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# A Study of Options Volatility Smile: Empirical Evidence from India

Namita Rajput[1] and Bharti[2*]

[1]Associate Professor in Commerce, Sri Aurobindo College, University of Delhi, India; namitarajput27@gmail.com

[2]Assistant Professor in Management, USMS, GGS Indraprastha University, India; bharti.1119@gmail.com

**Abstract**

According to the latest data compiled by Futures Industry Association (FIA) NSE's CNX Nifty Options is ranked in the first place for trading volumes globally. NSE uses Black Scholes model as a benchmark tool to fix the base prices of options underlying Nifty index and stocks. The model has certain anomalies and limitations. Our research examines the volatility smile pattern and the determinants for S&P CNX Nifty options from April 2014 to March 2015. We have used OLS regression to estimate the relationship between IV and moneyness. To assess the determinants that cause the smile pattern, we have used Granger Causality test. We conclude that there exists a positive relationship between implied volatility and moneyness and the volatility smile is more asymmetric for put options rather than call options. Also the time to expiration for an option and historical volatility are the important determinants of the observable asymmetric profile.

**Keywords:** Black-Scholes Model, Implied Volatility, Moneyness, Option Pricing, Volatility Smile

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## 1. Introduction

Derivatives market facilitates investors with a rich source of information for gauging market outlook. Their forward-looking nature and factoring of information helps to efficiently encapsulate the market perceptions of underlying asset prices in the future. Widely used as a tool for hedging, derivatives can also be used for speculation and arbitrage purposes to take a view on the future market direction. Various strategies like straddle, strangle, butterfly, collar etc. can help in generating income for investors under various market conditions. The advantage of limited loss and high profits seem to attract market participants more to invest in derivatives rather than underlying asset itself. Additionally, options can be used for trading in an environment of higher level of leverage compared to stocks, therefore offering comparatively higher returns for the same initial deposit.

In India, NSE, which is a leading exchange globally in terms of volumes in index options, introduced trading in the instrument on June 4, 2001. The options contracts are European style and cash settled and are based on the popular market benchmark S&P CNX Nifty index. As per the reposts by Business Standard, it has witnessed 5.67 million daily average contracts last fiscal in the segment as against 3.7 million contracts in 2013-14. The index has witnessed an increase in trading volumes of index options by 53% over FY 2013-14. Daily average volumes in index options on NSE have stood at 7.15 million. Going by latest data compiled by Futures Industry Association (FIA), NSE's CNX Nifty Options is ranked in the first place for trading volumes globally. In order to price Nifty index options, like other stock exchanges, National Stock Exchange (NSE) of India also uses the Black Scholes model as a benchmark tool to fix the base prices of options underlying Nifty index and stocks.

Attention in the theory of option pricing received a major motivation in 1973 with the seminal work on "The Pricing of Options and Corporate Liabilities", published in the Journal of Political Economy by Black and Scholes4 who developed closed-form formula to calculate the prices of European calls and puts, based on certain assumptions by showing how to hedge continuously the exposure on the short position of an option. Today, the Black Scholes option pricing formula is the most widely used model for pricing options that assumes that the underlying asset follows a geometric Brownian motion and has constant volatility. The assumptions of the Black Scholes formula imply that all options of the same underlying asset with the same maturity should have same implied volatility, in spite of different strike prices. The resultant graph if plotted should therefore be a flat

*Author for correspondence

surface. However, it was only in 1987, when the stock markets crashed, an anomaly was observed that the option prices violated the constant volatility approach. As a result, "volatility smile" or "skew" was observed to explain the differences between observed prices and theoretical values that arose due to the assumption of constant volatility. Volatility smile is the phenomena that is observed when implied volatility is plotted against strike prices. A smile shaped pattern is formed. The market expectation about the future realized volatility of the underlying asset over the remaining life of the option is called implied volatility. In the smile pattern, it was observed that the implied volatility (IV) of deep in the money and out of money options was higher than at-the money options resulting in a smile pattern.

The study of volatility has become a significant area of research within financial mathematics. Firstly, volatility helps us understand price dynamics since it is one of the key variables in a stochastic differential equation governing an asset price. To add to the above significance, volatility is the only variable in the Black Scholes option pricing model that is unobservable and subjective, thus, open to biasness as a result of which it is crucial to model accurately.

Due to the embryonic stage of the options market in India, only a limited research is available on the subject . Although previous research in Indian markets provide the evidence of existence of volatility smile, yet the period of study and sample taken have been limited. Our study tries to focus on the existence of volatility smile and the determinants of IV. Our research concludes that there exists a positive relationship between IV and moneyness and the volatility smile is more asymmetric for put options rather than call options. Also the time to expiration for an option and historical volatility are the important determinants of the observable asymmetric profile.

The paper is arranged as follows, Section I ,i.e. the present section is introduction followed by Section II of literature review. Next section is objectives and data followed by methodology. Section IV consists of analysis of results and determinants of volatility smile. The last section is summary and conclusion followed by references.

## 2. Literature Review

Hull and White[11] examine the European call options on assets having stochastic volatility. They conclude that volatility is correlated with stock price and concentrate on pricing the European call options on a stock subject to stochastic volatility. They conclude that frequent overpricing of options by the Black-Scholes model as well as the degree of overpricing increases with the time to maturity.

Bakshi, Cao, and Chen[1] study S&P 500 call option prices and derive an option model which allows volatility, interest rates and jumps to be stochastic. The data set used is from June 1, 1988 through May 31, 1991. The models are examined from three perspectives: (1). internal consistency of implied parameters with relevant time series data (2). out of sample pricing (3) hedging. The paper concludes that regardless of performance yardstick, taking stochastic volatility into account is of the first-order importance in improving upon the BS formula.

Haffner & Wallmeier[10] analyze the strike profile of implied volatilities of German DAX options for a time to expiration of 45 days. Method of WLS spline regressions over the sample period from 1995 to 1999 is used and a skewed strike pattern instead of smile is observed and the dynamics of the smile can be attributed to AR (1) process. The major determinants of market uncertainty, measured by volatility of volatility, and liquidity effects play an important role in explaining the pattern of DAX implied volatilities across exercise prices.

Dennis and Mayhew[6] study the various factors in explaining the volatility smile observed in the prices of options on individual stocks traded on the Chicago Board Options Exchange. They conclude that on an average, the slope of the volatility smile on stock options is slightly negative, but not as steep as the smile for S&P 500 index options. Also higher beta stocks have steeper smiles and these are more negatively pronounced for actively traded stocks. The steepness of the S&P500 smile is significantly related to the put/call volume ratio, but the result is not robust for individual stocks and firms with higher leverage have flatter smiles.

Beber[2] described the implied volatility function of the options on the Italian stock market index between November1995 and March 1998. The paper concludes that a typical smirk is observed for Mib30 stock index. Linear Granger Causality test is also performed on the data and it is concluded that a linear causal relation exists of the time to expiration, the number of transacted option contracts and historical volatility on the asymmetry of the smile profile[9].

Vagnani[18] in his study combined agent based simulations techniques, empirical analysis, and mathematical derivations, and proposed that the determinants of the volatility smile might be related to the behavior of traders, heterogeneous beliefs, learning, and institutionalized norms. The paper further inspects their implications for the emergence of the volatility smile. The investors use the widely accepted Black-Scholes formula to price options but with a measure of stock volatility that they derive from their subjective beliefs. Moreover, heterogeneity of traders' beliefs and the way traders update their expectations have non-trivial effects, both on equilibrium prices and on the emergence of the implied volatility smile. Also the "smile" in the implied volatility curve is likely to emerge in an environment in which traders rely on their subjective beliefs to resolve their uncertainty about the underlying stock. Sehgal and Vijayakumar[19] examine volatility smile and determinants of smile asymmetry using the S&P CNX Nifty index call and put options from FY 2004 to FY 2005. The study takes into account different measures of moneyness and concludes that volatility functions exhibit a positive slope for Indian markets in contrast with the mature markets that exhibit negative asymmetry profiles in general. It is also shown that historical volatility and time to expiration are the potential determinants of smile asymmetry in India, as is the case with international evidence.

Berggren & Blomkvist[3] use the SPX Index options traded on CBOE with underlying of S&P Composite 500 Index with the primary objective to understand the volatility surface, and to explain the intrinsic properties of the selected parameters in predicting the shape of the smile. Using the univariate OLS regression and multivariate regression followed by VAR Model. They conclude that TTM and logarithm of future S&PCOMP are significant measures in predicting the shape of the smile.

Parasuraman and Ramudu[15] study the NIFTY stock from 2004 to 2008 to analyze the historical volatility patterns. The study uses volatility cone, smile and surface as parameters and Hoadley Option Calculator is used for calculations. They conclude that historical volatility demonstrates a tendency to revert to the mean. The paper also studies the data from January 2010 to March 2010 to examine volatility smile and surface effects. The "smile" effect is analyzed and the differences in findings as between the call implied volatility and the put implied volatility is looked into. The paper also looks at the changes in implied volatility across various strike prices, given the same time frame using GARCH (1,1) model.

# 3. Objectives, Data and Methodology

The present study aims to understand the following objectives:

1. What kind of volatility smile relationship exists for Indian options market-whether asymmetric or symmetric?
2. To examine the varying volatility relationship across call and put options.
3. To examine the major determinants of volatility smile (symmetric/ asymmetric)

To fulfill the above objectives, data of S&P CNX Nifty options contract with underlying asset of S&P CNX Nifty Index traded on the NSE derivatives segment has been studied. The said index is composed of a 50 Stock Index of the NSE comprising the largest and most liquid companies in India, with 60% of the total market capitalization of the Indian stock market. NSE has European, cash settled option contracts having a maximum trading cycle of three months – the near month (one), next month (two) and far month (three). Last Thursday of the month is the expiration of the option contracts or the previous trading day if Thursday is a trading holiday. The stock exchange uses the option pricing formula based on the Black and Scholes model. Daily Nifty call and put contracts closing prices and trading volumes for near month maturity from April 1, 2014 to 31st March 2015 have been collected. Only near month contracts have been considered as next month and far month option contracts volume is low. The risk free rate is taken as 91-day T-bill rate from Reserve Bank of India website. The daily values of underlying asset, S&P CNX Nifty Index, is downloaded from the Indices segment of the NSE website. The daily total trading volumes on S&P CNX Nifty Index traded companies during our study period are obtained from the Equity segment of the NSE. Daily data files of call and put options are considered for a wide range of strike prices. All option contracts with zero transactions were removed. This was followed by eliminating the option contracts with last five trading days to expiration to remove liquidity bias. The contracts with spot price and strike price differential of 100 or more have also been eliminated.

## 3.1 Implied Volatility

The graphical plot of implied volatility with option moneyness gives volatility smile. In order to understand volatility smile, the relationship between IV and moneyness is to be studied. A suitable option pricing formula is used to calculate IV. We have used the Black Scholes option pricing formula to compute IV (σit) for each observed European call (Cit) and put (Pit) option closing price as shown in Equations (1) and (2):

$$C_{it} = S_0 (N\, d_1) - Ke^{-rT} N(d_2) \quad (1)$$

$$P_{it} = K^{e-rT} N(-d_2) - S0\, N(-d_1) \quad (2)$$

where

$$d_1 = \frac{\text{In}\left(S/K\right) + \left(r + \sigma^2_{it}/2\right)T}{\sigma_{it}\sqrt{T}}$$

$$d_2 = d_1 - \sigma_{it}\sqrt{T}$$

N(x): Cumulative Probability Distribution Function

S0: Stock index value at time, t=0

K: Strike price or Exercise price

r: Continuously Compounded Risk-Free Rate Of Return (91 Day T-Bill Yield Rate)

T: Time To Expiration Of The Option

Moneyness has been defined as the ratio between the exercise price and the average of the option prices relative to each average IV. It has been calculated as the absolute value of the ratio of the difference between index value and strike price to the index value (called M hereafter), i.e., |S-K/S|[13].

### 3.2 Model Specification

In the study we define the following linear equation for IV to evaluate the volatility smile for S&P Nifty options.

$$Y = \beta_0 + \beta_1 X + \varepsilon \qquad (3)$$

where Y represents the IV and X represents moneyness of the options. We use ordinary least square regression to estimate IV and the model is fitted on each trading day separately, assuming that IV is stationary during the day. The average of daily estimates is taken to represent the whole period. Hence we get the following model:

$$Y_{t,\tau} = \beta_0 + \beta_1 X_{t\tau} + \varepsilon_{t\tau}$$

Here, the dependent variable i.e. Y represents the implied volatility and X represents the moneyness, while t denotes trading days and τ is the options' time to maturity.

## 4. Analysis of Results

Table 1 gives the results obtained from the averages of the whole period. The average intercept ($\beta_0$) represents a general level of volatility for IV function. The average slope, i.e., $\beta_1$ characterizes the profile that is responsible for the asymmetry in the risk neutral probability function. It describes the change in IV to change in moneyness. The results show a positive $\beta_1$ for call and put options, implying a positive asymmetric smile for Indian markets in contrast to most mature markets[2,7,12,17]. This could be due to positive relation between movement of future stock prices and volatility. If there is expectation of increase or decrease in the underlying asset price movement in future, the volatility increases resulting in the formation of a smile pattern. Our results establish the existence of options smile.

### 4.1 Volatility Smile: Determinants and Factors

The factors that determine and might have an impact on volatility are categorized into the following groups:

- The first set of variables help in gauging the options market liquidity and study the IV term structure that helps in explaining the asymmetry in options' market. Two set of variables are used to study the liquidity aspect of options market:

► Residual time to expiration for the option and the daily trading volume of the options. Time to expiration (TTE) is calculated as ratio between the difference in the number of working days to the expiration date and the conventional working days in a year:

TTE= (Expiration date-Trading Date)/ 252

► Daily options trading volume (N) is summed for all strike prices, as a measure of option market liquidity. Liquidity might be a variable to affect the smile pattern as options that are more liquid lead to a steeper smile curve. Let ni is the number of contracts traded on i-option on day t, then,

$$N = \Sigma n_{it}$$

- The second set of variables helps in gauging the features of the underlying asset to evaluate the relationship between IV and asset variables. The asset behavior is different from the option behavior, and this helps in explaining the option mispricing. The various asset parameters to be studied are market momentum, volume of market transactions, historical volatility and volatility of volatility. Here following are the terms defined:

► Momentum (MoM) is calculated as the natural logarithm of the ratio between the index value (S&P CNX Nifty) and its 21-day SMA. The value will be high during bull times. Momentum helps in studying if the trend has any effect on the volatility smile. According to the momentum theory, investors expect future returns to be positive if the past returns have been positive, and they will tend to buy call options on the market index. Higher demand for call options, will put pressure on call prices that might affect the smile pattern.

► The volume of market transactions(VOL) is expressed as the total daily trading volume for all stocks that form part of the S&P CNX Nifty Index. It denotes the liquidity in the market for underlying asset.

► Historical volatility (HVOL) is calculated during the previous 14 trading days as the annualized standard deviation of logarithmic returns on S&P CNX Nifty settlement prices.

**Table 1.** Ordinary Least Square Regression Results

| Options | $\beta_0$ | $\beta_{0t}$ | $\beta_1$ | $\beta_{1t}$ | $R^2$ |
|---|---|---|---|---|---|
| Call | 0.391582 | 15.26933* | 0.693859 | 37.90127* | 0.238306 |
| Put | 0.245710 | 0.568234* | 13.97680 | 36.90875* | 0.560943 |

* denotes that it is significant at 5%level.

- Volatility of volatility (VVOL) is computed like the historical volatility, taking not the logarithmic returns, but standard deviations of historical volatility for previous 14 trading days.

The above variables are tested for stationarity using unit root test which confirms that they are stationary at significance level of 5%, except daily options trading volume that is stationary at first order. The Table 2 gives the correlation between different variables.

The Table 2 shows high level of correlations between underlying variables like historical volatility, momentum. The effect of historical volatility is high at around 61.62%.

## 4.2 Granger Causality Tests

In this section, we assess the determinants that granger cause the implied volatility smile shape. Accordingly, linear and VECM Granger tests are used to analyze the causality between the potential determinants described above and the estimated slope of OLS model ($\beta_1$). The premise of causality test is to understand the direction of relationship between any two variables, weather first variable causes second or vice versa. The null hypothesis is first variable does not granger cause second and second variable does not granger cause first. Following estimations are used by employing a lag length of 4 as per Schwarz Information Criteria:

$$Y_t = a_1 + \Sigma\, \beta_i\, \chi_{t-i} + \Sigma\, Y_i\, Y_{t-i} + e_{1t}$$

$$X_t = a_2 + \Sigma\, \theta_i\, \chi_{t-i} + \Sigma\, \delta_i\, Y_{t-i} + e_{2t}$$

where, $Y_t$ and $X_t$ are two variables and it is assumed that the lagged values of $Y_t$ and $X_t$ are uncorrelated white noise terms.

Following are the results of linear and VECM Granger Causality tests between $\beta_1$ and the potential determinants of smile pattern.

The Table 4 show the relationship between the smile profile and determinants of the smile. Table 3 is the linear Granger causality test for call and put options while Table 4 is the non linear VECM test for call and put options. The results show that time to expiration is a factor causing asymmetrical smile pattern for both the option types. As the option's time to maturity approaches, i.e. as the time to expiration decreases and the option approaches maturity, the smile magnitude increases. This effect

**Table 2.** Correlation Matrix

| | HVOL | MOM | OPTVOL | TEXP | VVOL |
|---|---|---|---|---|---|
| HVOL | 1.000000 | | | | |
| MOM | 0.240275 | 1.000000 | | | |
| OPTVOL | -0.147012 | -0.004210 | 1.000000 | | |
| TEXP | -0.071369 | -0.103548 | 0.029235 | 1.000000 | |
| VVOL | 0.616213 | 0.204321 | -0.230225 | -0.112305 | 1.000000 |

**Table 3(A).** Determinants of Smile asymmetry for options: Linear Test for Call Options

| Causal Direction | Lag length | F-statistic | p- value |
|---|---|---|---|
| TTE→β1 | 4 | 7.903* | 0.002 |
| N→β1 | 4 | 0.873 | 0.743 |
| MoM→β1 | 4 | 0.342 | 0.532 |
| VOL→β1 | 4 | 0.865 | 0.562 |
| HVOL→β1 | 4 | 5.467* | 0.012 |
| VVOL→β1 | 4 | 0.258 | 0,920 |
| β1→TTE | 4 | 1.965 | 0.126 |
| β1→N | 4 | 0.876 | 0.342 |
| β1→MoM | 4 | 1.354 | 0.256 |
| β1→VOL | 4 | 1.543 | 0.321 |
| β1→HVOL | 4 | 4.634* | 0.034 |
| β1→VVOL | 4 | 0.021 | 0.896 |

*denotes significant @5% level

**Table 3(B).** Linear Test for Put Options

| Causal Direction | Lag length | F-statistic | p- value |
|---|---|---|---|
| TTE→β1 | 4 | 5.903* | 0.000 |
| N→β1 | 4 | 0.654 | 0.653 |
| MoM→β1 | 4 | 0.871 | 0.213 |
| VOL→β1 | 4 | 0.453 | 0.783 |
| HVOL→β1 | 4 | 0.690 | 0.921 |
| VVOL→β1 | 4 | 0.532 | 0.672 |
| β1→TTE | 4 | 11.342* | 0.001 |
| β1→N | 4 | 0.213 | 0.542 |
| β1→MoM | 4 | 0.473 | 0.892 |
| β1→VOL | 4 | 0.689 | 0.563 |
| β1→HVOL | 4 | 10.126* | 0.030 |
| β1→VVOL | 4 | 0.693 | 0.437 |

*denotes significant @5% level

**Table 4.** Determinants of Smile asymmetry for options

**4(A).** VECM Test for Call Options

| Causal Direction | Degree of freedom | $X^2$ | p- value |
|---|---|---|---|
| TTE→β1 | 4 | 43.980* | 0.001 |
| N→β1 | 4 | 8.045 | 0.673 |
| MoM→β1 | 4 | 2.876 | 0.206 |
| VOL→β1 | 4 | 6.432 | 0.765 |
| HVOL→β1 | 4 | 12.254* | 0.047 |
| VVOL→β1 | 4 | 3.786 | 0.673 |
| β1→TTE | 4 | 5.764 | 0.432 |
| β1→N | 4 | 9.876 | 0.541 |
| β1→MoM | 4 | 3.458 | 0.107 |
| β1→VOL | 4 | 2.783 | 0.831 |
| β1→HVOL | 4 | 7.658* | 0.012 |
| β1→VVOL | 4 | 2.145 | 0.217 |

**Table 4(B).** VECM Test for Put Options

| Causal Direction | Degree of freedom | X2 | p- value |
|---|---|---|---|
| TTE→β1 | 4 | 18.653* | 0.000 |
| N→β1 | 4 | 3.125 | 0.234 |
| MoM→β1 | 4 | 2.431 | 0.875 |
| VOL→β1 | 4 | 1.346 | 0.461 |
| HVOL→β1 | 4 | 20.362* | 0.032 |
| VVOL→β1 | 4 | 6.543 | 0.681 |
| β1→TTE | 4 | 20.560* | 0.000 |
| β1→N | 4 | 2.134 | 0.371 |
| β1→MoM | 4 | 2.437 | 0.521 |
| β1→VOL | 4 | 1.543 | 0.351 |
| β1→HVOL | 4 | 13.479* | 0.000 |
| β1→VVOL | 4 | 7.432 | 0.371 |

is more pronounced for out-of-the-money options, i.e. options at low levels of moneyness, compared to in-the- money options that leads to a certain asymmetric smile pattern. Thus, it transforms the U-shaped smile pattern from a "wry grin" to a "reverse grin"[8]. Apart from TTE, historical volatility also has a significant impact on the smile pattern. As the volatility of the underlying index increased, exercise price bias increased for both, in-the-money and out-of-money options but with an asymmetric pattern as in-the money options tend to experience more implied volatility with higher historical volatility. The VEC Model also reveals similar results as obtained from Linear models. In mature and developed financial markets, similar results have been obtained. In our study, option trading volume, a parameter to measure option liquidity has no significant impact on the smile pattern. This is in contrast with the result that a higher option liquidity level leads to a higher implied volatility curve level, which is consistent with the prediction of the 'illiquidity premium' hypothesis and to more pronounced implied volatility skewness[5]. The trading volume is low in the initial days, and increases as the option nears maturity. Options have been used majorly as an investment vehicle rather than for hedging. Thus, even for low trading levels, the premium for in the money options rises, giving us positive asymmetric smile.

## 5. Conclusion

Current research is an attempt to study the U-shape form of graph formed between implied volatility and moneyness of options. According to the Black Scholes model, implied volatility of an option should be independent of its strike and expiration. However, it was only after the crash of 1987, that the pattern became skewed and was referred to as volatility smile. We focus on dual objectives: to examine the volatility smile; i. e relationship between option moneyness and implied volatility and secondly to find the potential determinants of the smile pattern. We have defined moneyness as the absolute value of the ratio of difference between index value and option strike price to the index value. Daily data of S&P CNX Nifty has been studied from 01st April 2014 to 31st March 2015. The model used is the Linear model using Ordinary Least Squares regression. Granger causality test has also been employed to study the direction of relationship between various option volatility determinants and the estimated slope parameter. Following are the results of the study:

- The volatility smile can be explained by the linear regression model with dependent variable as IV and moneyness as independent variable.
- A positively asymmetric smile pattern is observed for call and put options in Indian market. Although the smile asymmetry is more pronounced for put options.
- Our results are in contrast with those of mature and developed markets where a negative asymmetric smile curve is obtained. This can partially be explained by the difference in structure of the two markets with different transaction costs and also due to investor behavior. In India, options are mostly used as an investment vehicle, whereas in mature markets, options are used primarily as a hedging tool.
- It is observed that there exists high implied volatility patterns for in and out-of-the money options and low volatility figures for at-the-money options which gives a positively asymmetric smile pattern.

- In the paper, attempt has also been made to study the potential determinants of the smile profile and the symmetric pattern using Granger causality test. We conclude that time to expiration and historical volatility are the key factors for call and put options. This result is similar to that obtained in mature markets.

Black Scholes model has been the language for quoting option prices for a very long time. Even though there are biases and anomalies that exist in the model, yet it is the most popular one in practice used by academia and market makers alike. Investors may continue to use this model but with some cognizance.

## 6. Implications of the Study

Subject of implied volatility is an important area in option pricing especially because Black and Scholes model is a widely used tool in option pricing and the limitations of the model can have serious implications in the financial markets globally in terms of value.

- The present research will aid investors, financial practitioners, market makers and academia in understanding the option trading and factors that affect the volatility smile pattern for Indian market.
- Implied volatility, a key variable in the model is unobservable and open to subjectivity and as a result it becomes even more important to calculate it accurately.
- Our empirical results show the determinants and factors that affect the smile pattern in options. The key variables are important from the point of view of Indian market where enough research on the topic has still not taken place.
- We also reason that the presence of asymmetric smile pattern is mainly due to the use of options as an investment tool rather than for hedging in India in contrast with the mature markets where options are used primarily for hedging. The research can be used to further study the comparison between Indian and mature financial markets.
- From the point of financial practitioners, the concept of implied volatility is significant and can help them understand the volatility surface and smile patterns.
- To overcome the limitations of the Black Scholes model is an intellectual challenge and of importance to business and academia alike. Investors need an accurate model to calculate hedge ratio.
- The research will also aid in pricing and valuing of exotic options.
- Implied volatility represents an unbiased and efficient forecast of future riskiness, it can be used as a tool for risk management for portfolios where the payoffs are index dependent.
- The Granger causality test helped in finding the determinants of smile pattern, yet no empirical foundation has been laid so far to calculate the degree of dependency. Further research and study in the area will be a welcome step.

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