# SYNOPSIS

## Study on Effectiveness of Various Option-Pricing Models in Indian Stock Market

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## 1. Evolution of Pricing Models in Financial Markets – Introduction

According to standard (traditional) finance, financial markets are considered to be efficient, analytical and normative. It considers that people behave rationally i.e. they update their beliefs correctly when they receive new information as described by Bayes' law; and given their beliefs, agents make choices that are normatively acceptable. Hence the market prices are regarded as optimal estimates of true investment value at all times.

The Black-Scholes model introduced in 1973 is considered as a breakthrough in the field of option pricing. In 1997, the importance of the model was recognized when Merton and Scholes were awarded the Nobel Prize for economics. Even today it is considered by many as a standard "rational" model. The National Stock Exchange (NSE) calculates the option price to be listed in the market using the Black-Scholes formula. But, studies have documented that the actual market behaviour is different from the theoretical Black-Scholes model. The observation of the presence of volatility smiles and smirks has been considered as a major argument in this regard. Various options pricing models alternative to Black-Scholes have been evolved that seek to understand, fit and predict the market prices. The models include Constant

Elasticity of Variance model, Variance Gamma model, Heston model, Heston Nandi model, Jump Diffusion models etc. Even today, a number of researches are undertaken to evolve option pricing models that can predict the market behaviour better.

However, many studies have also shown that the empirically observed movement of stock prices differed from the theoretical paradigm. Many studies have been conducted to comprehend and represent the complexities of the observed financial markets. Thus, the field of behavioural finance emerged to understand and model the observed market behaviour.

## 2. Objectives of the Study

To test select option pricing models and identify the model that fit better the observed Option prices in Indian stock market.

## 3. Design of the Study

- The following models were chosen (as they were the most cited models in literature)
  - Black-Scholes model

    Implemented using the *BlackScholesOption()* function
  - Heston Nandi model

    Implemented using the *HNGOption()* function
  - Variance Gamma model

The function call was implemented in R. The parameters v and theta were optimized to fit the previous day's options data. The optimization was implemented using the bounded non-linear minimization function call *nlminb()*.

- Merton's Jump diffusion model

  The function call was implemented in R. The parameters a (average number of jumps per year), k (average jump size measured as a percentage of asset price) and s (standard deviation of size of percentage jump) were optimized to fit the previous day's options data (as mentioned in Hull, 2009). The optimization was implemented using the bounded non-linear minimization function call *nlminb()*.

- The one-month and three-month MIBOR rates (downloaded from NSE, India website (www.nse.com) was used as the risk-free rate for calculating prices of one-month and three-month options. For two month option pricing, the risk-free rate was calculated by averaging the values of one-month and three-month MIBOR rates. If the MIBOR rate was not available for a day, then the previous available day's MIBOR rates were used in calculation.

- The historical volatility for a particular day was calculated by calculating the standard deviation of the returns of the previous 252 days (using the close price).

The fit of the option pricing model was calculated based on the average pricing error of the model when compared with the actual market prices. The formula used is

$$Yearly\ Root\ Mean\ Square\ Percentage\ Error\ (in\ \%) = \sqrt{\frac{\sum_{\substack{Number\ of\ trading \\ days\ in\ an\ year}} \left[\frac{Actual\ Market\ Price - Predicted\ Model\ Price}{Actual\ Market\ Price}\right]^2}{Number\ of\ trading\ days\ in\ an\ year}} * 100$$

$$Monthly\ Root\ Mean\ Square\ Percentage\ Error\ (in\ \%) = \sqrt{\frac{\sum_{\substack{Number\ of\ trading \\ days\ in\ a\ month}} \left[\frac{Actual\ Market\ Price - Predicted\ Model\ Price}{Actual\ Market\ Price}\right]^2}{Number\ of\ trading\ days\ in\ a\ month}} * 100$$

- The pricing errors were analysed in (i) Yearly basis (ii) Monthly basis and the best-fit option pricing models were identified. The study analyzes the option pricing errors during three phases of the stock market (i) Bullish phase (ii) Crash phase (iii) Uncertain recovery phase after crash. The phases were visually identified from NSE NIFTY data from January 2005 to August 2017.

| Phase | Time Period |
|---|---|
| Bullish | January 2005 to December 2007<br>June 2012 to February 2015<br>January 2017 to August 2017 |
| Crash | January 2008 to April 2009<br>March 2015 to February 2016 |
| Uncertain Recovery | May 2009 to May 2012 |

| | |
|---|---|
| | March 2016 to December 2016 |

Table 1: Classification of Market phases and the relevant time period

## 4. Tools used for Analysis

The following tools have been used for the analysis.

- R (v3.4.1)

  R is a language and environment that provides a wide variety of statistical (linear and nonlinear modelling, classical statistical tests, time-series analysis, classification, clustering etc.) and graphical techniques. R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License in source code form (www.r.project.org)

- The following packages in R have been used in this study.
  - xlsx
  - zoo
  - actuar
  - fOptions

  The selection of the top six traded options and calculation of pricing errors for select option pricing model has been implemented in R.

- Microsoft Excel (v2010)

  The pricing errors of select option pricing models (got as output from R) was compared and analysed in Excel.

## 5. Scope of the study

- The study considers the observed market prices at National Stock Exchange, India (NIFTY).

- The study considers only NIFTY index options. The options where the total number of contract exceeds 400 have only been considered. Further only the top-six traded contracts have been considered for the study.

## 6. Type of Data and Data Source

- **Type of Data**: Secondary data of observed market price of the NIFTY index options and MIBOR rates have been considered for the study.

- **Data Source**: NIFTY index option prices and one-month & three-month MIBOR rates have been downloaded from National Stock Exchange (India) website www.nse.com. For two month option pricing, the risk-free rate was calculated by averaging the values of one-month and three-month MIBOR rates. If the MIBOR rate was not available for a day, then the previous available day's MIBOR rates were used in calculation.

- **Data Validity**:

  (i) A considerable length of time of 12 years from 2005 to 2017 of observed NIFTY index options price has been considered for the study.

  (ii) The options where the total number of contract exceeds 400 have only been considered.

| | |
|---|---|
| SUM (NO OF DAILY CONTRACTS IN SELECTED MONTH) > 400 | |

| | |
|---|---|
| SUM (NO OF DAILY CONTRACTS IN MONTH) <= 400 | NOT SELECTED |

(iii) Only the top-six traded contracts have been considered for the study.

| | |
|---|---|
| SORT DESCENDING (SUM OF NO OF DAILY CONTRACTS IN MONTH) IS IN 1 TO 6 POSITION | SELECTED |
| SORT DESCENDING (SUM OF NO OF DAILY CONTRACTS IN MONTH) IS NOT 1 TO 6 POSITION | NOT SELECTED |

## 7. Social Relevance of this study

"One of the funny things about the stock market is that every time one person buys, another sells, and both think they are astute." This is one of the quotes by noted American author William Feather. Many retail investors in Indian Stock market have been adversely impacted by the irrational buying and selling behavior that has not been backed by any scientific analysis. This has also driven to many cases of suicides committed driven by losses incurred.

This study explores the possibility of option price model fitment for fitment the market prices; and thereby provide an analytical base for retail investors to assist in making rational decisions for safer investments into the Indian stock market.

## 8. Limitations of the study

- Only four option pricing models were considered due to time constraints. There are many other option pricing models such as Implied Binomial Tree, Constant Elasticity of Variance, models using neutral networks and artificial intelligence etc. that can be tried.

- The observed market data was limited to National Stock Exchange (NSE), India. The time period was from January 2005 to August 2017.

## 9. Scope for future work

This study is limited to four models. Other models can be considered for pricing error analysis.

Recent studies also indicate that traditional theories are unable to represent the complexities of the observed financial markets; hence the field of behavioural finance is emerging to understand and model the observed market behaviour. Behavioural finance seeks to understand the impact/consequence of psychological decision processes on financial markets. It links the knowledge from psychological field with the standard established theories of finance. It considers that some financial phenomena can be better understood using models in which some agents are not fully rational (either because of preferences or because of mistaken beliefs). It also seeks to comprehend the ways investors gather and use information. Thus the field is considered as an add-on to the existing traditional theories and not as a replacement for the existing theories.

The field of behavioral finance is broadly divided into two sections (i) Cognitive psychology (ii) Limits to arbitrage. `Cognitive psychology' deals with the systematic errors made by investors in the process of thinking because of presence of various behavioral components/factors (sentiment) present in the investors. `Limits to arbitrage' in behavioral finance contends that it can be difficult for rational traders to undo the dislocations caused by less rational traders. The area of behavioural finance could be explored as part of further work.