constant volatility in the model, wherein the volatility pattern across strike prices and maturities was a flat line. However, subsequent empirical studies by MacBeth and Merville (1979) and Rubinstein (1985) provided evidence of the assumption's violation in the Black-Scholes model and the volatility parameters implied by the market prices of different options on the same underlying stock tend to differ. The market crash of 1987 and its impact in

  

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S&P 500 index options also revealed that the market implied volatilities varied with strike prices and maturities, and a “U” shaped smile pattern was observed in the index. This pattern of implied volatilities across strike prices with constant maturity was termed as the “volatility smile” and has been a significant and persistent feature in index markets since then. The pattern of implied volatilities across maturities was termed as the “term structure” and the combined pattern of implied volatility with maturities and strike prices was termed as “volatility surfaces” (Daglish et al., 2007).

Implied volatility and volatility smile has become significant indicators for researchers to understand the pricing of options (Poon and Granger, 2003) and for traders and analysts to decide on the buying behavior and profits (Weinberg, 2001). In fact, implied volatility has become a preferred notation among traders since the options are more often quoted in terms of volatility than option prices (Kermiche, 2014).The increasing liquidity of the options also gives rise to new information which has led researchers to study volatility (Schönbucher, 1999) and volatility smile patterns. Furthermore, volatility smile has also become a key indicator for traders for valuation of options and for hedging in ad hoc manner (Daglish et al., 2007). However, the actual profile of the volatility smile varies at different markets, underlying assets and time periods.

In this context, this study aims to capture the implied volatility patterns namely volatility smile, term structure and volatility surface of the Nifty 50 index options, the largest traded options index in the world in terms of volume. The sample period considered for the study is from January 2013 to December 2016, when the index options was the most actively traded index options in the world. The empirical study has been formulated in simple framework using the Dumas, Fleming and Whaley (1998) Deterministic Volatility Function (DVF) model and the smile patterns are captured using the different categories of options in terms of moneyness and maturities and subsequently mapped with the liquidity levels of options to get a holistic picture of the disposition of options. While previous studies in Nifty 50 index have captured the volatility smiles at different time periods and provided evidence for the existence of the smile patterns relevant to the sample period, this study differs from earlier studies by capturing the implied volatility smile patterns in its most active period and providing an exhaustive delineation of the smiles patterns for different implied volatilities and liquidities. This analysis would be beneficial to analysts, traders and investors for an understanding on the future trend in options prices and for their strategic decision making on investments.

## 2. LITERATURE REVIEW

### *2.1 Implied volatility and volatility smile*

Implied volatility of an option can be defined as the market’s assessment of the underlying asset’s

  

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volatility, as reflected in the options price (Mayhew, 1995). Implied volatility which are not directly observable are basically computed from the market observable parameters of the Black Scholes model. The parameters comprise of the options price, strike price of the options, time to expiration of the option contracts, underlying stock price and risk-free interest rate. Options contract are purchased by the investor by paying a premium called the options price. The strike price or the exercise price is the price incurred when the options contract is executed. The time to maturity is the number of days at which the options contract is to be executed or exercised. Implied volatility, the unknown parameter is that volatility that makes the model price exactly identical to the observed market price (Jackwerth, 2004).

Options with the same time to maturity but with different strike prices appeared to produce different implied volatility estimates for the same underlying asset and these varying implied volatilities when plotted against strike pieces had nonlinear shapes and popularly called as volatility smile, smirk, and sneer (Poon and Granger, 2003).Volatility smile patterns are generally observed using the determinants moneyness and maturities. The pattern observed when implied volatility is plotted across moneyness at constant maturity is referred to as "Volatility smile" and the pattern when implied volatilities are observed across different maturities are known as "Term structure". The pattern obtained when implied volatilities are plotted across moneyness and maturities are known as "Volatility surfaces". In the context of equity index options markets, where market jumps and fear of jumps are more prominent in short term, the market have started to display more sophisticated implied volatility smile patterns (Derman, 2003). The popular patterns of volatility smiles captured in several markets has been referred by researchers as the smile (Jackwerth and Rubinstein, 1996; Buraschi and Jackwerth,2001; Tompkins, 2001; Derman, 2003), skew (Weinberg, 2001) , smirk (Campa et al., 1998), sneer (Dumas, Fleming and Whaley, 1998; Chang et al., 2009), wry grin or reverse grin (Duque and Lopes, 2003).

In recent years, considerable attention has been imparted to the behavior of the implied volatilities of options contracts. In fact, the enormous growth of derivatives and the increasing liquidity of the options has led to the introduction of implied volatility indices across markets. Fleming, Ostdiek, and Whaley (1995) has noted that the volatility predictions of underlying asset based on the implied volatilities of options are more reliable than those obtained from the underlying asset owing to the fact that options contain more information.

### *2.2 Empirical studies on Volatility smiles*

Empirical studies on volatility smiles can be categorized as the studies on patterns across different markets and studies pertaining to models in ascertaining the smiles. Invariably, the earliest studies on volatility smiles after the 1987 market crash were predominantly concentrated in S&P 500

  

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index. Subsequently, the studies diverged in capturing evidence across different global markets and in model developments to capture the different aspects of the volatility smiles.

The studies were focused to capture the volatility smile patterns in several markets across the world. Studies by Jackwerth and Rubinstein (1996), Ait-Sahalia and Lo (1998), Dumas, Fleming and Whaley (1998), Buraschi and Jackwerth (2001), Tompkins (2001) examined volatility smile in the S&P 500 index during and after the market crash of 1987. Jackwerth and Rubinstein (1996) studied the US stock index S&P 500 index options at the time market crash of 1987 and reported the presence of a pronounced smile, Ait-Sahalia and Lo (1998) estimated asymmetric smile using non-parametric model in S& P 500 index options, and Dumas, Fleming and Whaley (1998) developed a Deterministic Volatility Function (DVF) model to capture implied volatilities of S&P 500 index options. Buraschi & Jackwerth (2001) reported that the smile in S&P 500 index options cannot be wholly attributed to deficiencies in the Black-Scholes formula, Tompkins (2001) studied S&P 500 index along with other classes of assets and found that consistencies existed in the shapes of standardized surfaces for the options in the same asset class.

Empirical studies in other global market indices were also widely carried out. Tompkins (2001) studied the US, Japanese, German and British stock indices namely the S&P 500, FTSE 100, DAX and Nikkei 225 and noted that standardized smiles did not vary substantially over time, Pena et al. (1999) examined the Spanish IBEX - 35 index futures and found presence of smile patterns of implied volatility across exercise price, Navatte and Villa (2000) examined the French CAC 40 stock index and showed that the various shapes of volatility smiles were consistent with different distributions of the underlying asset. Engstorm (2002) studied the Swedish StSE index options and found U shaped smile pattern across moneyness. Duque and Lopes (2004) studied the LIFFE London index options and found the presence of wry and reverse grins. Tanha and Dempsey (2015) in their study of the Australian SPI 200 futures noted that the shape of the money options volatility smile were responsive to macroeconomic parameters. Varma (2002) observed that volatility smile was different for Nifty futures and call and put options for the period June 2001 to February 2002, Sheghal and Vijaykumar (2008) observed U shaped volatility smile in Nifty-50 index options for calendar years 2004 and 2005, Singh and Pachori (2013) reported the presence of volatility smile during the year 2008, Shaikh and Padhi (2014) presented the existence of a classical U-shaped volatility smile for the year 2012, Rajput (2015) reported volatility smile was more asymmetric for put options rather than call options for the period April 2014 to Mach 2015.

### *2.3 Empirical models on volatility smiles*

Implied volatilities and volatility smiles were computed using several alternative approaches to Black Scholes models and they can be broadly classified as jump diffusion models, stochastic

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volatility models and local volatility models (Kermiche, 2014). Jump diffusion model was introduced by Merton (1976), in which a jump component was added to the Black Scholes diffusion process, to account for the instant adjustment of asset price when new information is received. The stochastic models comprised of Hull and White (1987), Stein and Stein (1991), and Heston (1993) and in these models the volatility of the underlying were considered to be stochastic in nature. These models did not retain the market completeness, overlooked the vital information available in highly liquid standard options and did not provide simple equations to estimate for standard options (Kermiche, 2014). These models were also unable to explain the biases in Black Scholes framework and predict smiles reflective of the market (Tanha and Dempsey, 2015).The local volatility models developed by Dupire (1994), Derman and Kani (1994) and Rubinstein (1994) overcame these gaps and offered simple equations using binomial and trinomial tree approach.

The Deterministic Volatility Function (DVF), an alternative approach, within this local volatility framework, proposed by Dumas Fleming Whaley (1998) derived implied volatilities as simple quadratic form in terms of moneyness and maturities. In their empirical study, Dumas Fleming Whaley (1998) used Black Scholes backward equation as a forward equation and inferred implied volatility of S&P 500 index options for the period June 1988 and December 1993, and proposed different structural forms of implied volatility in terms of moneyness and maturities. The smile equations proposed by Dumas Fleming and Whaley (1998) had flexibility of the volatility functions specification, but the model's predictions deteriorates with the complexity of the assumed volatility specification and passage of time. Figlewski (1989), Tanha and Dempsey (2015) have reported that in this approach implied volatility of options are noisy and also imply a varying volatility of the underlying. The critical assumption of the model, however, is that the volatility function is deterministic and remains stable through the option's life. The Dumas, Fleming and Whaley model (1998) that is widely used in practice due to its simplicity, its capability to retain market completeness of the Black Scholes Model serves as a precise fit of volatility in terms of market prices in terms of maturities and moneyness (Tanha and Dempsey, 2015).

### *2.4 Determinants of volatility smiles*

Volatility smile patterns were captured using several determinants such as moneyness, maturities, skewness, kurtosis, leverage, historical volatility, transacted volumes and macroeconomic variables. The widely used determinants to capture volatility smile were the moneyness and maturities of the options. Moneyness has varied definitions in literature (MacBeth and Merville, 1979; Dumas, Fleming and Whaley, 1998; Pena et al., 1999; Beber, 2001, Engström, 2002; Deo et al., 2008; Mitra, 2008), however it can be broadly defined as a ratio of strike price to stock price

  

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or vice versa. Options are categorized on the basis of moneyness as At-The-Money (ATM), In-The-Money (ITM), Out-of-The-Money (OTM) options. Time to expiration is the time period from introduction of strike to expiration, and options are widely classified as near month, middle month and far month contracts. The study by MacBeth and Merville (1979) was one of the earliest studies which used determinants moneyness and maturities to examine the volatilities of call options on six different stocks. Subsequent studies by Rubinstein (1985), Dumas, Fleming and Whaley (1998), Pena et al., (2001), Shegal and Vijaykumar (2008), Singh (2013) examined implied volatility using these determinants.

### *2.5 Volatility smile and Liquidity*

Liquidity of options refers to when the options are being actively traded by many investors and captured using the measure of number of contracts traded actively. The implied volatility of options in terms of liquidity varies across different categories. Among different options categorized based on moneyness, implied volatility of ATM options are more popular because of its highest liquidity, and primarily used for volatility forecasting (Poon and Granger,2005). Previous literature have revealed that the implied volatilities of the highly liquid ATM options are lower than the less liquid deep in- and out-of-the-money options , thus creating a smile-shaped pattern. In the case of options categorized based on maturities, near month options are more liquid than the other categories of options. Pena (1999) reported that liquidity was concentrated in the nearest expiration contracts in the year 1995 in Spanish ffiEX-35 index. Ederington and Guan (2001) using S&P 500 index options data reported average daily trading volumes at each relative strike price and in their study it was observed that trading was higher in out-of-the-money and short term options than in in-the-money-options and far month options. The study by Buraschi and Jackwerth (2001) in S&P 500 index options from 1986-1995 also provided evidence that out-of-the-money call or put options were much more liquid than in-the-money call or put options. Shaikh and Padhi (2014) examined the Nifty equity index for the year 2012 using degree of moneyness, time-to-expiration and liquidity of the strikes as determinants and recorded existence of a classical U-shaped volatility smile for moneyenss categories and volatility smirk for maturities. It was also reported that implied volatility was higher for less liquid options and lower for high liquid options.

Nifty 50 index options were introduced in India in the year 2001, has emerged as the largest traded index in the world (in terms of volume) in the year 2013, and maintained its leading position till date. Substantial body of research of Nifty 50 index options has been carried out to capture the volatility, stylized facts, market efficiency, information content, and empirical comparison of option pricing models. The previous studies of Nifty 50 index options that captured volatility smile were mostly confined to smaller sample period and less liquid market conditions prior to 2013.

  

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Moreover, only a limited evidence on various patterns of implied volatilities with respect to their liquidity levels were documented in literature for the most actively traded index Nifty 50. In this context, this study aims to capture three patterns of implied volatilities namely the volatility smile, term structure and volatility surface of Nifty 50 index options for longer sample period from January 2013 to December 2016 using determinants moneyness and maturities and also present a holistic framework in terms of liquidity of options.

## 3. THEORETICAL MODEL

In this study, volatility from the Black-Scholes (BS) model is captured using market option prices and subsequently implied volatility is computed and categorized using the Dumas, Fleming Whaley (1998) deterministic volatility approach to construct the required volatility smile across moneyness and maturities.

### *3.1 Black Scholes Model (1973)*

The Black Scholes model computes the pricing of European plain vanilla call options on non-dividend stock with the assumption that the return distribution is log-normally distributed.

$$C_{BS} = SN(d_1) - Ke^{-rt}N(d_2)$$

$$d_1 = \frac{\ln[S/K] + [r + 0.5\sigma^2]t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{\ln[S/K] + [r - 0.5\sigma^2]t}{\sigma\sqrt{t}} = d_1 - \sigma\sqrt{t}$$

where,

C denotes the price of a call option,
BS denotes the Black Scholes model,
S denotes the underlying asset price,
K denotes the option exercise or strike price,
t is the time to expiry in years,
r is the risk free rate of return,
N(d) is the standard normal distribution function,
and $\sigma^2$ is the variance of returns on the index.

In the Black Scholes model, the four parameters underlying index price, option exercise or strike price, time to expiry, risk free rate of return can be easily observed from the market. The underlying asset price is the asset which is being traded, and in the context of this paper underlying asset is the Nifty 50 index. The call option is the options contract which gives the trader or the investor the right to buy the underlying asset. The investor can take a decision either to execute the contract or let it expire at the time of maturity, and this flexibility offered by the options contract helps the investors to hedge risk. European type options are contracts that can be exercised only at the time of expiration of the contract. Volatility is the most crucial and only unknown parameter in the model, the implied volatility is inferred reciprocally from the Black Scholes model by capturing the actual call prices from the market and hence can be used to justify that the implied volatility reflects the actual volatility derived from market prices. In this approach, implied volatility captures the information contained in the other parameters from the market (Samsudin and Mohamad, 2016).

### *3.2 Dumas, Fleming, and Whaley (1998) model*

The empirical evidences on the existence of parabolic smile pattern of the implied volatility and its dependence on moneyness and maturity, violating the non-constant volatility assumption of Black Scholes model had motivated researchers practitioners to explore the dependence of implied volatility on moneyness and maturity. Dumas, Fleming, and Whaley (1998) model is a liner quadratic function of these three variables namely implied volatility, moneyness, maturities and are called as deterministic volatility functions (Pérignon, 2002).The determinants to capture the volatility smile pattern are moneyness and maturities and hence for the purpose of this study, we have focused only on the following DVF models to capture volatility attributable to both asset price and time for expiration.

Model 1 : $\sigma_{iv} = a0 + a_1K + a_2K^2 + a_3T + a_4KT$

Model 2 : $\sigma iv = a0 + a_1K + a_2K^2 + a_3T + a_4T^2 + a_5KT$

where

$\sigma_{iv}$ = Black-Scholes implied volatility

K = strike price

T = time to maturity and

$a_0$, $a_1$, $a_2$, $a_3$, $a_4$, $a_5$ are model parameters.

The above models are quadratic forms of volatility function since Black Scholes implied volatilities usually tend to have parabolic shapes (Dumas, Fleming and Whaley, 1998). This approach is a simple extension of Black Scholes model, and is used to obtain the volatility surfaces with index market's implied volatility without losing many of the theoretical and practical

  

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advantages of Black Scholes model.

## 4. METHODOLOGY

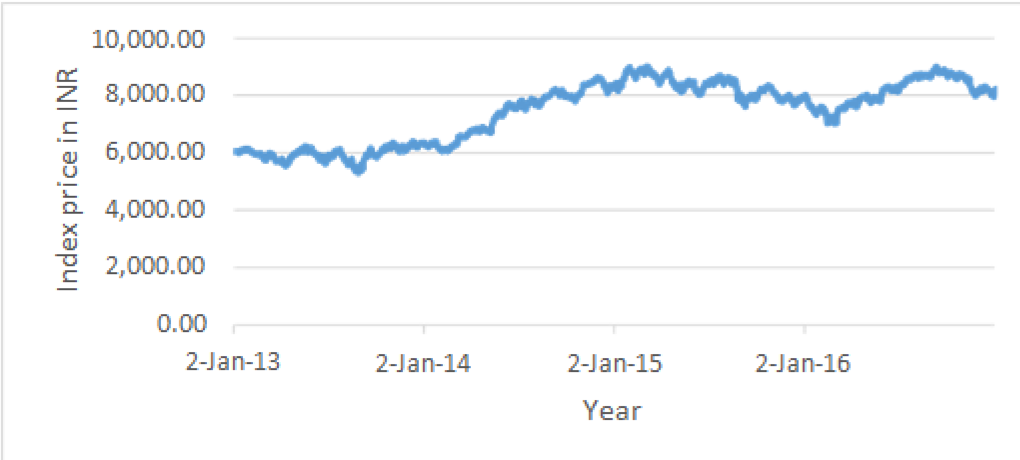
### *4.1 Data description -.Nifty 50 index and index options*

Nifty 50 index options trading commenced in India during June 2001, and within a span of less than 12 years has emerged as the global leading index in terms of number of contracts traded, and has maintained its position till date. The record turnover of Nifty 50 index options as of September 2016 was INR 8, 56,797 crores (NSE Market Pulse report December 2016). The Nifty 50 index options are European type call and put options, with 3 months for expiration and will expire in the last Thursday of the month and are cash settled. The instrument is referred as OPTIDX (options on index) and the underlying as NIFTY 50 (index).

The data of Nifty 50 index options were captured from National Stock Exchange (NSE) database for the period January 1, 2013 to December 31, 2016. The data comprised of European call type options, time to expiry, strike price, exercise price, underlying price, and number of contracts traded. The European call and put options written on the same underlying asset and calls and puts with identical exercise prices and expiration days should have the same implied volatility according to the put-call parity and hence only call options are considered for this study. The daily closing prices of the index were used in this study since Nifty index options is highly liquid implying that the closing prices of the options and the stock index are reasonably synchronous and would not have an impact on the results (Singh, 2013). The dividends are not taken into account since the Nifty 50 index is a price index which does not consider the returns arising from dividend receipts and only the capital gains arising due to price movements of constituent stocks are indicated in the price index (NSE official database) .The risk free interest rate are captured from 91 T-Bill rate with same maturities as options expiration from the Reserve Bank of India (RBI) database. In the study period from 2013 to 2016 the underling prices of the Nifty 50 index has varied from INR 6000 to INR 9000 as shown in Figure 1.

**Figure 1: Nifty 50 index movement**




Figures 2 and 3 displays various financial characteristics of Nifty 50 index options. Figure 2 provides evidence that the Nifty index return volatility tends to imply a mean reverting process. As noted by Mitra (2009), mean reversion is the propensity for a process to revert around its long run mean value and is vital in volatility as it influences the degree of volatility clustering, when other parameters are constant.

**Figure 2: Nifty 50 index returns distribution**

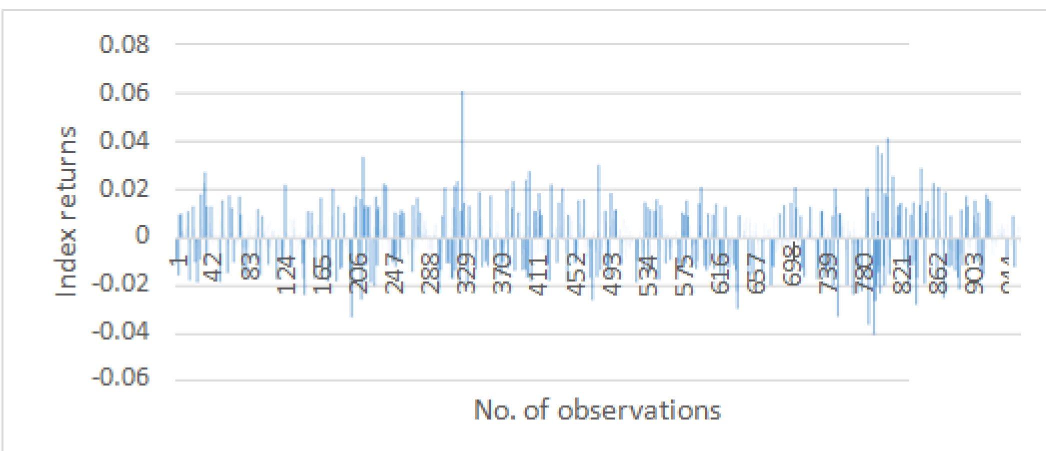



Figure 3 shows that for the period of study, the frequency plot of Nifty index return is non-lognormal, and slightly positively skewed and marginal heavy right tail. It can be inferred that positive index returns are more predominant than negative returns in the given sample period.

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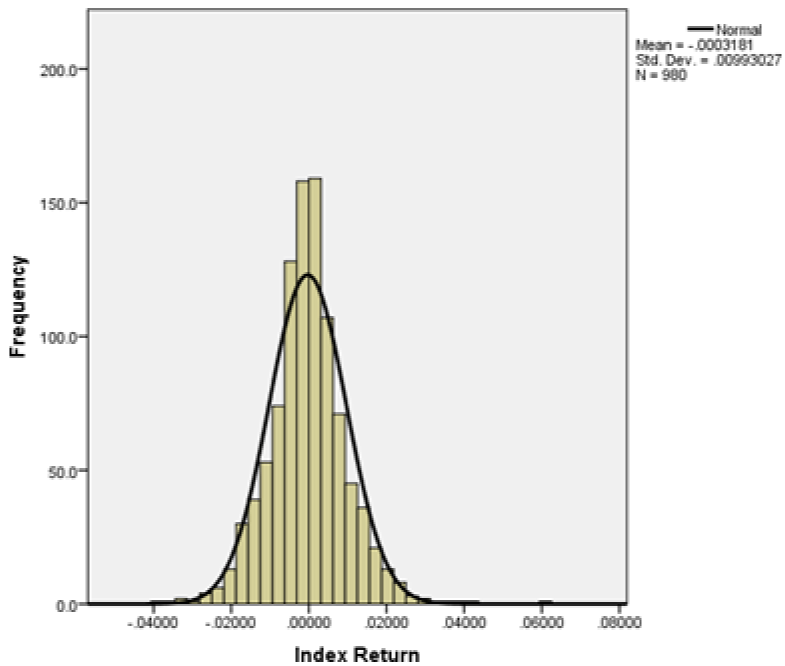
**Figure 3: Log non-normal distribution of return of Nifty 50 (January 2013–December 2016)**




Descriptive statistics for the daily index prices and returns for the period of study are displayed in Table 1. It can be observed from Table 1, the index returns are positively skewed as shown in Figure 3.

**Table 1: Descriptive statistics for Daily index prices, returns**

| *Details* | *Index Price* | *Index Return* |
|---|---|---|
| Mean | 7349.33 | -0.0003 |
| Median | 7701.7 | -0.0004 |
| Mode | 6313.8 | 0 |
| Std. Deviation | 1078.79 | 0.0099 |
| Skewness | -0.3 | 0.327 |
| Kurtosis | -1.42 | 2.548 |
| Range | 3711.25 | 0.1011 |
| Minimum | 5285 | -0.0402 |
| Maximum | 8996.25 | 0.061 |

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### *4.2 Data Categorization*

The data are categorized in fifteen categories comprising of five categories of moneyness and three categories of expiration. Moneyness is computed as the ratio of difference of strike price and underlying price to strike price. The definition of moneyness is varied in literature as S/K, K/S, S/K-1, and the definition adopted for this study is S/K-1 (Dumas, Fleming and Whaley, 1998), where S is the strike price, K is the underlying index price. The options are categorized into five groups in terms of moneyness and three groups of maturities, as shown in Table 2.

**Table 2: Options Categories based on Moneyness and Maturities**

| *Categories* | *Moneyness Range (in Percentage)* |
|---|---|
| VDITM (very-deep-in-the-money ) | > 15% |
| DITM (deep-in-the-money ) | > 10% |
| ITM (in-the-money ) | 10% to 5% |
| ATM (at-the-money) | 5% to -5% |
| OTM (Out-of-the-money ) | -5% to -10% |
| DOTM (deep-out-of-the-money ) | < -10 % |
| VDOTM (very-deep-out-of-the-money ) | < -15 % |
| *Categories* | *Maturities Range (in Number of Days)* |
| Near Month | < 30 |
| Middle Month | 31-60 |
| Far Month | 61-90 |

ATM is when the option's strike price is equal to the market price of the underlying asset (Nifty 50 Index). A call option is in-the-money if the underlying index price is higher than the option strike price and in this scenario, the trader makes profit when he exercises the options contract. A call option is out-of-the-money when the option strike price is higher than the market price of the underlying index. In case the trader exercises the options contract out-of-the-money he would incur loss. On the other hand, the trader can allow the contract to expire without executing it and the loss incurred would the option premium paid for the contract.

The initial dataset before screening comprised of 2, 17,981 data points of call options. The data was subjected to four exclusionary filters to remove the outliers. In the first filter, options with zero contracts were filtered and removed from the dataset, and only the actively traded options

  

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were taken for the study. The second filter removed the options not satisfying the zero boundary conditions applicable for call options.

$$S_t - Ke^{-rt} \leq C\,(S_t,\, t)$$

where St is the current underlying price, K is the strike price, r is the risk free interest rate and C (St ,t) is the call option price at time t.

The remaining data was then filtered by removing the options with less than 5 days to maturity since estimation of volatility are sensitive to nonsynchronous options prices and measurement errors (Dumas, Fleming and Whaley, 1996). The final filter removed very deep-in- the-money options and very deep-out-of-the-money options as they contain little information on volatility function (Dumas, Fleming and Whaley, 1996), and these prices does not reflect the true option values (Singh and Pachori, 2013). After carrying out these four filters in the data set the remaining 30,842 call options were taken for the study. Table 3 provides the number of filtered options in the categories of moneyness and maturities.

**Table 3: Nifty 50 index options categories after filtration**

| *Categories* | | *Maturities* | | | *Total options* |
|---|---|---|---|---|---|
| | | *Near month* | *Middle month* | *Far Month* | |
| *Degree of Moneyness ( in Number and Percentage)* | *DOTM* | 2472 | 2385 | 1635 | 6492 |
| | | 38% | 37% | 25% | |
| | *OTM* | 2047 | 1787 | 2956 | 6790 |
| | | 30% | 26% | 44% | |
| | *ATM* | 2534 | 4076 | 5647 | 12257 |
| | | 21% | 33% | 46% | |
| | *ITM* | 1161 | 1601 | 942 | 3704 |
| | | 31% | 43% | 25% | |
| | *DITM* | 712 | 667 | 220 | 1599 |
| | | 45% | 42% | 14% | |
| *Total options* | | 8926 | 10516 | 11400 | 30842 |

  

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Table 4 presents a comprehensive overview on the liquidity of the options in terms of number of contracts and their turnover, in categories of moneyness at fixed maturities. The table provides evidence that ATM options has the highest liquidity amongst all moneyness categories, with the active numbers of contracts traded being 46 % and turnover of ATM options being 45.83%. These figures are consistent with the observations of Poon and Granger (2003) that ATM options in general enjoys popularity by usually having largest trading volume. In the maturities categories, the near month and middle month options have more number of active contracts and turnover when compared to far month options.

**Table 4: Option categories, number of contracts and turnover**

| | ***Near Month*** | | | | |
|---|---|---|---|---|---|
| | *DOTM* | *OTM* | *ATM* | *ITM* | *DITM* |
| No. of observations | 2,472 | 2,047 | 2,534 | 1,161 | 712 |
| No. of Observations (%) | 28% | 23% | 28% | 13% | 8% |
| No. of contracts | 13,48,966 | 14,77,064 | 27,00,875 | 7,44,645 | 2,68,422 |
| Average no. of contracts | 545 | 721 | 1,065 | 641 | 378 |
| No. of contracts (%) | 21% | 23% | 41% | 11% | 4% |
| Turnover in Lakhs | 61,90,519 | 61,27,270 | 1,08,95,266 | 28,19,550 | 10,51,221 |
| Average Turnover in Lakhs | 2,504 | 2,993 | 4,299 | 2,428 | 1,476 |
| Turnover in Lakhs (%) | 23% | 23% | 40% | 10% | 4% |

| | ***Middle Month*** | | | | |
|---|---|---|---|---|---|
| | *DOTM* | *OTM* | *ATM* | *ITM* | *DITM* |
| No. of observations | 2,385 | 1,787 | 4,076 | 1,601 | 667 |
| No. of Observations (%) | 23% | 17% | 39% | 15% | 6% |
| No. of contracts | 10,05,858 | 19,40,730 | 32,30,726 | 5,89,402 | 1,59,480 |
| Average no. of contracts | 421 | 1,086 | 792 | 368 | 239 |
| No. of contracts (%) | 15% | 28% | 47% | 9% | 2% |
| Turnover in Lakhs | 42,39,575 | 85,34,295 | 1,34,74,063 | 25,01,553 | 5,39,799 |

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| | | | | | |
|---|---|---|---|---|---|
| Average Turnover in Lakhs | 1,777 | 4,775 | 3,305 | 1,562 | 809 |
| Turnover in Lakhs (%) | 14% | 29% | 46% | 9% | 2% |

***Far Month***

| | *DOTM* | *OTM* | *ATM* | *ITM* | *DITM* |
|---|---|---|---|---|---|
| No. of observations | 1,635 | 2,956 | 5,647 | 942 | 220 |
| No. of Observations (%) | 14% | 26% | 50% | 8% | 2% |
| No. of contracts | 4,19,245 | 16,57,794 | 27,10,427 | 1,53,687 | 30,055 |
| Average no. of contracts | 256 | 560 | 480 | 163 | 136 |
| No .of contracts (%) | 8% | 33% | 55% | 3% | 1% |
| Turnover in Lakhs | 17,88,536 | 68,09,749 | 1,07,78,983 | 8,13,916 | 1,20,472 |
| Average Turnover in Lakhs | 1,093 | 2,303 | 1,908 | 864 | 547 |
| Turnover in Lakhs (%) | 9% | 34% | 53% | 4% | 1% |

| | *DOTM* | *OTM* | *ATM* | *ITM* | *DITM* |
|---|---|---|---|---|---|
| No. of observations | 6,492 | 6,790 | 12,257 | 3,704 | 1,599 |
| No. of Observations (%) | 21% | 22% | 40% | 12% | 5% |
| No. of contracts | 27,74,069 | 50,75,588 | 86,42,028 | 14,87,734 | 4,57,957 |
| Average no. of contracts | 1,222 | 2,367 | 2,337 | 1172 | 753 |
| No.of contracts (%) | 15% | 28% | 47% | 8% | 2% |
| Turnover in Lakhs | 1,22,18,630 | 2,14,71,314 | 3,51,48,312 | 61,35,019 | 17,11,492 |
| Average Turnover in Lakhs | 5,374 | 10,071 | 9,512 | 4,854 | 2,832 |
| Turnover in Lakhs (%) | 16% | 28% | 46% | 8% | 2% |

  

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It can also be observed that ITM and DITM options has the least liquidity across all categories of maturities. In the class of maturities, the near month options had highest liquidity and far month options has the least liquidity. It can be due to the fact that the traders actively trade the options when the contracts are closer to expiration dates for realizing more profits.

## 5. ANALYSIS AND DISCUSSIONS

### *5.1 Implied volatility*

The volatility is computed as a reciprocal of Black Scholes model from observed parameters captured from the market namely the strike price, underlying price, risk free rate and time for expiration. The implied volatility is captured as a dependence of maturities and moneyness using DVF model of Dumas Fleming and Whaley (1998) models by rationalizing the functional explanation of the implied volatility component. Table 5 provides the average and standard deviation values of implied volatility across various categories of moneyness and maturities.

**Table 5: Implied volatility (Average and Standard Deviation) on Moneyness and Maturity categories**

| *Categories* | | *Degree of Moneyness* | | | | | *Maturities* | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *ATM* | *ITM* | *DITM* | *OTM* | *DOTM* | *FAR* | *MIDDLE* | *NEAR* |
| Model 1 | Standard Deviation | 0.0347 | 0.0390 | 0.0386 | 0.0344 | 0.0307 | 0.0200 | 0.0231 | 0.0233 |
| | Average | 0.1690 | 0.1936 | 0.2180 | 0.1693 | 0.1792 | 0.1421 | 0.1821 | 0.2146 |
| Model 2 | Standard Deviation | 0.0355 | 0.0475 | 0.0507 | 0.0384 | 0.0390 | 0.0167 | 0.0246 | 0.0353 |
| | Average | 0.1683 | 0.1915 | 0.2193 | 0.1722 | 0.1783 | 0.1497 | 0.1640 | 0.2262 |

It can be seen from the Table 5 that the average implied volatility as well as its standard deviation is high for options with near month contracts which is line with the previous literature, that for options with short maturities implied volatility is higher than options with longer maturities. Furthermore, it can be seen that the average implied volatility and its standard deviation is high for DITM and ITM options, and low for ATM options and marginally high for ITM options supporting the existence of volatility smile pattern. Table 6 provides the average and standard deviation values of implied volatilities across different moneyness at fixed maturities. In near month contracts, DITM options have the highest average volatility, and ATM options has the lowest average volatility. Likewise, for middle and far month contracts DITM has the highest

  

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average volatility, whereas OTM and ATM options has the lowest average volatility.

**Table 6: Implied volatility (Average and Standard Deviation) on sub option categories of maturities in terms of moneyness**

| | *Near Month Contracts* | | | | |
|---|---|---|---|---|---|
| | *DOTM* | *OTM* | *ATM* | *ITM* | *DITM* |
| Implied volatility (Standard Deviation) | 0.067 | 0.050 | 0.060 | 0.091 | 0.124 |
| Implied volatility (Average) | 0.252 | 0.187 | 0.167 | 0.249 | 0.368 |
| | *Middle Month Contracts* | | | | |
| | *DOTM* | *OTM* | *ATM* | *ITM* | *DITM* |
| Implied volatility (Standard Deviation) | 0.028 | 0.033 | 0.045 | 0.057 | 0.063 |
| Implied volatility (Average) | 0.168 | 0.146 | 0.155 | 0.183 | 0.244 |
| | *Far Month Contracts* | | | | |
| | *DOTM* | *OTM* | *ATM* | *ITM* | *DITM* |
| Implied volatility (Standard Deviation) | 0.027 | 0.029 | 0.037 | 0.056 | 0.065 |
| Implied volatility (Average) | 0.158 | 0.142 | 0.146 | 0.166 | 0.223 |

### *5.2 Implied volatility patterns*

The non-linear shapes of implied volatility plots across strike prices are called as volatility smile, smirk or sneer (Poon and Granger,2003).The implied volatilities are plotted against the various categories of moneyness and maturities to examine the pattern of volatility smile and term structure. It can be observed that the implied volatilities computed from Model 1 and 2 are marginally different (Table 5), however the pattern exhibited by both the volatilities are almost similar and hence implied volatilities computed from Model 2 are used in examining volatility smile patterns for this study.

  

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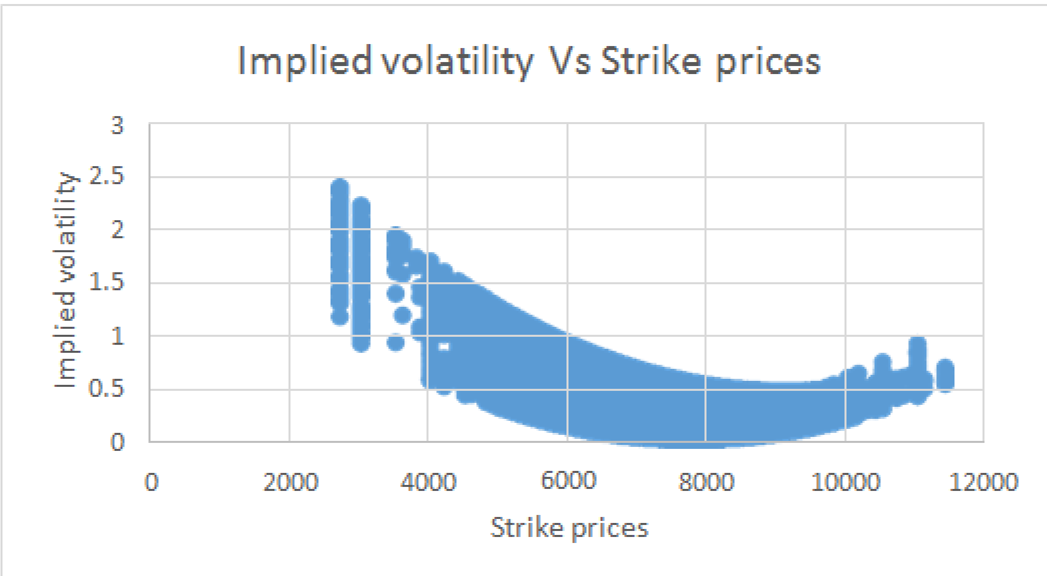
Figure 4 displays the volatility smile of Nifty 50 index options where the implied volatility is plotted against strike prices, and a half smile pattern is observed for the sample period 2013 to 2016. The higher implied volatilities at low strike prices gradually decreases and reaches the lowest value at strike price of INR 8000 and then marginally increases with further augment in strike price demonstrating a smile pattern across different strike prices.

**Figure 4: Implied volatility across strike prices**




**5.2. a. Volatility smile**

Volatility smile is the pattern of implied volatility across degree of moneyness. In this study, implied volatility is plotted across five degrees of moneyness namely DOTM, OTM, ATM, ITM, DITM. Figure 5 displays the volatility smile across these five categories of moneyness. Given the wide range of option prices, the deviations of the values from both the models are quite small and the solid fitted value line appears to fall on the observed prices across all option series. It can be observed that a pronounced smile pattern can be seen across the entire categories of moneyness (Figure 5).

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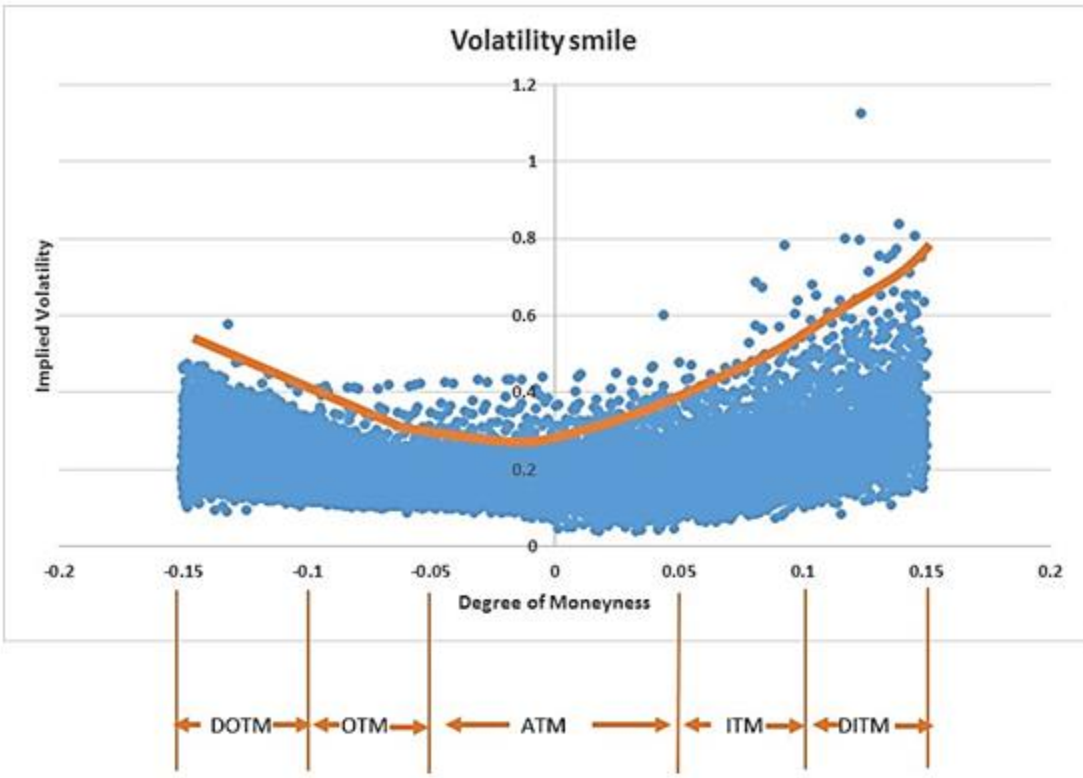
**Figure 5: Volatility smile- Implied volatility across various degrees of moneyness**

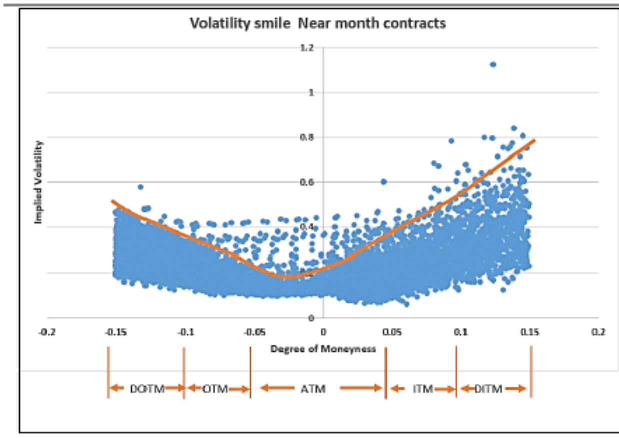
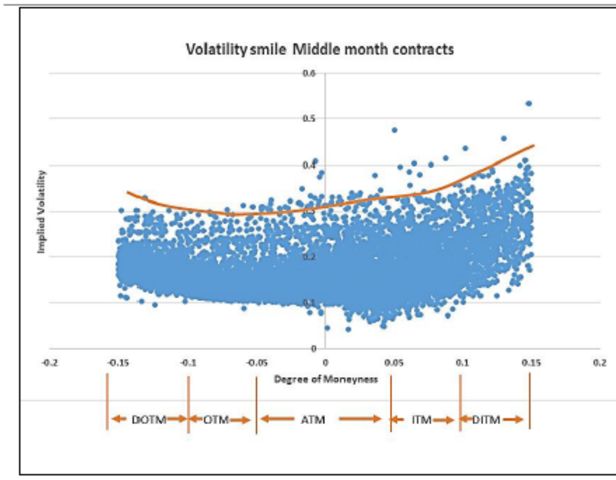
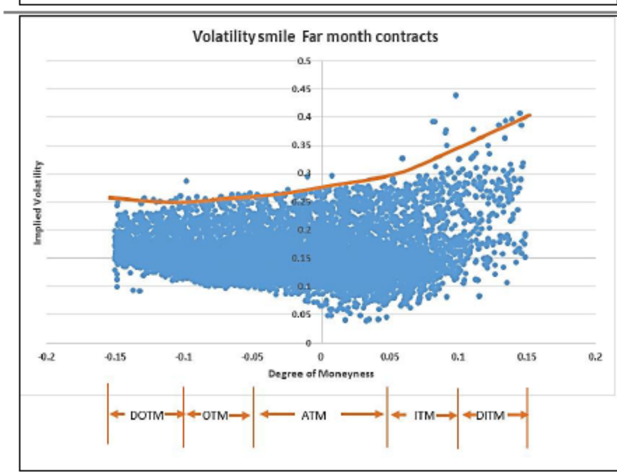



It can be observed from the smile pattern across moneyness categories plotted at constant maturities, that the smile shape is prominent across ATM options. In case of OTM and DOTM options a downward sloping smile is observed and in case of ITM and DITM an upward sloping smile. The results are consistent with the previous studies that the DITM and DOTM options have higher implied volatility than ATM options (Singh 2013, Shaikh and Padhi, 2014). It is apparent that the volatilities varies across moneyness, substantiating the violation of constant volatility assumption of the Black-Scholes (1973) model and providing evidence for persistence of volatility smile in the Nifty 50 Index options.

Figure 6 shows the volatility smile across individual categories of moneyness at fixed maturities and the relevant implied volatility levels and the liquidity levels of the options in these categories.

**Figure 6: Volatility Smile across five categories of Moneyness**

| *Volatility Smile Patterns across moneyness at constant maturities* | *Shape of smile pattern, Implied volatility and Liquidity of options* |
|---|---|
|  | • A pronounced "U" smile pattern is observed for Near month contracts<br>• Average implied volatility for ATM options is lowest and highest for DITM and DOTM options<br>• ATM options has the highest liquidity of 40% of contracts traded and turnover and DITM and ITM has the least liquidity (Table 4)<br>• ATM options has the lowest average implied volatility of 0.167 (Table 6) |
|  | • A flat smile pattern is observed for Middle month contracts<br>• Average implied volatilities of DOTM,OTM and ATM options are lower compared to ITM and DITM<br>• ATM options has the highest liquidity of 47% of the contracts transacted (Table 4) |
|  | • Upward sloping smile is found in Far month contracts<br>• Average implied volatilities of ATM and OTM contracts are lowest and highest for ITM and DITM options<br>• ATM options has the highest liquidity of 53% of contracts transacted, and DITM has the least liquidity of 1 % of contracts (Table 4) |

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**5.2.b. Term structure**

The pattern of implied volatility across maturities is called as the term structure and a comprehensive term structure pattern across different maturities can be seen in Figure 7.

**Figure 7: Term structure: Implied volatility across various maturities**

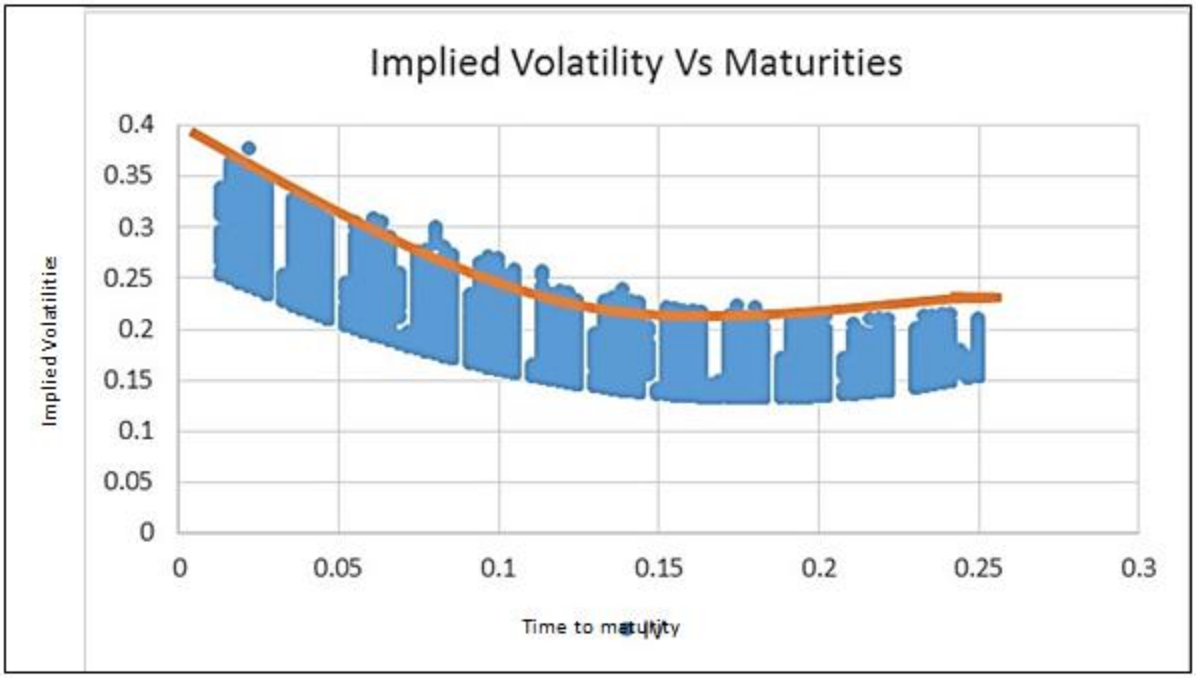


Figure 8 gives term structure patterns across near month, middle month and far month options. It can be observed that the term structure across all maturities is a grin / half smile pattern. However, when the term structure is plotted across individual maturities, sloping downward pattern is seen in near month maturities indicating that the volatility is highest close to the expiration, and subsequently declining as the maturities increase. This inverse relationship between implied volatilities and maturities imply that options with shorter maturities has higher volatilities which is consistent with the findings of Shaikh and Padhi (2014) in Nifty 50 index options.

  

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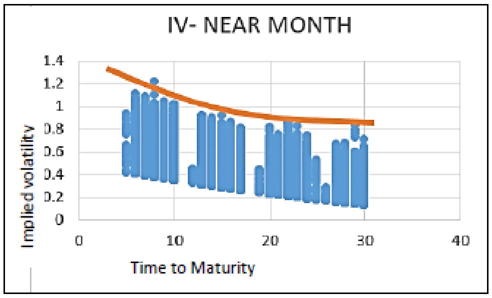
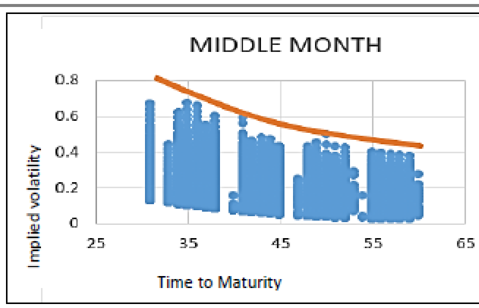
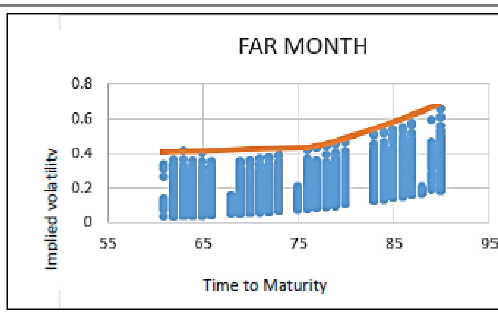
**Figure 8: Term structure – Near month, Middle month and Far month options**

| *Patterns* | *Maturities Categories and Shape* |
|---|---|
|  | • Downward sloping shape observed for near month contracts<br>• Contracts with closest maturities between 5- 10 days have highest implied volatilities<br>• Near month options contracts has highest average implied volatility of 0.21 (Table 6)<br>• Liquidity of near month contracts are high with 36% (Table 4) |
|  | • Downward sloping pattern observed for middle month contracts<br>• Implied volatilities decreases as the expiration date increases and lowest for options with 55-60 days for maturities<br>• Average implied volatilities is high with a value of 0.18 (Table 6)<br>• Liquidity of near month contracts are high with 37% (Table 4) |
|  | • Upward sloping shape observed for far month contracts<br>• Implied volatilities increases as the expiration date increases and highest for options with 85-90 days for maturities<br>• Average implied volatilities is least with a value of 0.142 (Table 6)<br>• Liquidity is least with 27% contracts transactions (Table 4) |

### 5.2. c. Volatility surface

The pattern of implied volatility across moneyness and maturities is the volatility surface. By plotting the three parameters - implied volatilities, maturities and moneyness, a pronounced U smile can be observed as shown in Figure 9. The shorter maturity options and DITM and ITM options have higher implied volatilities. The ATM options have lower implied volatilities and OTM and DOTM options have marginally higher implied volatilities at higher maturities giving

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rise to the pronounced smile pattern.

**Figure 9: Volatility Surface – Implied volatility across moneyness and maturities**

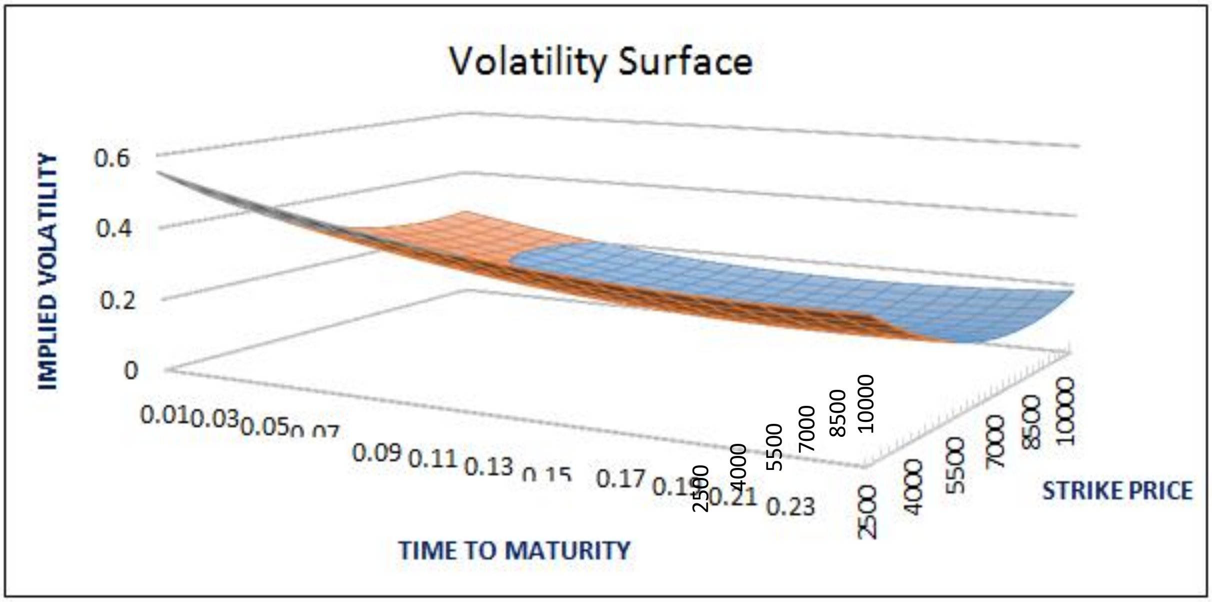


Table 7 summaries the volatility smile patterns, level of implied volatility and liquidity observed at each category of moneyness and maturities

  

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**Table 7: Volatility smile pattern and Liquidity of options in the sub-categories of moneyness and maturities**

| *Categories* | | *Maturities* | | | *Overall Smile/ Term Structure Pattern* |
|---|---|---|---|---|---|
| | | *Liquidity* | *Implied Volatility* | *Smile pattern* | |
| Degree of Moneyness | DOTM | Average | Average | Downward sloping | Prominent U smile pattern |
| | OTM | High | Lowest | Downward sloping | |
| | ATM | Highest | Lowest | Prominent U | |
| | ITM | Low | Highest | Upward sloping | |
| | DITM | Lowest | High | Upward sloping | |
| Maturities | Near month | High | Highest | Downward sloping | Grin / Half smile pattern |
| | Middle month | High | Average | Downward sloping | |
| | Far month | Low | Lowest | Upward sloping | |

The major findings from this study are recapitulated as follows. The study has established the presence and persistence of volatility smile in Nifty 50 index options during the period of highest liquidity from 2013 to 2016.Volatility smile has a rather U-shaped smile pattern when the volatilities are averaged within groups according to their moneyness at fixed maturities of near month, middle month and far month contracts. Among the different moneyness categories of options in volatility smile, ATM options are close to the minimum of the smile curve while having the highest liquidity. DITM options have the highest average implied volatility and the magnitude of the smile is found to increase in these options which has the lowest liquidity. Volatility smile pattern is more pronounced in the fixed near month maturity options than the middle and far month maturity options. Term structure pattern across maturities shows a decreasing profile for near and middle month contracts and upward sloping term structure for far month maturities thus having a Grin / Half smile pattern across maturities. Near month options contracts which are highly liquid have highest average implied volatility, whereas middle month options which are also actively traded has lower average implied volatility than near month options. Far month options contracts

  

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with lowest liquidity have the least average implied volatility leading to a downward sloping term structure. Volatility surface pattern across moneyness and maturities have a pronounced smile pattern.

## 6. LIMITATIONS AND FUTURE SCOPE

This paper has studied the volatility smile patterns during the period 2013 to 2016 when the Nifty 50 index was at its highest liquidity level, and has provided a comprehensive framework of the options smile patterns, implied volatility levels with the corresponding liquidity levels of the options. The study can be extended to previous sample periods when the index had lesser liquidity levels to capture and compare the prevalent smile patterns, and categorise on the basis of the liquidity levels of options.

The study has applied the most widely acclaimed Dumas, Fleming and Whaley (1998) model to capture the implied volatilities on the basis of moneyness and maturities owing to its simplicity, and its capability of retaining the theoretical and practical advantages of Black Scholes model and market based parameters. However, other models such as the stochastic models which are more sophisticated in computations can also be tried to capture the smile patterns in the Nifty 50 index options. Furthermore, it would be interesting to extend this study to examine the plausible reasons for the presence of the smile and its behavior for varied liquidity levels, perhaps in an attempt to integrate it with the existing literature and can be taken for future research.

## 7. CONCLUDING REMARKS

Derivatives are the most significant financial innovation in recent times offering a copious of benefits to the traders and investors such as risk protection, speculation and price discovery. In India, the Nifty 50 index options has emerged as the most active traded index in the world within a short span of twelve years since introduction. In financial markets implied volatility, a good metric for determining risk exposure has been widely used by traders and analysts for trading and projecting future trends of the options. Practitioners widely use implied volatility to understand the option price dynamics, to model the pricing of options, and to forecast future volatilities. An understating of the volatility smile and the different patterns for different liquidity and volatilities levels would be beneficial to the traders and analysts to speculate the future trend in market level and decide on their buying behaviour. In this context, this paper was aimed to examine the presence of volatility smile in the largest traded index in the world, the Nifty 50 index options using a recent dataset from the period from January 1, 2013 to December 31, 2016.

This study has established the presence and persistence of volatility smile of Nifty 50 index during its most active period. It was observed that the volatility smile pattern was a pronounced "U"

  

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smile, and the term structure was a “Grin” or “Half smile” pattern. A comprehensive analysis on the smile pattern in terms of moneyness and maturities was carried out, and a holistic framework based on volatilities and liquidities were presented in this study. The findings from the study provides empirical evidence that when options are categoriesd according to moneyness, the ATM options having the highest liquidity, the lowest implied volatility and is at the minimum position of the smile curve. Whereas, the DITM and ITM options with least liquidity had the highest implied volatility and highest position in the smile curve. It can also be noted that when the options were categoriesd based on maturities, the near month options with highest liquidity had the highest implied volatility and as the time for expiration increased the magnitude of the term structure pattern decreased. These inferences between the liquidity of options and implied volatility patterns are synchronous with previous literature (Longstaff, 1995, Pena et al., 2001). Based on the findings from this study, different trading strategies can be adopted by traders and investors for their investment decisions.

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