International Journal of Operations Research and Artificial Intelligence

www.ijorai.reapress.com

Int. J. Oper. Res. Artif. Intell. Vol. 2, No. 1 (2026) 23–30.

Paper Type: Original Article

Determinants of Option Pricing Errors: Evidence from Tehran Derivatives Market

Danial Mohammadi[1,*], Emran Mohammadi[1], Zhina Nanvay Savojbolaghi[2]

[1] Department of Financial Engineering, School of Industrial Engineering, University of Science and Technology, Tehran, Iran; d_mohammadi@ind.iust.ac.ir; e_mohammadi@iust.ac.ir.

[2] Department of Finance, Research Sciences Branch, Islamic Azad University Tehran, Iran; zhina.savajbolaghi@srbiau.ac.ir.

Citation:

Received: 18 June 2025 *Revised: 22 September 2025* *Accepted: 02 January 2026*	Mohammadi, D., Mohammadi, E., & Nanvay Savojbolaghi, S. (2026). Determinants of option pricing errors: Evidence from Tehran derivat market. *International Journal of Operations Research and Artificial Intelligence, 2* (1), 23-30.

Abstract

In recent years, the growing volume of option contract trading has underscored the importance of accurate and reliable valuation of these financial instruments. Despite the widespread adoption of the Black-Scholes-Merton (BSM) model for pricing options, empirical evidence suggests that this model is subject to pricing errors. The present study investigates the influence of three key variables, historical volatility, the moneyness status of the underlying asset, and time to maturity, on the pricing error of the BSM model. Empirical analysis reveals systematic discrepancies between the theoretical prices produced by the BSM model and observed market prices. Using panel data regression and the Stata statistical software, the study estimates the effect of the aforementioned variables on model error. The results indicate a positive and statistically significant relationship between each variable and the magnitude of the pricing error. The dataset consists of options contracts traded between 2020 and 2024 on the Tehran Stock Exchange. Additionally, the Root Mean Squared Error (RMSE) was calculated, showing that the BSM model's estimated prices deviated from actual market prices by approximately 61%, highlighting the need for improved pricing accuracy in emerging markets.

Keywords: Option contracts, Volatility, Pricing error, Black-Scholes-Merton model, Tehran securities exchange.

1 | Introduction

Among the most prominent financial derivative instruments are options and futures contracts, both of which are extensively traded across global financial markets [1]. The utilization of financial derivatives within the investment landscape continues to grow steadily, driven by three principal objectives: Risk management, price discovery, and transaction cost reduction [2]. Options, in particular, have emerged as a fundamental

Corresponding Author: d_mohammadi@ind.iust.ac.ir

https://doi.org/10.48314/ijorai.v2i1.85

component of modern financial systems and are widely employed in major, reputable markets around the world [3]. An option contract provides its holder with the right, but not the obligation, to buy or sell a specific underlying asset at a predetermined price on or before a specified expiration date. This optionality allows the holder to choose whether or not to exercise the contract based on prevailing market conditions [4]. In Iran, the introduction of derivative instruments into the financial market is a relatively recent development. These contracts were formally launched in 2016 and have been actively traded since. Notably, the volume of options trading has experienced significant growth since 2019. Given this upward trend, the accurate and reliable valuation of options has become a critical concern. As options trading continues to expand both domestically and globally, ensuring accurate pricing with minimal deviation is of paramount importance.

Currently, the Black-Scholes-Merton (BSM) pricing model remains the dominant framework employed by market participants for valuing options contracts [5]. The selection of an optimal investment portfolio further enables investors to maximize returns by strategically allocating capital to appropriate assets [6]. The BSM model, widely recognized as a milestone in financial engineering, is extensively utilized by leading global stock exchanges, institutional investors, and traders [7]. Despite its widespread application, discrepancies persist between the theoretical prices produced by the BSM model and the actual market prices of options, highlighting the presence of pricing errors. Uncertainty regarding future economic conditions further exacerbates these discrepancies and plays a significant role in financial decision-making processes [6]. The present study seeks to identify and examine the key determinants of such pricing errors, thereby contributing to enhanced precision in options valuation using the BSM framework. Empirical comparisons between model-derived and observed market prices of options contracts reveal measurable deviations, underscoring the importance of investigating the model's limitations. Blind reliance on the BSM's output, without accounting for its known shortcomings, may lead to suboptimal investment decisions and potential financial losses. Accordingly, this study aims to synthesize insights from prior literature and empirically examine the factors that contribute to pricing deviations. Specifically, it investigates whether certain variables influence the divergence between theoretical and market prices of options traded on the Tehran Stock Exchange (TSE) derivatives market. Using a panel data regression approach, this research evaluates the effect of three key variables on the pricing error of the BSM model:

I. Time to maturity (i.e., the number of days remaining until expiration)

II. Moneyness (i.e., whether the option is in-the-money, at-the-money, or out-of-the-money)

III. Historical volatility of the underlying asset

To ensure the robustness of findings, the analysis incorporates a diverse set of underlying assets, including equities and Exchange-Traded Funds (ETFs), across multiple sectors. The Root Mean Squared Error (RMSE) metric is ultimately used to quantify the pricing error associated with the BSM model.

2|Literature Review

Several empirical studies have examined the pricing errors of the BSM model and identified key factors influencing these discrepancies. Azur [8] applied the Kolmogorov-Smirnov test and found that strike price significantly affects BSM pricing errors, with higher strike prices increasing error magnitude. Wu et al. [9] analyzed call options on 50 ETFs from the Shanghai Stock Exchange, rejecting the hypothesis that BSM prices match market prices. Their findings showed that pricing errors vary significantly with maturity, highest for short-term options, and with moneyness, where out-of-the-money options exhibit greater mispricing than in-the-money ones. Kumar and Agrawal [7] investigated Indian stock options and identified volatility as a primary determinant of pricing errors, with higher volatility causing larger discrepancies. Batten [10] studied foreign exchange options and reported mispricing up to 23% for at-the-money options, emphasizing the influence of moneyness and time to maturity on errors. Amilon [11] highlighted systematic overpricing of out-of-the-money options and underpricing of in-the-money options by BSM, especially under high volatility, and demonstrated that feedforward neural networks can effectively reduce such biases. McBeth and Merville [12] empirically confirmed that BSM underprices in-the-money and overprices out-of-the-money options, with mispricing severity increasing for shorter maturities and extreme moneyness. He noted that BSM prices are more accurate for at-the-money options with longer maturities (≥90 days). Reviewing these studies reveals four critical variables affecting BSM pricing errors: strike price, maturity, historical volatility, and moneyness. This study focuses on three of these variables to assess their impact on pricing errors in options traded on the TSE.

3 | Theoretical Framework

Asset valuation refers to the process of determining the current value of an asset. In the context of this study, the market price of an option contract serves as a fundamental parameter, as the option buyer acquires the contract by paying this market-determined price to the seller. In return, the buyer obtains the right, but not the obligation, to exercise the option at maturity. As such, establishing a fair and accurate price for an option contract is of considerable importance. The market price of an option reflects the prevailing price at which the contract is actively traded in the market. Over the years, numerous theoretical models have been developed for the valuation of options, among which the BSM model, introduced in 1973, remains the most influential and widely applied. The BSM model is often referred to as a pricing function, as it expresses the theoretical value of an option as a function of several key variables: The strike price, the current price of the underlying asset, time to expiration, the risk-free interest rate, and the asset's price volatility [13]. The theoretical price of a European call option under the BSM model is given by *Eq (1)*.

$$c = S.N(d_1) - K.e^{-rt}.N(d_2). \tag{1}$$

The price of a put option under the BSM model is calculated using *Eq. (2)*.

$$p = K.e^{-rt}.N(-d_2) - S.N(-d_1). \tag{2}$$

The parameters d_1, d_2, and $N(d)$ are calculated using *Eqs. (3)-(5)*, respectively.

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}. \tag{3}$$

$$d_2 = \frac{\ln\left(\frac{S}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}. \tag{4}$$

$$N(-d_1) = 1 - N(d_1). \tag{5}$$

The Black-Scholes model relies on several key assumptions: 1) a constant short-term risk-free interest rate, 2) lognormally distributed asset prices following a stochastic process, 3) no dividend payments during the option's life, 4) European-style exercise only at expiration, 5) absence of transaction costs and taxes, 6) infinite divisibility of securities, 7) no arbitrage opportunities, 8) continuous trading, and 9) identical borrowing and lending rates for all investors. This study adopts assumptions commonly found in prior literature, drawing on six relevant studies to identify four variables affecting BSM pricing error. Of these, three variables, historical volatility, moneyness, and time to maturity, were selected due to their relevance to option contracts traded on the TSE. Unlike sensitivity analyses that isolate individual factors, this study uses real market data to examine how multiple variables jointly impact pricing errors in practice. Derivative instruments, such as options, are contractual agreements whose value depends on various characteristics of the underlying asset and market conditions. By analyzing these factors, this research aims to empirically assess the validity and limitations of the BSM model in an emerging market context.

4 | Research Methodology

This study covers a five-year period from 2019 to 2023 and focuses on option contracts on stocks and ETFs listed on the TSE. Its objective is to analyze factors influencing the pricing error of the BSM model and evaluate their impact on valuation accuracy. Due to low trading volumes in some contracts, a representative sample was selected rather than the entire population to ensure reliability. The sample includes options traded at least once every three months, excludes those with fewer than six days to expiration, and removes underlying assets with only one expiration cycle. The selected underlying asset symbols are detailed in *Table 1*.

Table 1. Underlying assets used in the study.

Symbol	Industry	Type
Khodro	Automotive and auto parts	Stock
Khesapa	Automotive and auto parts	Stock
Khebahman	Automotive and auto parts	Stock
Shepna	Oil products, coke and nuclear fuel	Stock
Shetran	Oil products, coke and nuclear fuel	Stock
Folad	Basic metals	Stock
Fameli	Basic metals	Stock
Zob	Basic metals	Stock
Vabemelat	Banks and financial institutions	Stock
Vabesader	Banks and financial institutions	Stock
Shasta	Diversified industrial companies	Stock
Hi web	Information and communication	Stock
Ahrom	ETFs	Investment fund
Sarv	ETFs	Investment fund
Shetab	ETFs	Investment fund

This study conducts a literature review to identify key variables influencing the BSM model's pricing error. Transaction data for option contracts traded on the TSE from 2019 to 2023 were obtained from the exchange's database. The dataset includes theoretical and market prices, time to maturity, underlying asset volatility, and moneyness status. Panel regression analysis is employed to assess the impact of independent variables, time to maturity, historical volatility, and moneyness, on the BSM pricing error, measured as the percentage deviation between theoretical and market prices. The RMSE is used as the primary metric to quantify model error. Key methodological details include:

I. Prediction errors are evaluated over rolling 30-day windows.

II. Historical volatility is estimated via the standard deviation of daily log returns over the past 90 trading days.

III. Time to expiration is calculated in years by dividing remaining trading days by 240.

IV. Moneyness is defined as the ratio of the underlying asset price to strike price, categorizing options as in-the-money if above 1, otherwise out-of-the-money.

The RMSE metric calculation is detailed in *Eq. (6)*.

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{\hat{y}_i - y_i}{y_i}\right)^2}. \tag{6}$$

The theoretical price of an option contract, denoted as $\hat{y}_i$, is obtained using the BSM model. The market price (i.e., the traded price) of the option contract is represented as y_i. To compute the RMSE, the following steps are performed:

I. The difference between each theoretical price and its corresponding market price is calculated.

II. The difference is divided by the market price of the option.

III. The squared value of each resulting error is computed.

IV. The squared errors are summed and divided by the total number of observations.

V. The square root of the obtained value is taken to determine the RMSE.

VI. The final RMSE value is multiplied by 100 to express the results as a percentage.

RMSE is a robust metric for assessing the accuracy of the BSM model since it assigns greater weight to larger errors due to squaring the deviations. This characteristic makes RMSE one of the most precise methods for model error evaluation. This study aims to examine the impact of three key variables, historical volatility, option moneyness status, and time to expiration, on the pricing error of the BSM model. This analysis is conducted using multiple regression estimation, and the results are evaluated to determine the influence of each variable on model error. The regression model used in this study is formulated as *Eq. (7)*.

$$Y_i = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + u_i. \quad (7)$$

5 | Research Findings

Using Stata software, the F-Limer test was conducted, and the results are presented in *Table 2*. Since the p-value is less than 5%, the null hypothesis (H_0) is rejected. This result indicates that the fixed effects model (panel model) should be used for estimation.

Table 2. Underlying assets used in the study.

Fixed Effects Regression Estimation (F-Limer Test Result)			
Independent Variables	**Coefficient**	**Standard Error**	**p-Value**
Intercept	-0.5217	0.0110	0.000
In-the-money status	0.1320	0.0064	0.000
Days to maturity	0.2543	0.0137	0.000
Historical volatility	0.2580	0.1045	0.000
F-Limer test p-value		0.000	

Since the F-Limer test rejected the null hypothesis (H_0), the next step was to conduct the Hausman test to determine whether the fixed effects model or the random effects model is more appropriate. The Hausman test p-value was 0.000, which is less than 0.05. This result leads to the rejection of the null hypothesis (H_0), indicating that the fixed effects model is the correct specification for this study. The results of the Hausman test are presented in *Table 3*:

Table 3. Hausman test results.

Hausman Test Independent Variables	Correlation Coefficient		Standard Error Mean
	Fixed Effects	Random Effects	
In-the-money status	0.1320	0.1248	0.0028
Days to maturity	0.2543	0.2586	0.0031
Historical volatility	0.2580	0.2584	0.0045
Hausman test p-value		0.000	

To address autocorrelation and heteroskedasticity, the Feasible Generalized Least Squares (FGLS) method was applied. The final results regarding the effects of independent variables on the dependent variable, after resolving autocorrelation and heteroskedasticity issues, are presented in *Table 4* below.

Table 4. Final regression estimation results after resolving autocorrelation and heteroskedasticity issues.

Final Regression Estimation			
Independent Variables	**Coefficient**	**Standard Error Mean**	**p-Value**
Intercept	-0.3396	0.0077	0.000
In-the-money status	0.1107	0.0038	0.000
Days to maturity	0.0928	0.0113	0.000
Historical volatility	0.1668	0.0054	0.000
Overall model p-value		0.000	

Table 4 represents the final panel regression estimation. The p-value column indicates that the p-values of all variables are below 5%, confirming their statistical significance and impact on the dependent variable. The standard error mean column reflects the estimation error of the sample compared to the population, which is relatively low, suggesting strong generalizability of the results. The correlation coefficient column, the key column, presents the final effects of the independent variables on the error of the BSM model.

I. If the time to maturity, expressed as a fraction of a year, decreases by 1%, the Black-Scholes model error decreases by 9.28%.

II. If the historical volatility of the underlying asset increases by 1%, the Black-Scholes model error increases by 16.68%.

III. If the ratio of the underlying asset price to the strike price (which represents the in-the-money status) increases by 1%, the model error increases by 11.07%.

To estimate the pricing error of the Black-Scholes model, the RMSE metric is used. RMSE measures the difference between predicted and actual values, where a lower RMSE indicates a more reliable model and better pricing accuracy for options. According to Willmott and Matsuura [14], *Table 5* presents the calculated RMSE, which is 0.559135. This result implies that the Black-Scholes model prices options with an error of approximately 56% relative to the market price.

Table 5. RMSE calculation for the BSM model.

Model Name	RMSE
BSM model	0.60112

To demonstrate the explanatory power of the regression equation, the coefficient of determination (R^2) is used. This metric indicates how well the estimated dependent variable ($\hat{y}_i$) approximates its actual value (y_i). When a new variable is added to the model, R^2 increases, but at the same time, the degrees of freedom decrease. Therefore, the adjusted coefficient of determination ($\overline{R}^2$) is used, which accounts for the number of predictors in the model. Naturally, $\overline{R}^2 \leq R^2$ is always less than or equal to R^2, which measures what percentage of variations in the independent variables explain the variations in the dependent variable. As shown in *Table 6*, the coefficient of determination (R^2) is 7.42%, and the adjusted coefficient of determination is 7.51% [15].

In other words, 6.36% of the variation in the independent variables (time to maturity, historical volatility, and in-the-money status) explains the variation in the dependent variable (Black-Scholes model error). The difference between R^2 and is 0.0001, which indicates that the independent variables added to the model were appropriately selected. A smaller gap between R^2 and suggests that the inclusion of independent variables was justified, which is the case in this regression model.

Table 6. Calculation of coefficient of determination and adjusted coefficient of determination.

Metric	Calculated Value
Coefficient of determination (R^2)	0.0742
Adjusted coefficient of determination	0.0751

6 | Research Findings

I. Impact of underlying asset volatility: As the volatility of the underlying asset increases, the BSM model error increases. Conversely, when volatility decreases, the model error also decreases.

II. Impact of in-the-money status: The more an option contract is in the money, the higher the BSM model error. As the contract moves toward at-the-money or out-of-the-money status, the model error decreases.

III. Impact of time to maturity: As the number of days remaining until expiration decreases, the BSM model error decreases. Conversely, a longer time to maturity leads to an increase in model error.

IV. Investment recommendations: Based on the research findings, which indicate a positive correlation between the independent variables (historical volatility, in-the-money status, and time to maturity) and the Black-Scholes pricing error, the following recommendations are proposed:

V. Select options with shorter time to maturity: Investors should consider options with fewer days remaining until expiration. The study results show that, assuming other factors remain constant, the closer an option is to expiration, the lower the Black-Scholes model error.

VI. Avoid high-volatility stocks: Since historical volatility has a positive correlation with pricing error, investors should avoid trading options based on highly volatile stocks. The greater the stock price fluctuations, the less reliable the BSM model becomes for option pricing.

VII. Manage in-the-money status carefully: Since in-the-money status has a positive correlation with model error, investors should avoid options where the difference between the strike price and the current asset price is too high or too low. Otherwise, they should account for this difference in their pricing and trading decisions.

7 | Conclusion

This study investigated the determinants of pricing errors in the BSM model using option contracts traded on the TSE between 2019 and 2023. The empirical findings indicate that historical volatility, moneyness, and time to maturity all have a positive and statistically significant effect on the magnitude of pricing errors. In particular, options with higher underlying asset volatility, deeper in-the-money positions, and longer maturities exhibit larger deviations between theoretical and market prices. Furthermore, the estimated RMSE of approximately 60% demonstrates that the BSM model faces considerable limitations in accurately pricing options in the Iranian derivatives market.

The results suggest that the assumptions underlying the BSM framework may not fully capture the characteristics of emerging markets, where lower liquidity, market inefficiencies, and higher volatility can lead to substantial mispricing. Therefore, investors and practitioners should exercise caution when relying solely on the BSM model for valuation and trading decisions. Future research may improve pricing accuracy by incorporating alternative option pricing models, stochastic volatility specifications, or machine-learning techniques and by considering additional determinants such as liquidity, trading volume, and macroeconomic conditions.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

All data are included in the text.

Funding

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] Esmailzadeh, A., & Amiri, H. (2015). Investigating the new means of financing and implementing it in Bank Tejarat. *Financial economics quarterly*, *9*(31), 57-75. (**In Persian**). https://dorl.net/dor/20.1001.1.25383833.1394.9.31.5.8

[2] Behradmehr, N., & Tahmasabi, N. (2022). Pricing the gold coin options of iran mercantile exchange market:"Black scholes" and "put-call parity"approaches pricing the gold coin options of Iran mercantile exchange market:"Black Scholes" and "Put-Call Parity"approaches. *Financial economics*, *60*(16), 69–92. (**In Persian**). https://doi.org/10.30495/fed.2022.697605

[3] Nasiri, K., & Askarzadeh, G. (2023). Empirical investigation of Black-Scholes pricing model in Tehran Stock Exchange call option transactions. *Financial economics quarterly*, *65*(17), 51–72. (**In Persian**). https://doi.org/10.30495/fed.2023.707979

[4] R, R. (2018). *Basics of financial engineering and risk management*. Position organization. (**In Persian**). https://samta.samt.ac.ir/product/13402/

[5] Saebi, M. (2020). *Research methods in management*. Publications of the Presidential Public Administration Training Center. (**In Persian**). https://www.novinbook.net/

[6] Mohammadi, D., Mohammadi, E., Shokri, N., & Heidari, N. (2023). The use of support vector machine and Naive Bayes algorithms and its combination with risk measure and fuzzy theory in the selection of stock portfolio. *Journal of advances in finance and investment*, *17*(3), 177–206. (**In Persian**). https://www.magiran.com/paper/2672512

[7] Kumar, R., & Agrawal, R. (2017). An empirical investigation of the blackscholes call option pricing model with reference to NSE. *International journal of bric business research*, *6*(2), 1–11. https://doi.org/10.14810/ijbbr.2017.6201

[8] Azor, P. A., & Amadi, I. U. (2020). Analytical solution of black-scholes equation in predicting market prices and its pricing bias. *Asian journal of probability and statistics*, *2020*(8), 17–23. https://doi.org/10.9734/ajpas%2F2020%2Fv8i230202

[9] Wu, Q., Kuang, X., Wu, B., & Xu, X. (2023). Pricing of Shanghai stock exchange 50 ETF options based on different volatility models. *PloS one*, *18*(12), e0288266. https://doi.org/10.1371/journal.pone.0288266

[10] Batten, J. A., & Ellis, C. A. (2005). Paramater estimation bias and volatility scaling in Black–Scholes option prices. *International review of financial analysis*, *14*(2), 165–176. https://doi.org/10.1016/j.irfa.2004.06.008

[11] Amilon, H. (2003). A neural network versus Black–Scholes: A comparison of pricing and hedging performances. *Journal of forecasting*, *22*(4), 317–335. https://doi.org/10.1002/for.867

[12] 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. https://doi.org/10.2307/2327242

[13] Nissi, A., & Salmani Qaraei, K. (2018). *Financial engineering and market modeling with the MATLAB*. Allameh Tabatabaei University Press. https://www.novinbook.net/financial-engineering-modeling-markets

[14] Willmott, C. J., & Matsuura, K. (2005). Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance. *Climate research*, *30*(1), 79–82. https://doi.org/10.3354/cr030079

[15] Gujarati, D. N. (1995). *Basic econometrics*. McGraw-Hill Companies. https://www.amazon.com/s?k=basic+econometrics&adgrpid=1333708167672275