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Black-Scholes Option pricing model and its relevancy in Indian options market: A Review

Arun Chauhan[1], Ravi Gor[2]
[1]*Department of Mathematics, J. & J. College of Science, Nadiad, Gujarat, India*
[2]*Department of Mathematics, Gujarat University, Ahmedabad, India*

Abstract: *In 1973 Fischer Black and Myron Scholes gave the well-known option pricing model, 'Black-Scholes model' in their paper "The pricing of Options and Corporate Liabilities". After this paper, large number of researchers/academicians has worked on Black-Scholes option pricing model and try to generalise the classical BS model. We have collected papers published during 1973 to 2020 related to Black-Scholes option pricing model. In this paper we have reviewed all the papers in which such generalisations/modifications are proposed. After this, we have reviewed all the papers on the Relevancy of BS model in Indian options market.*

Keywords: *Black-Scholes model, Generalised Black-Scholes model, Indian options market, Relevancy of Black-Scholes model.*

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I. Introduction

Derivatives are becoming most important financial instruments in current days. The most common derivatives are options, forwards, futures, swaps. Among all different types of derivatives, options are the most common derivatives traded in exchange-traded market all over the world. In very broad sense, there are mainly two types of options, one is call option and other is put option. Further these options can be classified into European options and American options.

Black-Scholes(B-S) Option Pricing Model gives the theoretical value of European call and put options by using complex mathematical concepts. This model was first introduced by Fischer Black and Myron Scholes in 1973, and then Robert Merton generalized this model to its current form. The B-S model has not been able to portrait the real market situations by mathematical equations. This model heavily used in almost all markets as a useful approximation for theoretical value of options. But without considering the limitations of model, if we apply it in real market, we might face big loss in market. B-S model also has some limitations. To overcome from BS model's limitations, several different generalizations in B-S model have been done by researchers as well as practitioners. First, we have reviewed papers on Testing of BS model in stock markets of different countries. Then, we have also collected the papers in which comparison of BS model have been done with different option pricing models. Further, we have reviewed all the research papers having generalizations or modifications in classical BS model and reviewed them in detail. And finally, we have reviewed some papers on the significance of the BS option pricing model in the Indian options market.

II. Review of Literatures

2.1. Testing the Classical B-S model in real market

MacBeth and Merville (1979) observed options prices for six underlying securities, twelve thousand option prices for one-year time period. They concluded and we quoted, "The B-S model predicted prices are on average less (greater) than market prices for in the money (out of the money) options. With the lone exception of out of the money options with less than ninety days to expiration, the extent to which the B-S model under-prices (overprices) an in the money (out of the money) option increases with the extent to which the option is in the money (out of the money), and decreases as the time to expiration decreases. B-S model prices of out of the money options with less than ninety days to expiration are, on average, greater than market prices; but there does not appear to be any consistent relationship between the extent to which these options are overpriced by the B-S model and the degree to which these options are out of the money or the time to expiration." They also found in (1980) that, suppose there is possibility to exercise option contract before expiration time, then the price of this type of options will be below the theoretical price computed by Black-Scholes model.

Gultekin et al. (1982) have empirically tested the Black-Scholes option pricing model on call options which are near to expiration. They have observed that the value of the options depends on life of the options. The option prices of high volatile stocks and out-of-the money options are overvalued, and option prices of low volatile stocks and in-the-money options are overvalued.

Levy and Byun (1987) have compared B-S model price and observed market price of options. They have constructed 95 percent of confidence interval for call option contracts. They observed less than 95 percent of the market price fall within the range. For out-of-the-money and at-the-money options for long expiration period, and high volatile stocks, we can get best relation between actual market price and B-S model price.

Sheikh (1991) examined the call option prices of S&P 100 Index with 14 months data. They found that the theoretical price obtained using B-S model of S&P 100 calls differed from market prices.

Choi and Wohar (1994) studied S&P 500 index options from the year 1987 to 1989. From the empirical investigations of this index they suggested that, the classical B-S model underprice the set of options 'deep in-the-money calls and deep out-of-the-money puts' compared to the set of options 'deep out-of-the-money calls and deep in-the-money puts'. Also, they suggested that ex-dividends gained from put-call parity yield a less bias than those of Black-Scholes model.

Corrado and Su (1997) have examined the extended Black-Scholes model developed by Corrado ans Su (1996) which suggests skewness and kurtosis in the option-implied distributions of stock returns as the source of volatility skews. They tested this model on four actively traded stock options. They found significantly non-normal skewness and kurtosis in the option-implied distributions of stock returns.

Gencay and Salih (2003) observed that the errors in pricing the stock options using Black-Scholes model increases as we approach the deep out-of-the-money options, and mispricing worsens with increased volatility. In results they indicated that the Black-Scholes model is not the proper pricing tool in high volatility situations especially for very deep out-of-the-money options.

McKenzie et al. (2007) have studied options with underlying asset as ASX200 Index which is traded in Australian share market. In the paper the authors used maximum likelihood approach and a qualitative regression to check the significance of Black-Scholes model in Australian stock market. In conclusion they have come up with result that the Black-Scholes model is significant statistically in Australian market at 1% level. They also suggested that if we use implied volatility and jump-diffusion method, we can improve the statistical significance of the Black-Scholes model.

Frino et al. (2019) also tested Black-Scholes option pricing model for Australian options market. They have performed cross sectional tests of B-S model by using latest available market data. Finally, they concluded that Black-Scholes model is efficient and capable for effectively pricing the options in Australian options market.

2.2 Comparison of Black-Scholes model with other option pricing models

Sterk (1982) has tested and compared empirically Roll option pricing model and modified Black-Scholes option pricing model for American style options. Sterk concluded that Roll model leads to significantly smaller deviations from market prices than modified Black-Scholes model which includes dividends. Also, the modified B-S model overprices in-the-money options and underprices out-of-the-money options.

Further in 1983 Sterk again compared two models Modified Black-Scholes model (stock with dividends) and RGW model. Sterk found that option pieces computed by RGW model are notably closer to real market option prices. Sterk also stated that using RGW model, one might earn more arbitrage profit over time than Black-Scholes model.

Ball and Torous (1985) have compared Merton call option pricing model and Black-Scholes option pricing model. The Merton's model includes jumps in the underlying asset's return. They have compared these models on options of stocks listed on NYSE. They found no operationally significant differences between Merton model prices and Black-Scholes model prices of the call options written on stocks.

Kim and Kim (2004) have investigated the option price of Korean KOSPI 200 Index when volatility is taken as stochastic. They have compared four different stochastic volatility models ad hoc Black-Scholes, Heston and Nandi's GARCH type model, Madan et al.'s variance gamma model and Heston's continuous-time stochastic volatility model. They found that Heston's model outperforms the other models.

Burger and Kliaras (2013) compared three option pricing models namely, the Black-Scholes model, the Merton-Jump approach and the double exponential jump diffusion model. In the paper, they mentioned that the theoretical option price calculated by Kou model is more accurate.

Khan et al. (2013) incorporate modification in classical B-S model formula. They have made modification in formula by adding some extra variables related to risk-free interest rate. They also describe the new computation process of risk-free interest rate with respect to new variable. After this they have empirically tested and compared B-S model prices by using assumed interest rate as well as new risk-free interest rate.

Gulen et al. (2019) focuses on discrete behaviour of linear and nonlinear Black-Scholes option pricing model. They proposed a new method which combines a sixth order finite difference (FD6) scheme in space and a third–order strong stability preserving Runge–Kutta (SSPRK3) over time to generalize the option pricing model. Then they compared the computed results with available literature and the exact solution. The computed results revealed that the current method seems to be quite strong both quantitatively and qualitatively with minimal computational effort.

2.3 Generalisation/Modification of Black-Scholes model

Merton (1976) derived an option pricing formula for the underlying stocks whose return are generated by combination of continuous and jump processes. Merton stated that, unlike Black-Scholes option pricing formula the new formula also does not depend on investors knowledge about expected return on the underlying stocks.

Meisner and Labuszewski (1984) modified the classical Black-Scholes model and provided a BASIC computer program. They develop this model to price options on securities, commodities and futures.

Duffie (1988) extended the Black-Scholes model and derive a new formula to price value of security whose dividends depend on securities with diffusion dividend and price processes. Duffie found this new formula by solving the PDE to find the price of derivative contract on underlying asset. He got the solution in terms of the Feynman-Kac formula.

A new option pricing formula presented by McDonald and Bookstaber (1991). They used generalised beta distribution of second kind and derive option pricing formula. This new formula is generalisation of celebrated Black-Scholes formula, so Black-Scholes formula is a special case of this new option pricing formula.

Lo and Wang (1995) have implemented many continuous-time linear diffusion processes to predict underlying asset's return used in pricing options. They have constructed an adjustment for predictability to the Black-Scholes formula. They also gave numerical examples to show importance of their method.

Corrado and Su (1996) have modified the classical Black-Scholes model because the classical model generally misprices deep-in-the-money and deep-out-of-the-money options. They adapt a Gram-Charlier series expansion of the normal density function to provide skewness and kurtosis adjustment terms in Black-Scholes formula. By using this method, they estimated option-implied coefficients of skewness and kurtosis in S&P 500 stock index returns.

Sherrick et al. (1996) used the no-arbitrage option pricing model to retrieve probability distributions of underlying futures prices. They show that Burr III distribution gives less errors comparative to lognormal distribution.

Kim and Kunitomo (1999) generalized the classical Black-Scholes model by changing constant interest rates to stochastic interest rates. Thus, in this case, the classical Black-Scholes model is special case of extended B-S formula.

In well accepted Black-Scholes option pricing model, we use Brownian motion and normal distribution to study the option prices and return of assets. Despite of worldwide acceptance of classical Black-Scholes model, the empirical investigation suggested two main problem in classical model are the leptokurtic and asymmetric features and the volatility smile. Kou (2000) proposes a novel model with three properties, 1) it has leptokurtic and asymmetric features, under which the return distribution of the assets has a higher peak and two heavier tails than the normal distribution, especially the left tail; 2) it leads to analytical solutions to many option pricing problems, including: call and put options, and options on futures; interest rate derivatives such as caplets, caps, and bond options; exotic options, such as perpetual American options, barrier and lookback options; 3) it can reproduce the "volatility smile".

Savickas (2002) introduced an option pricing formula which is based on Weibull distribution. This new model was tested on S&P 500 index options. The benefits of proposed model are its algebraic simplicity and its implementation.

Chawla et al. (2003) proposed new Generalized trapezoidal formula (GTF(α)) to improve classical Black-Scholes model. They have demonstrated that the using GTF (1/3) we can improve approximations at the exercise price.

Ahmed and Abdulalam (2004) gave a new tool to derive Black-Scholes differential equation which is transformed to heat equation. They modified the Black-Scholes equation by using the telegraph reaction diffusion equation. They numerically studied the generalised B-S equation and found the effect of time constant.

Dutta and Babbel (2005) have used g and h distribution to derive a closed form option pricing formula for European options. They have compared this distribution with lognormal, GB2, Weibull and Burr-3 distributions.

Ki et al. (2005) found an option pricing formula for the underlying security whose return follows extended normal distribution. They have tested this new model empirically and compared this model with Black-Scholes, ad hoc Black-Scholes and Gram Charlier distribution models. The findings in this paper tells that the actual density of the underlying security have skewness to the left and tall peaks. They also concluded that the new formula for option pricing is more relevant than classical B-S, ad hoc B-S and Cram-Charlier formula.

It can be observed that, out-of-the-money put prices (and in-the-money call prices) are relatively high compared to the Black–Scholes price. To overcome this problem, Christoffersen et al. (2006) developed a new discrete-time dynamic model of stock returns with inverse Gaussian innovations. The model allows for conditional skewness as well as conditional heteroskedasticity and a leverage effect. They derived an analytic option pricing formula consistent with this stock return dynamic. They have tested empirically the model using S&P500 index options, the result shows that the new inverse Gaussian GARCH model's performance is superior to a standard existing nested model for out-of-the money puts.

In literature there are many articles available which have changes constant interest rate and constant volatility to stochastic interest rates and stochastic volatility. But there is a lack of comprehensive study on these modified models which can tell us the impact of these new models on option pricing in real market. Bakshi et al. (2010) have done this job by first proposing a new option pricing model which accepts stochastic interest rate and stochastic volatility. After this they have empirically tested and compared this model with three other existing models namely, classical Black-Scholes model, stochastic interest rate but constant volatility model, constant interest rate but stochastic volatility model. In concluding remark, they have found that, the model with stochastic volatility and stochastic interest rate outperforms the other three option pricing models.

Peng and Yao (2011) have generalised the Classical Black-Scholes option pricing model and they have used a central difference spatial discretization on a piecewise uniform mesh and an implicit time stepping technique to get the generalised formula. They also found this approach accurate and stable while performed numerical experiments. They have suggested to use this model to find value of American style options.

Edeki et al. (2016) have used the constant elasticity of variance model and modifies the classical B-S model for pricing the options on stocks. This modified model provides the alternate option to the classical B-S model for stock option price. They have marked in the paper that; the main advantage of new model is the stock price volatility is a function of underlying stock price instead of taking constant. Edeki et al. (2016) have also generalised the classical Black-Scholes model to effectively find the price of options on stocks. They have used constant elasticity of variance (CEV) model with dividend yield to generalise the model. They have included non-constant volatility power function of stock price and parameter for dividend yield.

We know that Black-Scholes model is widely used to find the theoretical value of vanilla type European options. In real share market to find the option price, people use different models for different underlying assets. Burgess (2017) derived the modified Black-Scholes model and review this model for different asset categories.

All the pricing models in the existing literature, assume that the underlying assets price is not bounded, that is, the price of underlying may take values from zero to infinity. But in practice there is no chance that any underlying asset's price could reach infinity. A modification to the B–S formula, which considers that option traders often have their own expected (finite) range of the underlying price in mind, which is very reasonable and attractive idea to refine B-S model. Such a modification was carried out by Zhu and He (2018) and assumed that the log-returns of the underlying asset follow a truncated normal distribution within a certain period with fixed upper and lower bounds. After finding closed form formula for option pricing, they have carried out empirical studies on European call options of S&P 500 index from January 2011 to December 2011 to compare the pricing performance of new proposed model and that of the Black–Sholes model with real market data.

Chowdhury et al. (2020) have tried to find stock price (closing price) by modifying classical B-S model. They have made some changes in Black-Scholes model to find the strike price and expiration time of options to compute stock price in market. They have used ML approach with the help of Rapidminer software to check the model in real market.

2.4 Black-Scholes on Indian Options Market

Saurabha and Tiwari (2007) studied the variations suggested by Corrado and Sue (1996) in Black-Scholes option pricing model. They incorporated non-normal skewness and kurtosis in classical B-S model. They have tested the model for call options on S&P CNX Nifty index and shown that the new formula yields value much closer to market prices.

We know that, Fisher Black has modified the Black-Scholes model by replacing the spot price term (S) by the discounted value of futures price (Fe^{-rt}). This Black's modified model is widely used to price options defined on different physical commodities. Mitra (2008) compares Classical Black-Scholes model with Black's modified model for Nifty index options. It is found that the Black formula provides better result in comparison to Black-Scholes formula for Nifty options.

Nagarajan and Malipeddi (2009) have aslo compared classical Black-Scholes model and modified Black-Scholes model suggested by Corrado and Sue (1996). They have shown that if we use the implied volatility of previous day to price options then Black-Scholes price is significantly closer to market price than modified Black-Scholes price. They also concluded that, the call options on index are 1.5 percent more priced than Black-Scholes price during upward trend compared to downward trend in market.

Tripathi and Gupta (2010) have examined the predictive accuracy of the Black-Scholes model to price the Nifty index options. They have also compared the two-option pricing model, Classical Black-Scholes model and Generalised Black-Scholes model proposed by Corrado and Su (1996). They have used S&P CNX NIFTY near-the-month call options for the period January 1, 2003 to December 24, 2008. In result they have shown that BS model is mis specified as the implied volatility graph depicts the shape of a 'Smile' for the study period. There is significant under-pricing by the original BS model and that the mispricing increases as the moneyness increases. Even the modified BS model misprices options significantly. However, pricing errors are less in case of the modified BS model than in case of the original BS model. Based on Mean Absolute Error (MAE) authors have concluded that the modified BS model is performing better than the original BS model.

Singh and Ahmad (2011) tried to forecast S&P Nifty 50 index option prices by using implied and time series econometric volatility models as inputs to Classical B-S model. They have used implied volatility and volatility from GARCH models. Finally concluded that implied volatility outperforms GARCH volatility.

Singh et al. (2011) investigated three type of option pricing models, Discrete time Heston model, Nandi GARCH model and Black-Scholes model. They have tested the models on S&P CNX Nifty 50 index options relative to market price using error metrics, moneyness-maturity wise. They have concluded that in12 out of 15 moneyness – maturity groups Black-Scholes model price has less error in compare to other models.

Khan et al. (2013) have given the new way to take interest rate in Black-Scholes model. They empirically tested new model for two stock options CE9000 and PE8500. The option prices calculated by BS model with changing the interest rate calculation have compared with the option price calculated by BS model with existing risk-free interest rate. They have shown that new interest rate method gives batter result compared to existing method.

Panduranga (2013) attempted a study of relevancy of Black-Scholes option pricing model for selected cement stock options of Indian stock market. They gave the result of paired sample T-test which revealed that there is no significant difference between theoretical BS price and market price.

Panduranga (2013) attempted a study of relevancy of Black-Scholes option pricing model for selected Banking stock options of Indian stock market. They gave the result of paired sample T-test which revealed that there is no significant difference between theoretical BS price and market price.

Nagendran and Venkateswar (2014) have used around 95,000 call options for testing the Black-Scholes option pricing model in Indian option market. They have incorporated the implied volatility into Black-Scholes model to test the performance of Black-Scholes model. They concluded that the Black-Scholes model with implied volatility has improved 64.23% predictive ability of call option prices.

Priyan and Mohanti (2014) also tested the Black-Scholes model to price the S&P CNX Nifty index options. The authors have used the Nifty index's data from April 2008 to March 2012. They have suggested following volatility estimators to efficiently price the options: (i) Historical Standard Deviation (HSD) (ii) Weighted Implied Standard Deviation (WISD), and (iii) Average Implied Standard Deviation (AISD).

Sharma and Arora (2015) have tried to find the relevancy of BS model for Indian options market. They have tested the Black-Scholes model on ten stock's option contracts. They have found that Black-Scholes model is partially relevant for these stock option contracts.

Nandan and Agrawal (2016) have tried to check different methods of volatility estimation to find CNX Nifty index options. They have studied 10 years data from 2003 to 2012 to perform this task. They concluded that if we use Implied volatility then the model gives better result than simple variance and Volatility from EGARCH (1,1) model.

Sudhakar (2016) studied the efficiency of Black-Scholes model for Nifty 50 index options. He has used regression analysis on the theoretical price from January 2008 to December 2014. He concluded that Black-Scholes model performs well to predict the real market values of call options excluding for the out-of-the-money and deep out-of-the-money option contracts.

Kumar and Agrawal (2017) investigated the efficiency of Black-Scholes model used for valuation of call option contracts written on Eight Indian stocks quoted on NSE. In literature we can observe that the classical Black-Scholes Model misprices options which are deep out-of-the-money and highly volatile. In this paper, they have calculated the theoretical options prices of Nifty stock call options by using the Black-Scholes option pricing Model. Then these theoretical prices are compared with the actual quoted prices in the market to gauge the pricing accuracy.

Srivastava and Shastri (2018) have made an attempt to check the relevance of Black-Scholes model for Indian stock market. They have concluded that the option values have insignificant relevance to the market values.

III. Conclusions And Scope For Future Research

We bifurcate all the research papers in four categories namely, (i) Testing the Classical B-S model in real market (ii) Comparison of Black-Scholes model with other option pricing models (iii) Generalisation/Modification of Black-Scholes model and (iv) Black-Scholes on Indian Options Market.

In first category our observation is, impact of Black-Scholes option pricing model depends on many factors, i.e. underlying assets, time of contract, moneyness, etc. In some case the Black-Scholes model perform well whereas in some case the model doesn't fulfil our expectations. In second category, we have studied the papers in with comparison of classical Black-Scholes model with Modified black-Scholes model, Roll model, RGW model, and Merton's Jump diffusion model have been done. In most of the case, Black-Scholes model underperform the other option pricing models. In third category, we have reviewed the papers in which, different kind of generalisations or modifications in Black-Scholes model have been carried out. We have observed from these papers that, there are many excellent works have been done in this field, and we can get benefits from these generalised models by using them in real market. In forth category, we have studied the papers which are based on Indian options market. Many researchers have done the empirical investigations of Black-Scholes model for Indian stock market. But there are very less papers available for Generalised Black-Scholes models on Indian options market. There is a large scope for researchers to study the different types of generalised Black-Scholes model on different types of options in Indian options market. In literature there are so many modified Black-Scholes model by which one can test them on Indian market. One can further modify by changing the distributions, volatility, interest rates in classical Black-Scholes model and then check for Indian options market. This way we can find the better theoretical price of options traded in Indian share market, and this will be useful to many market practitioners and ultimately useful to the economy of India.

References

[1]. Ahmed, E., & Abdusalam, H. A. (2004). On modified Black–Scholes equation. *Chaos, Solitons & Fractals*, *22*(3), 583-587.

[2]. Bakshi, G., Cao, C., & Chen, Z. (2010). Option pricing and hedging performance under stochastic volatility and stochastic interest rates. *Handbook of quantitative finance and risk management*, 547-574.

[3]. Ball, C. A., & Torous, W. N. (1985). On jumps in common stock prices and their impact on call option pricing. *The Journal of Finance*, *40*(1), 155-173

[4]. Burger, P., & Kliaras, M. (2013). Jump Diffusion Models for Option Pricing vs. the Black Scholes Model. *Working paper*.

[5]. Burgess, N. (2017). A Review of the Generalized Black-Scholes Formula & It's Application to Different Underlying Assets. *Available at SSRN 3023440*.

[6]. Chawla, M. M., Al-Zanaidi, M. A., & Evans, D. J. (2003). Generalized trapezoidal formulas for the Black–Scholes equation of option pricing. *International Journal of Computer Mathematics*, *80*(12), 1521-1526.

[7]. Choi, S., & Wohar, M. E. (1994). S & P 500 index options prices and the Black-Scholes option pricing model. *Applied Financial Economics*, *4*(4), 249-263.

[8]. Chowdhury, R., Mahdy, M. R. C., Alam, T. N., Al Quaderi, G. D., & Rahman, M. A. (2020). Predicting the stock price of frontier markets using modified Black–Scholes Option pricing model and machine learning. *Physica A: Statistical Mechanics and its Applications*, 124444.

[9]. Christoffersen, P., Heston, S., & Jacobs, K. (2006). Option valuation with conditional skewness. *Journal of Econometrics*, *131*(1-2), 253-284.

[10]. Corrado, C. J., & Su, T. (1996). S&P 500 index option tests of Jarrow and Rudd's approximate option valuation formula. *Journal of Futures Markets: Futures, Options, and Other Derivative Products*, *16*(6), 611-629.

[11]. Corrado, C. J., & Su, T. (1996). Skewness and kurtosis in S&P 500 index returns implied by option prices. *Journal of Financial research*, *19*(2), 175-192.

[12]. Corrado, C. J., & Su, T. (1997). Implied volatility skews and stock return skewness and kurtosis implied by stock option prices. *The European Journal of Finance*, *3*(1), 73-85.

[13]. Duffie, D. (1988). An extension of the Black-Scholes model of security valuation. *Journal of Economic Theory*, *46*(1), 194-204.

[14]. Dutta, K. K., & Babbel, D. F. (2005). Extracting probabilistic information from the prices of interest rate options: Tests of distributional assumptions. *The Journal of Business*, *78*(3), 841-870.

[15]. Edeki, S. O., Owoloko, E. A., & Ugbebor, O. O. (2016, February). The modified Black-Scholes model via constant elasticity of variance for stock options valuation. In *AIP Conference proceedings* (Vol. 1705, No. 1, p. 020041). AIP Publishing LLC.

[16]. Edeki, S. O., Ugbebor, O. O., & Owoloko, E. A. (2016). On a dividend-paying stock options pricing model (SOPM) using constant elasticity of variance stochastic dynamics. *International Journal of Pure and Applied Mathematics*, *106*(4), 1029-1036.

[17]. Frino, A., Lodh, S. C., & Khan, E. (2019). The black scholes call option pricing model and the Australian options market: Where are we after 15 years. *The International Journal of Accounting and Business Society*, *1*(1), 40-57.

[18]. Gençay, R., & Salih, A. (2003). Degree of mispricing with the black-scholes model and nonparametric cures. *Economics and Finance. Annals*, *4*, 73-101.

[19]. Gulen, S., Popescu, C., & Sari, M. (2019). A New Approach for the Black–Scholes Model with Linear and Nonlinear Volatilities. *Mathematics*, *7*(8), 760.

[20]. Gultekin, N. B., Rogalski, R. J., & Tinic, S. M. (1982). Option pricing model estimates: Some empirical results. *Financial management*, 58-69.

[21]. Khan, M. U., Gupta, A., & Siraj, S. (2013). Empirical testing of modified Black-Scholes option pricing model formula on NSE derivative market in India. *International Journal of Economics and Financial Issues*, *3*(1), 87.

[22]. Khan, M. U., Gupta, A., & Siraj, S. (2013). Empirical testing of modified Black-Scholes option pricing model formula on NSE derivative market in India. *International Journal of Economics and Financial Issues*, *3*(1), 87.

[23]. Ki, H., Choi, B., Chang, K. H., & Lee, M. (2005). Option pricing under extended normal distribution. *Journal of Futures Markets: Futures, Options, and Other Derivative Products*, *25*(9), 845-871.

[24]. Kim, I. J., & Kim, S. (2004). Empirical comparison of alternative stochastic volatility option pricing models: Evidence from Korean KOSPI 200 index options market. *Pacific-Basin Finance Journal*, *12*(2), 117-142.
[25]. Kim, Y. J., & Kunitomo, N. (1999). Pricing options under stochastic interest rates: A new approach. *Asia-Pacific Financial Markets*, *6*(1), 49-70.
[26]. Kou, S. G. (2000, March). A jump diffusion model for option pricing with three properties: leptokurtic feature, volatility smile, and analytical tractability. In *Proceedings of the IEEE/IAFE/INFORMS 2000 Conference on Computational Intelligence for Financial Engineering (CIFEr)(Cat. No. 00TH8520)* (pp. 129-131). IEEE.
[27]. Kumar, R., & Agrawal, R. (2017). An empirical investigation of the Black–Scholes call option pricing model with reference to NSE. *International Journal of BRIC Business Research (IJBBR)*, *6*(2), 1-11.
[28]. Kumar, R., & Agrawal, R. (2018). A Close Look into Black-Scholes INDEX Nifty 50 Put Option Pricing Model: Evidence from Indian National Stock Exchange. *Asian Journal of Management*, *9*(1), 407-412.
[29]. Levy, H., & Byun, Y. H. (1987). An Empirical Test of the Black-Scholes Option Pricing Model and the Implied Variance: A Confidence Interval Approach. *Journal of Accounting, Auditing & Finance*, *2*(4), 355-369.
[30]. Lo, A. W., & Wang, J. (1995). Implementing option pricing models when asset returns are predictable. *The Journal of Finance*, *50*(1), 87-129.
[31]. MacBeth, J. D., & Merville, L. J. (1979). An empirical examination of the Black-Scholes call option pricing model. *The journal of finance*, *34*(5), 1173-1186.
[32]. MacBeth, J. D., & Merville, L. J. (1980). Tests of the Black-Scholes and Cox call option valuation models. *The Journal of Finance*, *35*(2), 285-301.
[33]. McDonald, J. B., & Bookstaber, R. M. (1991). Option pricing for generalized distributions. *Communications in Statistics-Theory and Methods*, *20*(12), 4053-4068.
[34]. McKenzie, S., Gerace, D., & Subedar, Z. (2007). An empirical investigation of the Black-Scholes model: evidence from the Australian Stock Exchange. *Australasian Accounting, Business and Finance Journal*, *1*(4), 5.
[35]. Meisner, J. F., & Labuszewski, J. W. (1984). Modifying the Black-Scholes option pricing model for alternative underlying instruments. *Financial Analysts Journal*, *40*(6), 23-30.
[36]. Merton, R. C. (1976). Option pricing when underlying stock returns are discontinuous. *Journal of financial economics*, *3*(1-2), 125-144.
[37]. Mitra, S. K. (2008). Valuation of Nifty Options Using Black's Option Pricing Formula. *ICFAI Journal of Derivatives Markets*, *5*(1).
[38]. Nagarajan, T., & Malipeddi, K. (2009). Effects of market sentiment in index option pricing: a study of CNX NIFTY index option. *Available at SSRN 1490758*.
[39]. Nagendran, R., & Venkateswar, S. (2014). Validating Black-Scholes model in pricing Indian stock call options. *Journal of Applied Finance and Banking*, *4*(3), 89.
[40]. Nandan, T., & Agrawal, P. (2016). Pricing Efficiency in CNX Nifty Index Options Using the Black–Scholes Model: A Comparative Study of Alternate Volatility Measures. *Margin: The Journal of Applied Economic Research*, *10*(2), 281-304.
[41]. Panduranga, V. (2013). An Empirical analysis of Black–Scholes option pricing model for select Banking stocks. *Vidyaniketan Journal of Management and Research*, *1*(2), 23-30.
[42]. Panduranga, V. (2013). Relevance of Black-Scholes option pricing model in indian derivatives markets–a study of cement stock options. *International Journal of Multidisciplinary Research in Social and Management Sciences*, *1*(4), 91-95.
[43]. Peng, J., & Yao, K. (2011). A new option pricing model for stocks in uncertainty markets. *International Journal of Operations Research*, *8*(2), 18-26.
[44]. Priyan, P. K., & Mohanti, D. (2014). Testing pricing efficiency of index options using Black-Scholes model: evidence from Indian index options market. *Abhigyan*, *32*(3), 15-29.
[45]. Saurabha, R., & Tiwari, M. (2007). Empirical Study of the effect of including Skewness and Kurtosis in Black Scholes option pricing formula on S&P CNX Nifty index Options. *Available at SSRN 1075583*.
[46]. Savickas, R. (2002). A simple option‐ pricing formula. *Financial Review*, *37*(2), 207-226.
[47]. Sharma, M., & Arora, K. (2015). Study of relevance of Black-Scholes model in Indian stock option market. *International Journal of Advance Research and Innovative Ideas In Education*, *1*(4), 324.
[48]. Sheikh, A. M. (1991). Transaction data tests of S&P 100 call option pricing. *Journal of Financial and Quantitative Analysis*, *26*(4), 459-475.
[49]. Sherrick, B. J., Garcia, P., & Tirupattur, V. (1996). Recovering probabilistic information from option markets: Tests of distributional assumptions. *Journal of Futures Markets*, *16*(5), 545-560.
[50]. Singh, V. K., & Ahmad, N. (2011). Forecasting Performance of Volatility Models for Pricing S&P CNX Nifty Index Options via Black-Scholes Model. *IUP Journal of Applied Finance*, *17*(3).
[51]. Singh, V. K., Ahmad, N., & Pachori, P. (2011). Empirical analysis of GARCH and Practitioner Black-Scholes Model for pricing S&P CNX Nifty 50 index options of India. *Decision (0304-0941)*, *38*(2).
[52]. Srivastava, A., & Shastri, M. (2018). A study of relevance of Black-Scholes model on option prices of Indian stock market. *International Journal of Governance and Financial Intermediation*, *1*(1), 82-104.
[53]. Sterk, W. (1982). Tests of two models for valuing call options on stocks with dividends. *The Journal of Finance*, *37*(5), 1229-1237.
[54]. Sterk, W. E. (1983). Comparative performance of the Black-Scholes and Roll-Geske-Whaley option pricing models. *Journal of Financial and Quantitative Analysis*, 345-354.
[55]. Sudhakar, A. (2016). Analysis of The Efficacy of Black-scholes Model-An Empirical Evidence from Call Options on Nifty-50 Index. *Pacific Bussines Review International Volume*, *9*.
[56]. Tripathi, V., & Gupta, S. (2010). Effectiveness of the Skewness and Kurtosis adjusted Black-Scholes model in pricing Nifty call options. *Available at SSRN 1956071*.
[57]. Zhu, S. P., & He, X. J. (2018). A modified Black–Scholes pricing formula for European options with bounded underlying prices. *Computers & Mathematics with Applications*, *75*(5), 1635-1647.

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