# HISTORICAL AND IMPLIED VOLATILITY: AN INVESTIGATION INTO NSE NIFTY FUTURES AND OPTIONS

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## ABSTRACT

*The broad objective of the paper is to have an understanding of the movement of volatility over a fair period in respect of the market portfolio. Also, it enables an understanding on how divergent the implied volatility has been from this estimate. It uses Volatility Cone, Volatility Smile and Volatility Surface as the parameters. The study takes different rolling periods percentiles of volatility.* ***Hoadley Options Calculator*** *is used for calculation and analysis purpose. The study empirically proves that there is a clear reversion to the mean as indicated by the volatility cone. The study of volatility smiles in respect of NIFTY options throws up different patterns. The Garch (1.1) model reveals that historical volatility for the period from 2004 to 2004 and for the year 2009 were estimated. Interestingly, but not totally surprisingly, the average implied volatility of calls and puts on Nifty during the period January to March 2010 showed differences.*

## I. INTRODUCTION

The Black Scholes model requires us to input the volatility estimate for getting the value of an option. All the other inputs are easy to reckon, but volatility is a matter of estimation and expectation. Traders and investors estimate volatility based on their perspective and will get different model option prices. Ultimately the market option prices are decided by a weighted average of these estimates. The volatility that comes about from the price is the implied volatility and in most cases this is far removed from any legitimate estimate of the past volatility (historical volatility).

Volatility has been a subject of great controversy over the years. Empirical research has not been able to show a ready pattern on the movement of volatility. Research has concentrated on areas like the best possible estimates of historical volatility, how the historical volatility would tend to revert towards the mean, throw the implied volatility is related to historical volatility, and the differences in all this when it comes to out of the money options.

This paper seeks to look at the benchmark NIFTY stock during the period from 2004 to 2009 and analyze the historical volatility patterns. Later, we try to look at what evidence we can draw from the historical volatility estimates to use it for comparing with implied volatility. We also examine the phenomenon of volatility smiles and surfaces, and finally attempt a rough forecast based on the Garch (1.1) model.

Specifically we look at the application of volatility smiles in respect of the index options during the period January to March 2010. On examination of the volatility smile on a daily basis we see changes happening with the "smile" changing its shape almost on a daily basis. What is more the implied volatility estimates are different for the puts and calls during the same period.

Another analysis that has been done is on the historical volatility over the period from 2004 to 2009 and to see the "cone" effect of reverting to the mean. The historical volatility for various periods from 30 days on to 570 days has been carried out and the results are very interesting.

First we show the scope, objectives and the methodology used in the paper. We then look at select existing literature on the subject, including findings of other research. Later we discuss the model in detail. The last part consists of findings, conclusions and limitations of the study.

## II. SCOPE, OBJECTIVES AND METHODOLOGY

The paper aims to look at the NIFTY movements during the period 1st January, 2004 to 31st December, 2009. At the first stage, the historical volatility for various time periods during 2004-2008 is analyzed and we ascertain whether the historical volatility is demonstrating a tendency to revert to the mean. Next, we ascertain the implied volatility of NIFTY-based options during the period 1st January 2010 to 31st March, 2010. The "smile" effect is analyzed and the differences in findings as between the call implied volatility and the put implied volatility is looked into. We also look at the changes in implied volatility across various strike prices, given the same time frame. We have used the Hoadley Options Calculator for all purposes of calculation (Hoadley Trading and Investment Tools, the Hoadley Finance Add-in for Excel © 2001-2010, Peter Hoadley).

The study is exploratory in the sense that only the NIFTY index is considered and not all the stocks that form part of it. Also, a medium term has been reckoned for the purpose of calculating historical volatility, the study on implied volatility has been restricted to the 3-month period subsequent to this.

The broad objective of the paper is to have an understanding of the movement of volatility over a fair period in respect of the market portfolio. Also, it enables an understanding on how divergent the implied volatility has been from this estimate.

## III. EMPIRICAL OBSERVATIONS ON VOLATILITY

Over the years a number of research papers have been brought out seeking to explain the movements of volatility and improving our understanding as to the factors that cause changes in volatility. While there is large number of studies available on the topic, we tried our level best to review some the most important and pertinent researches as under:

Attempting to develop a model for volatility for the Indian stock market, Thiripal Raju and Rajesh (2010), found out that among all the models, the main equation was the most apt one to test the volatility of the stock markets. Application of GARCH and Auto Correlation resulted in proving that measurement of volatility in the stock market is an important phenomenon from the view point of decision making by the investors. The study also demonstrated significant auto correlation in daily returns and a tendency to volatility clustering.

In their model, Ozenbas *et al* (2009), found out that the volatility of a firm level component of stock price returns has increased relative to the market and industry components which resulted in a great puzzle. Using dynamic general equilibrium model, their research indicate whether the firms adjusted their capital structure if their stock price becomes more volatile and the effects. The study found out that the larger stock volatility risk translated into higher financing cost inducing the firms to rely less on borrowed capital.

Christner Ron (2009), made an attempt to study US stock market volatility as a result of 2008 fall. The research evaluated and analyzed weekly movements in some volatility variables for a period of eight months of 2008, four months pre and post 2008 fall respectively. Having compared the variables with the movement in NYSE, NASDAQ and S&P stock index the study found out that the relative volatility in the variables appears to be three times the volatility of indexes. The study also found out that the possible extreme situations and volatility are likely to re-occur in near future.

Badani (2009), in his study attempted to assess the impact of US stock market volatility on Indian stock markets. Basing the study on the daily closing values of S&P 500 and S&P CNX NIFTY, it revealed that there has been significant response asymmetry in spill over effects and thus returns in the Indian Stock markets were found to be more sensitive to negative shocks in the US markets rather than positive shocks.

Lake and Andreas (2009), attempted to explore the effects of returns and volatility pertaining to oil price on the Greek, the US, the UK and the German stock markets. Applying E-GARCH models and structural equation models, the study identified that the effects of oil price returns had a major effect since the investors use the futures market to hedge their position.

Cheng and Mei-Hsingh (2008), in their study examined the effects of intraday volatility interruption mechanism employed by the Taiwan stock exchange. The results evidenced that approximately the interruptions were followed by another interruption within the same day leading to a cluster of interruptions. The study evidenced that the trading suspension to reduce excessive volatility is highly limited and hence proved that the hypothesis called' learning by trading 'which suggests that the trading interruption impedes information transmission

Studying on predictability and volatility of stock returns in the US, UK and Japanese market, Marios Marvides (2003), found out that the returns of the stock market could be predicted by dividend price ratios and dividend growth rates. He also identified that there was persistence in the variance of stock returns due to the said ratios.

Richard A. Michel Felder (2005), attempted to analyze stock returns volatility and predictability for seven markets. He found out that the emerging markets have higher volatility yet lower persistence of shocks than immature markets. He also found out that the impact of non-trading days on volatility of emerging market stock returns is greater than that of mature markets.

Jamshed Y. Uppal (1998), investigated into stock return volatility in the Karachi Stock Exchange. He found out that the variants of the weekly changes increased significantly following opening of the market, but stabilised after the opening at a new and higher level. The study also revealed that except for the period immediately following the opening, the market appears to be informational efficient.

Lubos Pastor and Robert F. Stambeugh (2011), in their study attempted to find out if the stocks are really less volatile in the long run. In contrast to annualised volatility of stock returns being lower conventionally in the long horizons due to mean reversion they found out that the stocks are substantially more volatile in the long run. They also proved that mean reversion contributes strongly to reducing long term variance but it is more than offset by various uncertainties.

Tobias Adrian and Joshua Rosenberg (2008), explored cross sectional pricing of volatility risk by decomposing equity market volatility into short and long run components. Their study found out that prices of risk are negative and significant for both volatility components.

As it has been highlighted in the researches above, estimates of volatility are an important part of trading in both the securities and the derivatives market. The study of volatility centers on the following:

- The importance of volatility estimation – for pricing of products and knowing the risk attributes of a portfolio
- Historical and implied volatility
- The concept of moving averages volatility and the need to give greater weights to the most recent evidence
- Volatility cones representing the tendency of volatility to revert to the mean over the long period.
- Volatility smiles representing the differences in the estimates of implied volatility for different strike prices for the same underlying security
- The supposed tendency of implied volatility to tend to approach the historical mean over the longer period
- The Garch(1.1) estimate of volatility which seeks to be an improvement to the Exponential Weighted Moving Average EWMA estimates

Models that seek to estimate volatility recognize that there could be periods of high volatility and some other times of low volatility. Research has also been undertaken on specific differences in volatility between the close of one trading day and another; and more interestingly from the close of trading on Fridays and the close of trading on the Mondays next. There have been a number of research papers which establish that volatility is higher during trading days than on holidays, which then is the justification for taking the number of days in the year to be 252.

In the Exponential Weighted Moving Average (EWMA) method the weights decrease exponentially as we move back in time. Estimation of future volatility is made by this method by just taking the current estimate of volatility change and the most recent observation from the market variable. When a new observation emerges, a corresponding new percentage of change is calculated in order to update the volatility estimation. Also, with the arrival of the Garch (1.1) model, EWMA just becomes a special case of this model.

**IV. The model used in this paper.**

Historical closing prices of NIFTY have been taken for the period 1st January, 2004 to 31st December, 2008. Based on these closing prices, the specified volatility measures for various rolling periods were ascertained. Specifically we get the following information:

1. The average historical volatility reckoning the entire horizon but taking specifically 30,60, 90 days and so on as the rolling period, one period at a time
2. The maximum and minimum volatility during the period
3. The most recent volatility during the period under reckoning
4. Taking the 95% confidence level, the upper and lower confidence boundary for the estimate
5. The $90^{th}$ , $70^{th}$ , $50^{th}$ , $30^{th}$ and the $10^{th}$ percentile of volatility

Then we graph the average, minimum and maximum volatility during the period specifically to ascertain whether the volatility tends to revert to the mean. Also, the graph will depict the state of the average volatility for various rolling periods as well.

We look at the implied volatility on a daily basis for various strike prices in respect of the call and put options expiring in March, 2010. The analysis is in respect of the period from January 2010 to March 2010 of the same options. The "volatility smile" effect and the "volatility surface" effect is also examined.

Next, we analyze the instantaneous volatility using the Garch (1.1) model. This is done for various periods into the future – we have specifically shown the forecasts for 1 day to 20 days. This analysis has been done separately based on the 5-year volatility (from 2004 to 2008).
The Hoadley's Options software has been used for calculations purposes.

**V. Findings**

For the period from 2004 to 2008, the historical volatility estimates taking various rolling prices as indicated in the table below were ascertained. The table also contains other parameters on historical volatility.

**Table 1: Historical Volatility for the period 1st January 2004 to 31st December 2008, using various rolling periods between 30 and 120 days**

| **Rolling days ->** | **30** | **60** | **90** | **120** |
|---|---|---|---|---|
| Average | 0.26 | 0.26 | 0.27 | 0.27 |
| Maximum | 0.78 | 0.63 | 0.54 | 0.52 |
| Minimum | 0.09 | 0.12 | 0.13 | 0.14 |
| Latest | 0.42 | 0.62 | 0.54 | 0.51 |
| Upper confidence level (95%) | 0.57 | 0.76 | 0.64 | 0.58 |
| Lower confidence level (95%) | 0.34 | 0.53 | 0.47 | 0.45 |
| $90^{th}$ percentile | 0.47 | 0.43 | 0.41 | 0.38 |
| $50^{th}$ percentile | 0.31 | 0.31 | 0.33 | 0.34 |
| $30^{th}$ percentile | 0.22 | 0.23 | 0.24 | 0.24 |
| $10^{th}$ percentile | 0.17 | 0.18 | 0.19 | 0.19 |

**Table 2: Historical Volatility for the period 1st January 2004 to 31st December 2008, using various rolling periods between 150 and 240 days**

| **Rolling days ->** | **150** | **180** | **210** | **240** |
|---|---|---|---|---|
| Average | 0.27 | 0.27 | 0.27 | 0.27 |
| Maximum | 0.48 | 0.45 | 0.46 | 0.45 |
| Minimum | 0.15 | 0.16 | 0.16 | 0.16 |
| Latest | 0.48 | 0.44 | 0.44 | 0.45 |
| Upper confidence level (95%) | 0.54 | 0.50 | 0.48 | 0.50 |
| Lower confidence level (95%) | 0.43 | 0.40 | 0.40 | 0.41 |
| $90^{th}$ percentile | 0.38 | 0.37 | 0.37 | 0.36 |

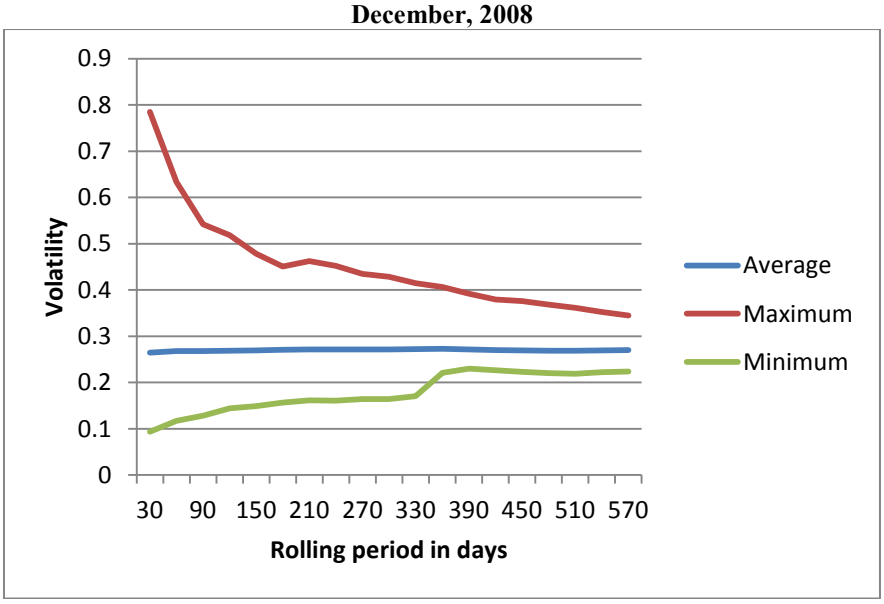
| | | | | |
|---|---|---|---|---|
| 50th percentile | 0.31 | 0.29 | 0.29 | 0.30 |
| 30th percentile | 0.25 | 0.26 | 0.27 | 0.27 |
| 10th percentile | 0.22 | 0.21 | 0.22 | 0.24 |

**Table 3: Historical Volatility for the period 1st January 2004 to 31st December 2008, using various rolling periods between 270 and 360 days**

| **Rolling days ->** | **270** | **300** | **330** | **360** |
|---|---|---|---|---|
| Average | 0.27 | 0.27 | 0.27 | 0.27 |
| Maximum | 0.43 | 0.43 | 0.41 | 0.41 |
| Minimum | 0.16 | 0.16 | 0.17 | 0.22 |
| Latest | 0.43 | 0.42 | 0.41 | 0.41 |
| Upper confidence level (95%) | 0.47 | 0.46 | 0.45 | 0.44 |
| Lower confidence level (95%) | 0.40 | 0.39 | 0.38 | 0.38 |
| 90th percentile | 0.35 | 0.34 | 0.33 | 0.32 |
| 50th percentile | 0.29 | 0.29 | 0.29 | 0.29 |
| 30th percentile | 0.26 | 0.25 | 0.26 | 0.25 |
| 10th percentile | 0.25 | 0.25 | 0.25 | 0.24 |

The cone effect can be seen from the figure 1 below. The horizontal axis shows the rolling period in days and the vertical axis shows the volatility. The clear reversion to the mean which is an empirically- proved phenomenon can be seen in the chart.

**Figure 1: Volatility cone in respect of historical volatility during the period 1st January 2004 to 31st December, 2008**




Now taking the Garch (1.1) model, the predicted volatility for the periods of 1 day to 20 days from the closure of the historical-volatility-estimation period is shown below. Separate tables are shown taking the historical volatility of 2004-2008 as the basis, and the historical volatility of 2009 as the basis.

**Table 4: Garch (1.1) forecasts of volatility based on 4 year historical volatility from 1st January, 2005 to 31st December, 2008**

| **Number of days of forecast** | **Estimate of Historical volatility** | **Number of days of forecast** | **Estimate of Historical volatility** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1 | 0.32 | 11 | 0.32 |
| 2 | 0.32 | 12 | 0.32 |
| 3 | 0.32 | 13 | 0.32 |
| 4 | 0.32 | 14 | 0.32 |
| 5 | 0.32 | 15 | 0.32 |
| 6 | 0.32 | 16 | 0.32 |
| 7 | 0.32 | 17 | 0.32 |
| 8 | 0.32 | 18 | 0.32 |
| 9 | 0.32 | 19 | 0.32 |
| 10 | 0.32 | 20 | 0.32 |

The following table shows the Garch (1.1) estimates based on the 1-year historical volatility

**Table 5: Garch (1.1) forecasts of volatility based on 1 year historical volatility from 1st January, 2009 to 31st December, 2009**

| Number of days of forecast | Estimate of historical volatility | Number of days of forecast | Estimate of historical volatility |
|---|---|---|---|
| 1 | 0.20 | 11 | 0.21 |
| 2 | 0.20 | 12 | 0.21 |
| 3 | 0.20 | 13 | 0.21 |
| 4 | 0.20 | 14 | 0.21 |
| 5 | 0.20 | 15 | 0.21 |
| 6 | 0.21 | 16 | 0.22 |
| 7 | 0.21 | 17 | 0.22 |
| 8 | 0.21 | 18 | 0.22 |
| 9 | 0.21 | 19 | 0.22 |
| 10 | 0.21 | 20 | 0.22 |

Next, the implied volatility estimates during the period from 1st January to 31st March, 2010 was analyzed, and the results of average implied volatility during the period across all strike prices is shown below in respect of select dates in the period (the first two and the last two dates of each month has been taken).

**Table 6: Average Implied Volatility observed across all strike prices during select dates in the period from 1st January 2010 to 31st March, 2010**

| Period | Average implied volatility calls | Average implied volatility puts |
|---|---|---|
| 4-Jan-10 | 0.22 | 0.32 |
| 5-Jan-10 | 0.21 | 0.29 |
| 6-Jan-10 | 0.21 | 0.28 |
| 7-Jan-10 | 0.23 | 0.29 |
| 8-Jan-10 | 0.21 | 0.28 |
| 11-Jan-10 | 0.20 | 0.28 |
| 12-Jan-10 | 0.20 | 0.27 |
| 13-Jan-10 | 0.20 | 0.28 |
| 14-Jan-10 | 0.19 | 0.27 |
| 15-Jan-10 | 0.19 | 0.27 |
| 18-Jan-10 | 0.19 | 0.27 |
| 19-Jan-10 | 0.19 | 0.28 |

| | | |
|---|---|---|
| 20-Jan-10 | 0.19 | 0.35 |
| 21-Jan-10 | 0.22 | 0.29 |
| 22-Jan-10 | 0.21 | 0.29 |
| 25-Jan-10 | 0.22 | 0.30 |
| 27-Jan-10 | 0.24 | 0.32 |
| 28-Jan-10 | 0.24 | 0.31 |
| 29-Jan-10 | 0.22 | 0.31 |
| 1-Feb-10 | 0.23 | 0.29 |
| 2-Feb-10 | 0.23 | 0.31 |
| 3-Feb-10 | 0.22 | 0.31 |
| 4-Feb-10 | 0.23 | 0.32 |
| 5-Feb-10 | 0.26 | 0.34 |
| 6-Feb-10 | 0.25 | 0.33 |
| 8-Feb-10 | 0.29 | 0.35 |
| 9-Feb-10 | 0.29 | 0.33 |
| 10-Feb-10 | 0.27 | 0.34 |
| 11-Feb-10 | 0.24 | 0.34 |
| 15-Feb-10 | 0.24 | 0.34 |
| 16-Feb-10 | 0.24 | 0.35 |
| 17-Feb-10 | 0.23 | 0.33 |
| 18-Feb-10 | 0.24 | 0.33 |
| 19-Feb-10 | 0.26 | 0.36 |
| 22-Feb-10 | 0.35 | 0.36 |
| 23-Feb-10 | 0.26 | 0.36 |
| 24-Feb-10 | 0.28 | 0.36 |
| 25-Feb-10 | 0.33 | 0.35 |
| 26-Feb-10 | 0.26 | 0.32 |
| 2-Mar-10 | 0.26 | 0.31 |
| 3-Mar-10 | 0.19 | 0.33 |
| 4-Mar-10 | 0.20 | 0.33 |
| 5-Mar-10 | 0.26 | 0.31 |
| 8-Mar-10 | 0.18 | 0.34 |
| 9-Mar-10 | 0.23 | 0.33 |
| 10-Mar-10 | 0.20 | 0.33 |
| 11-Mar-10 | 0.31 | 0.34 |
| 12-Mar-10 | 0.27 | 0.36 |
| 15-Mar-10 | 0.39 | 0.40 |
| 16-Mar-10 | 0.26 | 0.43 |
| 17-Mar-10 | 0.69 | 0.47 |
| 18-Mar-10 | 0.70 | 0.62 |
| 19-Mar-10 | 0.74 | 0.57 |
| 22-Mar-10 | 1.18 | 0.81 |
| 23-Mar-10 | 1.35 | 1.08 |

The volatility smile chart (Figure 2) shows different shapes when analyzed at various points of time during the period 1st January 2010 to 31st March, 2010. The following is the volatility smile chart shown for three different dates in the period in respect of the put implied volatility.

**Figure 2: Volatility Smile showing implied volatility of puts for various exercise prices as on 5th January, 2010**

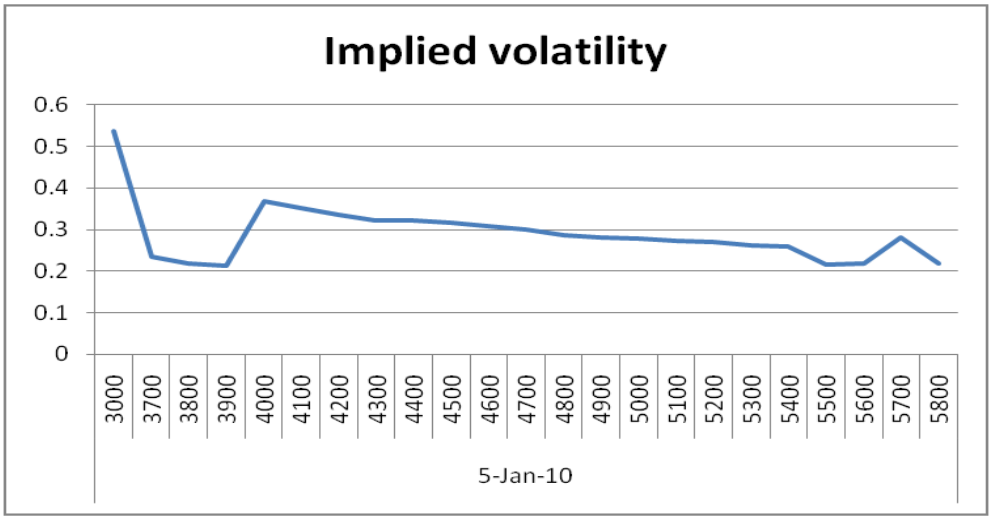



**Figure 3: Volatility Smile showing implied volatility of puts for various exercise prices as on 26th February, 2010**

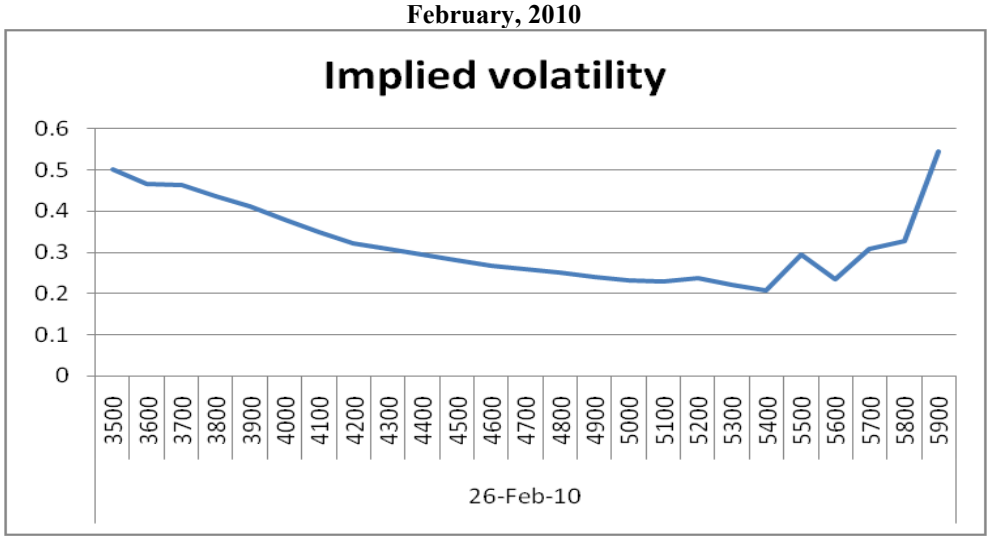
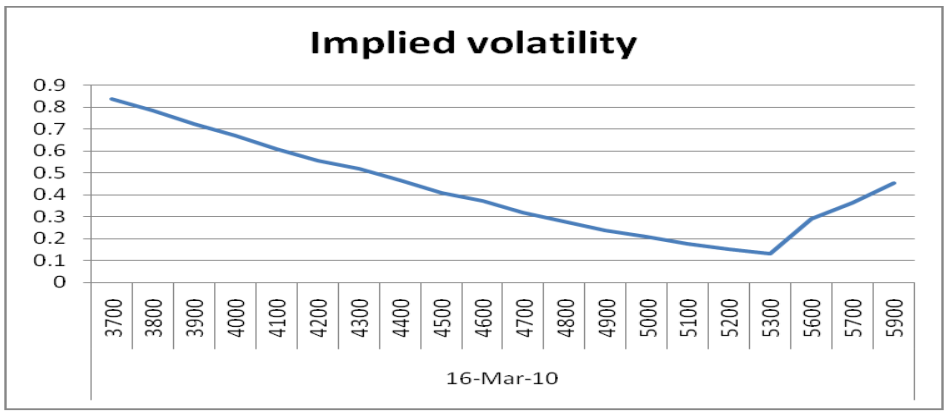



**Figure 4: Volatility smile showing implied volatility of puts for various exercise prices as on 16th March, 2010**



## VI. CONCLUSION

Various studies on volatility and implied volatility over the years have shown conflicting results on the relationship with each other. In this exploratory study of NIFTY spot and NIFTY options, we find the implied volatility being different across various time periods in the horizon and for various exercise prices. While not particularly volatile, the market did show steep tendencies during the period under study. We study the NIFTY stock during the period 2004 to 2009 and look at various facets of historical volatility and the established tendency to revert to the mean. The study of volatility smiles in respect of NIFTY options for the period from January to March, 2010 throws up different patterns. Lastly, we make Garch (1.1) estimates on future volatility based on past records. Our conclusions in this paper are based on the rolling period volatility for 30, 60, 90 days and so on for the entire horizon. It is arguable that the results might have been different with just the annualized volatility estimates. Also, interestingly, but not totally surprisingly, the average implied volatility of calls and puts on Nifty during the period January to March 2010 showed differences. While it will be imprudent to make far-reaching conclusions from a relative small size as above, this study appears to indicate that immediate past historical volatility does not appear to have any bearing on the short run implied volatility.

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