



Modified Black-Scholes Model for Valuing Employee Stock Options with Constant Exit Rate: A Case Study of a Banking Company in Indonesia

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Abstract

Employee Stock Options (ESO) are a form of compensation given to employees in the form of shares that can be purchased within a specified period. In ESO assessment, the Black-Scholes model assumes that employees remain employed until the option reaches maturity, thus not including the factor of employees leaving the company before the options can be exercised. This study aims to determine the value of Employee Stock Options (ESO) by adding a constant exit rate factor. This research uses a historical data-based approach by utilizing the closing price of BANK XYZ shares and the yield on 5-year Indonesian government bonds (Indonesia 5-Year Government Bond Yield) during the January–December 2025 period. The closing price on January 2, 2025 is used as the initial reference for the stock price parameter in the model calculation. The difference between the standard Black-Scholes value and the ESO value becomes more apparent as the maturity period lengthens because the survival probability decreases. By adding a constant exit rate factor, the model can account for the possibility of employees leaving before maturity, which is not considered in the standard Black-Scholes model.

Keywords: Employee Stock Options; Black-Scholes Model; Constant Exit Rate; Volatility; Banking Companies

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1. Introduction

Banking companies currently face intense competition due to advances in financial technology and highly dynamic market changes. The quality of human resources is a crucial asset for a company to thrive in an increasingly competitive market [1]. Employees with superior skills and competencies will make significant contributions to the company. Therefore, a company must create incentives that can retain talented employees and prevent them from leaving [2, 3]. One type of incentive that is widely used is the provision of employee stock options (ESO) or Employee Stock Options which provide stock options to employees with a long-term vision that has been determined by the company [4, 5]. ESO gives employees the right to purchase company shares at a predetermined price as a token of appreciation for their hard work. This strategy allows companies to boost work motivation and reduce the risk of employee resignation [2].

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ESO is a stock-based compensation that gives employees the right to acquire company shares after a waiting period (vesting period), without requiring employees to exercise if the market situation is unfavorable [6]. In banking companies, ESO is used by companies to retain employees who have superior competencies in the company [7]. However, option rights can be lost if the employee resigns before the option reaches maturity. This situation creates challenges for companies in determining the accurate fair value of ESO [6, 8]. Failure to adjust for resignation factors can result in overestimated or undervalued option values. The risk of employees resigning before the option maturity must be taken into account in the ESO valuation [9, 10].

Assessing ESO requires a valuation method that can more accurately describe its characteristics. The Black-Scholes model is the most frequently used method for valuing ESO because it takes into account the current stock price, volatility, risk-free interest rate, and maturity duration [11, 12]. In banking firms, the Black-Scholes model is used as an initial method for estimating the value of options related to stock-based compensation. However, the Black-Scholes model is designed only for options traded in public markets, with assumptions that are not entirely relevant to ESO [13]. The Black-Scholes model does not consider the vesting period, employee exercise behavior, and forfeiture risk due to resignation, so the fair value estimate is not accurate if applied directly to ESO [12]. These limitations require modifications to the model that can accommodate behavioral factors of employee resignations.

According to Kladviko and Zervos [14], Stock option valuations need to consider resignation risk, as this factor can cause the option to be exercised early or forfeited before maturity. The risk of ESO forfeiture not only affects the determination of fair value but also impacts the determination of the fair value of the option. If an employee resigns before reaching the option maturity, the rights to the options granted are assumed to have lapsed [9]. Therefore, the employee resignation rate is modeled using a constant exit rate [15]. This approach assumes that the chance of an employee leaving the company until maturity is reached is a risk that is taken into account in the ESO assessment.

Based on the problems and shortcomings of previous research [14, 16] an employee behavioral approach is needed in the stock option valuation process. Therefore, this study aims to calculate the fair value of ESO by modifying the Black-Scholes model with adjustments for employee resignation risk using a constant exit rate approach. In this method, employee exit is modeled with a constant exit rate, so that the employee's chance of resigning is assumed to remain constant throughout the period until maturity [17]. This approach assumes that the employee's chance of leaving the company before maturity is considered as an employee exit risk in the ESO assessment.

2. Methods

The data used in this study consist of daily stock price data obtained from Yahoo Finance and historical data on the 5-year Indonesian government bond yield (Indonesia 5-Year Government Bond Yield). The stock data comprise the daily closing prices of BANK XYZ shares during the January–December 2025 period. The closing stock price on January 2, 2025, amounting to 9,900, is used as the initial stock price parameter (S) in the model calculation. This date serves only as the initial reference for the stock price parameter and not as the valuation date for directly determining the market value. In addition, a strike price of 9,900 is assumed using an at-the-money approach, in which the strike price is set approximately equal to the stock price during the assessment period.

Daily stock price data for the January–December 2025 period are used to calculate daily stock returns and estimate stock price volatility. Meanwhile, historical data on the 5-year Indonesian government bond yield over the same period are used to determine the risk-free interest rate, calculated as the average daily yield during the observation period. These historical data are used to estimate the model parameters, including the initial stock price, strike price, stock volatility, and risk-free interest rate. The estimated parameters are subsequently used as inputs in the

calculation of Employee Stock Option (ESO) value using the modified Black-Scholes model, which incorporates an exit rate factor.

2.1. Research Data and Parameters

This research utilizes a literature review focused on analyzing conceptual ideas and theories through scientific reference sources. The literature was obtained from various references relevant to the research topic, including the Black-Scholes model and stock option valuation. This study aims to determine the value of European-type stock options by developing Black-Scholes models with the assumption of a constant exit rate as a form of adjustment to real conditions in the company. The data used in this study is secondary data, which includes closing prices obtained from Yahoo Finance sources, as well as data on 5-year Indonesian government bond yields (Indonesia 5-Year Government Bond Yield) for the period January – December 2025 as a proxy for the risk-free interest rate, as a parameter in the calculation of the modified Black-Scholes model. The variables and parameters used in this study are presented in Table 1.

Table 1: Parameter Description

Parameter	Description
S	Stock Price
K	Strike Price
T	Time To Maturity
r	Risk-Free Interest Rate
σ	Volatility
λ	Exit Rate
$P(T)$	Survival Probability
d_1	Black-Scholes Parameter
d_2	Black-Scholes Parameter
V_{ESO}	Employee Stock Option Value
V_{BS}	Black-Scholes Option Value

Based on the above parameters, data processing is performed to calculate stock returns and volatility. Stock returns are calculated using the log-return method stated in Eq. (1)

$$R_t = \ln \left(\frac{S_t}{S_{t-1}} \right) \quad (1)$$

where S_t and S_{t-1} are the closing prices of the stock on day t and the previous day. Stock volatility is calculated using the standard deviation of daily returns as stated in Eq. (2)

$$\sigma_{\text{daily}} = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (R_i - \bar{R})^2} \quad (2)$$

Then the annual volatility is given which is used in the Black-Scholes model expressed in Eq. (3)

$$\sigma = \sqrt{252} \sigma_{\text{daily}} \quad (3)$$

Assuming there are 252 trading days in a year, the approach states that the volatility calculation accurately represents stock price risk. In this research, the concept of the exit rate which is modeled as a hazard rate is assumed to have a constant value during the maturity period, so that the employee's chance of resigning from the company is assumed to remain constant during that period. With the employee resignation risk factor, assuming a constant exit rate λ during the maturity period in Eq. (4)

$$\lambda = \text{constant} \quad (4)$$

The model assumes that the probability of employees resigning from the company is constant during the maturity period.

2.2. Black-Scholes Model

The Black-Scholes model assumes that stock prices follow a stochastic process known as Geometric Brownian Motion (GBM). This model is used for stock price changes that are unstable but have a certain trend, which is stated in Eq. (5)

$$dS = \mu S dt + \sigma S dB_t \quad (5)$$

By applying the risk-free portfolio approach (hedging argument), the Black-Scholes partial differential equation is obtained, which is stated in Eq. (6)

$$\frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS \frac{\partial V}{\partial S} - rV = 0 \quad (6)$$

This equation describes the relationship between the option value, stock price, and time. For European type call options, the Black-Scholes equation is stated in Eq. (7)

$$V_{BS} = SN(d_1) - Ke^{-r(T-t)}N(d_2) \quad (7)$$

The parameters d_1 and d_2 used in Eq. (7) are defined in equations (8) and (9)

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{1}{2}\sigma^2\right)(T-t)}{\sigma\sqrt{T-t}} \quad (8)$$

and

$$d_2 = d_1 - \sigma\sqrt{T-t} \quad (9)$$

In the Black-Scholes framework, the value of a European call option depends on the current stock price, strike price, risk-free interest rate, volatility, and time to maturity. The cumulative standard normal distribution function $N(\cdot)$ represents the risk-neutral probability that the option will finish in the money at maturity.

2.3. Black-Scholes Model with Constant Exit Rate

The Black-Scholes model basically does not consider the risk of losing option rights due to employee resignation before the option reaches maturity. In ESO, this condition is relevant because not all employees survive until the option rights can be exercised. In this study, the exit rate λ value used was not obtained from employee turnover data, but was used as a scenario to analyze the effect of the exit rate on the ESO value. The exit rate values used are 0.10, 0.15, 0.20, and 0.25. Use of these values to see changes in ESO values when employee turnover rates differ. In this study, the exit rate value in this study is a value used for analysis purposes and is not the result of calculating employee turnover in a company. The Black-Scholes model was developed by including a constant exit rate factor denoted by λ , which is the probability of an employee leaving the company during the period used in the model. With the probability of employee continuity up to time T expressed through the survival function in Eq. (10)

$$P(T) = e^{-\lambda T} \quad (10)$$

The survival function comes from the survival analysis approach, where the probability of an exit rate risk is expressed in exponential form based on the hazard rate constant (λ). In this study, employees who leave before reaching the option maturity are assumed to lose the right to exercise the option. Therefore, the option value needs to be adjusted to the possibility of the employee remaining employed until maturity is reached. The survival probability factor is used to describe the chances of employees surviving until maturity so that option rights can still be used. By combining the Black-Scholes option value with survival probability, we obtain an employee stock option valuation model which is stated in Eq. (11)

$$V_{ESO} = e^{-\lambda T} \left[SN(d_1) - Ke^{-rT} N(d_2) \right] \quad (11)$$

The model shows that the value of employee stock options is influenced by both the market price and the probability of the employee remaining until maturity. An increase in the exit rate will decrease the probability of employees remaining, thus reducing the chance of options being exercised and decreasing the option value of ESO.

In this study, the vesting period and maturity are distinguished. In this model, T is used as the option maturity in the Black-Scholes calculation. The vesting period is the time an employee must pass before the option can be exercised, while the maturity period is the time limit for the option to be valid. If an employee leaves the company before maturity, the options are considered to have lapsed (forfeiture).

In this study, the assumption of forfeiture applies if an employee leaves after the vesting period has completed but before the option reaches maturity. This is because the risk of employee departure is calculated from the option period until maturity. Therefore, employees who leave the company before maturity are considered to have forfeited their rights to the option (complete forfeiture). This study does not account for early exercise of options and dividends. Options are also assumed to be non-transferable. Furthermore, employee departures are assumed to be unaffected by changes in stock prices.

Sensitivity analysis was performed only on changes in the exit rate. This is because this study focused solely on the effect of employee exit risk on the ESO value. Meanwhile, other parameters such as stock price, strike price, volatility, and the risk-free interest rate were held constant so that changes in option value could reflect the effect of changes in the exit rate.

In this study, the dividend factor is not included in the calculation because this study focuses on the effect of the exit rate on the ESO value. In addition, the research model assumes that options cannot be transferred to other parties and that employees do not exercise the options before maturity (early exercise). And employee behavior such as the level of caution towards risk (risk aversion) has also not been considered in this study.

The entire calculation process in this study uses Microsoft Excel with parameters in the form of stock price, execution price (strike price), volatility, risk-free interest rate, maturity time, and exit rate. The calculation is carried out in stages by starting to calculate the value on Black-Scholes, survival probability, until obtaining the ESO value after adding the exit rate factor.

3. Results and Discussion

This chapter presents the results of data processing and calculations using the modified Black-Scholes model with a constant exit rate. The results are analyzed to examine the effect of a constant exit rate on the value of Employee Stock Options (ESO) by comparing them with the standard Black-Scholes model.

3.1. Employee Stock Options

In this study, employee stock options (ESO) use the Black-Scholes model which adds a constant exit rate factor. This study uses a retrospective scenario analysis approach by utilizing historical data on the closing price of BANK XYZ shares during the period January–December 2025 obtained from Yahoo Finance sources. In addition, the yield data of 5-year Indonesian government bonds during 2025 is used as a risk-free interest rate parameter in the calculation of the modified Black-Scholes model.

In the first stage, calculate the daily stock return using the log-return equation stated in equation (1). Based on the data processing, both positive and negative daily returns were obtained, indicating fluctuations in stock prices during the observation period from January to December 2025. The results of the daily stock return calculations are shown in Figure 1.

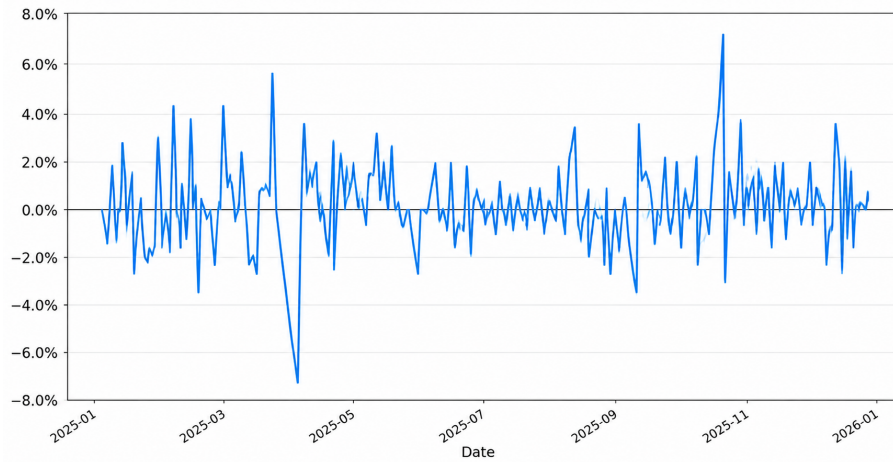


Fig. 1: Daily Stock Return of BANK XYZ

From the calculation of the daily return of BANK XYZ shares, The mean daily return was -0.0006 , or -0.06% , indicating a negative average daily return during the observation period. Meanwhile, Equation (2) yields a daily return standard deviation of 0.018183 . The annual volatility calculated using Equation (3) is 0.288651 . This value indicates the level of stock price fluctuation, a parameter in the Black-Scholes model that will be modified.

Furthermore, the risk-free interest rate uses data on 5-year Indonesian government bond yields for 2025, as follows:

$$r = 0.061593.$$

The complete model parameters are presented in Table 2.

Table 2: Model Parameters

Parameter	Value
S	9.900
K	9.900
T	1,2,3,4,5
r	0.061593
σ	0.288651
λ	0.10; 0.15; 0.20; 0.25
$P(T)$	$e^{-\lambda T}$

The parameter values in Table 2 form the basis for calculating Employee Stock Options (ESO). The maturity period (time to maturity) used is 1 to 5 years to see changes in option value over different periods. To calculate the survival probability, this study assumes a constant exit rate of $\lambda = 0.10, 0.15, 0.20, 0.25$. Each exit rate value is used to see the effect of employee exit rates on ESO values at different time periods.

Table 3: Black-Scholes Option Values

T	V_{BS}
1	1422.66
2	2149.17
3	2742.42
4	3257.87
5	3717.83

Table 3 shows that the Black-Scholes value tends to increase with increasing maturity. At $T = 1$ year, the option value is 1422.66, then increases to 3717.83 when $T = 5$ years. This shows that the longer the expiration time of the option, the greater the change in stock prices which

can affect the increase in the option value. This value will be used in the Employee Stock Option calculation which takes into account Survival Probability with various constant exit rates.

Table 4: Survival Probability

T	$\lambda = 0.10$	$\lambda = 0.15$	$\lambda = 0.20$	$\lambda = 0.25$
1	0.90484	0.86071	0.81873	0.77880
2	0.81873	0.74082	0.67032	0.60653
3	0.74082	0.63763	0.54881	0.47237
4	0.67032	0.54881	0.44933	0.36788
5	0.60653	0.47237	0.36788	0.28650

In Table 4, the survival probability calculation shows a decrease with increasing maturity and increasing exit rate (λ) value. The survival probability at an exit rate of $\lambda = 0.10$ is much higher than the exit rate values of $\lambda = 0.15$, $\lambda = 0.20$ and $\lambda = 0.25$. This shows that the greater the exit rate, the smaller the chance of employees remaining until the option maturity. In addition, increasing time to maturity causes the survival probability value to decrease. This shows that the longer the maturity period, the less likely an employee is to remain until the option is exercised. As a result, the employee's chances of receiving the granted stock options are also lower.

Table 5: Employee Stock Option Values

T	$\lambda = 0.10$	$\lambda = 0.15$	$\lambda = 0.20$	$\lambda = 0.25$
1	1287.28	1224.49	1164.78	1107.97
2	1759.59	1592.14	1440.63	1303.54
3	2031.63	1748.64	1505.07	1295.43
4	2183.82	1787.96	1463.86	1198.50
5	2254.83	1756.18	1367.71	1065.18

Table 5 shows the ESO value for each exit rate. At an exit rate of $\lambda = 0.10$, the ESO value increases as the time to maturity increases, from 1287.28 at $T = 1$ to 2254.83 at $T = 5$. This indicates a lower level of risk of employee exit so that the influence of the maturity time is still greater on the value of the option which experiences an increase.

At an exit rate of $\lambda = 0.15$, the ESO value increased from 1224.49 at $T = 1$ to 1787.96 at $T = 4$. However, at $T = 5$ the ESO value decreased to 1756.18. This condition shows that increasing the maturity period does not always cause the option value to increase, because the greater risk of employee departure can reduce the possibility of employees retaining their option rights until the maturity period.

At an exit rate of $\lambda = 0.20$, the ESO value increases from 1164.78 at $T = 1$ to 1505.07 at $T = 3$. After that, the ESO value decreases to 1463.86 at $T = 4$ and decreases again to 1367.71 at $T = 5$. At an exit rate of $\lambda = 0.25$, the ESO value increases to a maximum of 1303.54 at $T = 2$. After that, the ESO value decreases to 1295.43 at $T = 3$ and 1198.50 at $T = 4$, and then decreases to 1065.18 at $T = 5$.

These results show that the greater the exit rate value, the greater the influence of the risk of employee leaving on the ESO value. At an exit rate of $\lambda = 0.10$, increasing the time to maturity still has a positive effect on the option value because employees still have a greater chance of remaining until maturity. However, when the exit rate is $\lambda = 0.15$, $\lambda = 0.20$, or $\lambda = 0.25$, the increase in option value becomes smaller because the risk of employees leaving becomes greater. Additionally, although a longer time to maturity may increase the option value, the value may decrease when the probability of employees remaining with the company becomes sufficiently low. This condition shows that there is an influence between the increase in the maturity period and the risk of employee turnover in determining the ESO value.

The calculation results show that increasing the maturity date does not always increase the ESO value for each exit rate. At low exit rates, increasing the maturity date still has a

positive effect on option value because employees have more time to remain and exercise their options. However, at higher exit rates, increasing the maturity date also increases the likelihood of employees leaving the company before the options can be exercised. Therefore, the ESO value does not always increase and may decrease over time.

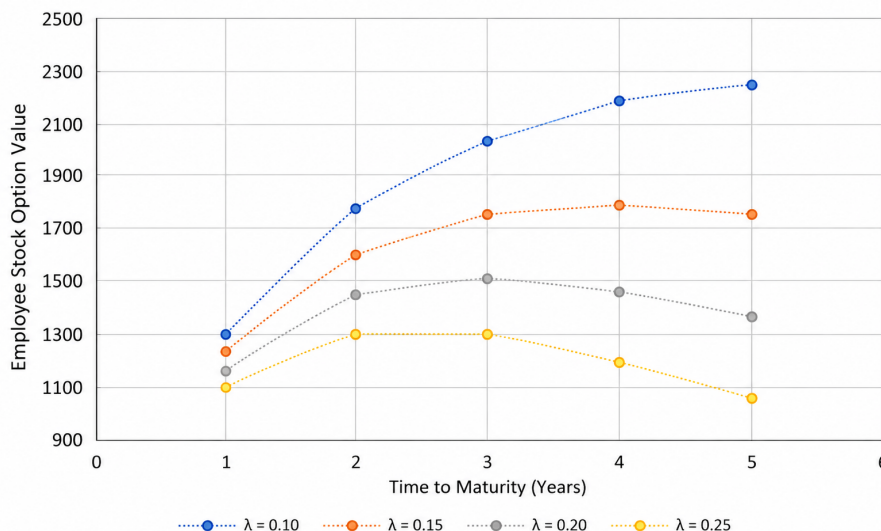


Fig. 2: Employee Stock Option Value Under Different Constant Exit Rates

Figure 2 shows that the ESO value has a different pattern at each exit rate level. At an exit rate of $\lambda = 0.10$, the ESO value continues to increase as maturity increases. At $\lambda = 0.15$, the ESO value increases until $T = 4$, then decreases at $T = 5$. At $\lambda = 0.20$, the ESO value increases until $T = 3$, then decreases until $T = 5$. Meanwhile, at $\lambda = 0.25$, the ESO value increases until $T = 2$, then decreases until $T = 5$. This shows that the effect of maturity on the ESO value is different at each exit rate level.

Table 6: Percentage Decrease in ESO Value against Standard Black-Scholes

T	$\lambda = 0.10$	$\lambda = 0.15$	$\lambda = 0.20$	$\lambda = 0.25$
1	9.52%	13.93%	18.13%	22.12%
2	18.13%	25.92%	32.97%	39.35%
3	25.92%	36.24%	45.12%	52.76%
4	32.97%	45.12%	55.07%	63.21%
5	39.35%	52.76%	63.21%	71.35%

Table 6 shows that adding the exit rate factor decreases the ESO value compared to the standard Black-Scholes value. The amount of the decrease depends on the exit rate value used. The greater the exit rate value, the greater the decrease in the ESO value. This shows that the higher the possibility of an employee leaving the company, the smaller the opportunity for the employee to retain their option rights until they reach maturity. In addition, the longer the time to maturity, the greater the influence of the risk of employee departure on the ESO value.

4. Conclusion

This study applies the Black-Scholes model with survival probability adjustments to determine Employee Stock Options (ESO) by assuming a constant exit rate. The approach used focuses on calculating the likelihood of employees resigning from the company before reaching option maturity, but takes into account the employee's chances of remaining until the option can be exercised.

The results of the calculations show that the survival probability value will decrease with increasing maturity time. Employee Stock Option values show different changes at each exit rate and maturity level. The greater the exit rate value, the lower the ESO value obtained because the employee's chances of remaining until maturity are smaller. At an exit rate of 0.10, the ESO value continues to increase from $T = 1$ to $T = 5$. At an exit rate of 0.15, the ESO value increases to $T = 4$, then decreases at $T = 5$. At an exit rate of 0.20, the ESO value increases to $T = 3$, while at an exit rate of 0.25 the ESO value increases to $T = 2$ and then decreases.

The effect of maturity on ESO values shows different patterns at different exit rates. At low exit rates, increasing maturity tends to increase ESO values. However, at higher exit rates, increasing maturity does not always increase ESO values due to the increased likelihood of employees leaving before reaching maturity.

The main contribution of this research is by adding the risk factor of employee exit through survival probability in ESO research with the Black-Scholes model. This approach can be used to examine the impact of employee turnover risk on ESO values. However, the results of this study are still limited by the assumption of a constant exit rate used in the study calculations.

This study still has limitations, the use of the exit rate value in this study is still an assumption or only a scenario to see the effect of employee departure on the ESO value, so it does not yet describe the actual condition of employee turnover in the company. In addition, this study has not considered other factors such as early exercise of options, dividends, and the influence of changes in model parameters such as volatility, stock price, strike price, and risk-free interest rate. Therefore, further research is expected to use actual employee turnover data and consider other factors that can influence the ESO value so that the valuation results are more in line with the actual facts.

CRediT Authorship Contribution Statement

Permadi Yulianto: Conceptualization, methodology, mathematical modeling, data analysis, numerical computation, formal analysis, software implementation, validation, visualization, writing—original draft, and writing—review and editing. **Rudianto Artiono:** Supervision, Validation, and review

Declaration of Generative AI and AI-assisted technologies

No generative AI or AI-assisted technologies were used during the preparation of this manuscript.

Declaration of Competing Interest

The authors declare no competing interests

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Data and Code Availability

The stock price data used in this study were obtained from Yahoo Finance, while the risk-free interest rate data were obtained from historical data on 5-year Indonesian government bond yields for the period January–December 2025. Calculations were performed using Microsoft Excel based on the formulas and parameters described in this study. Data and calculation details are available from the corresponding author upon reasonable request.

References

- [1] B. Rusianto and K. Khasmir. “The Impact of Competence and HR Quality on Organizational Performance with Motivation as an Intervening Variable at Bank Indonesia”. In: *International Journal of Environmental, Sustainability, and Social Science* 4.6 (2023), pp. 1919–1926. DOI: [10.38142/ijesss.v4i6.940](https://doi.org/10.38142/ijesss.v4i6.940).
- [2] Andrew Pendleton and Andrew Robinson. “Employee behavior in employee stock option plans: Why do some employees acquire company stock?”. In: *Human Resource Management* 62.2 (2023), pp. 197–211. DOI: [10.1002/hrm.22139](https://doi.org/10.1002/hrm.22139).
- [3] Qiaoqiao Li and Hong Zhang. “The Causal Effect of Option Ownership on Employee Performance: Empirical Evidence from Personnel Data”. In: *Labour Economics* 69 (2021), p. 101966. DOI: [10.1016/j.labeco.2021.101966](https://doi.org/10.1016/j.labeco.2021.101966).
- [4] Camil Ciprian Cirnu. “Evaluating the Financial Implications of Employee Stock Option Plans: Costs and Benefits for Financial Institutions”. In: *Revista de Studii Financiare* 10.19 (2025), pp. 197–209. DOI: [10.55654/JFS.2025.10.19.12](https://doi.org/10.55654/JFS.2025.10.19.12).
- [5] Shintya Nafitri Hayuningrum and Rudianto Artiono. “Pemodelan Matematika Opsi Saham Karyawan Menggunakan Metode Binomial Enhanced American”. In: *MATHunesa: Jurnal Ilmiah Matematika* 11.2 (2023), pp. 186–191. DOI: [10.26740/mathunesa.v11n2.p186-191](https://doi.org/10.26740/mathunesa.v11n2.p186-191).
- [6] Rudianto Artiono and Dayat Hidayat. “Binomial Approach for the Valuation of Employee Stock Option with Some Features: Vesting Period, Exit Rate, Reload, and Reset”. In: *E3S Web of Conferences*. Vol. 328. EDP Sciences, 2021, p. 06006. DOI: [10.1051/e3sconf/202132806006](https://doi.org/10.1051/e3sconf/202132806006).
- [7] Tim Leung and Yang Zhou. “A Top-Down Approach for the Multiple Exercises and Valuation of Employee Stock Options”. In: *International Journal of Theoretical and Applied Finance* 23.2 (2020), p. 2050004. DOI: [10.1142/S0219024920500041](https://doi.org/10.1142/S0219024920500041).
- [8] Qing Gong, Hong Zhang, and Li-An Zhou. “Retention Effects of Employee Stock Options: Evidence from Bunching at Vesting Dates”. In: *Economic Development and Cultural Change* 74.3 (2026), pp. 777–816. DOI: [10.1086/737154](https://doi.org/10.1086/737154).
- [9] Tim Leung and Ronnie Sircar. “Accounting for Risk Aversion, Vesting, Job Termination Risk and Multiple Exercises in Valuation of Employee Stock Options”. In: *Mathematical Finance* 19.1 (2009), pp. 99–128. DOI: [10.1111/j.1467-9965.2008.00359.x](https://doi.org/10.1111/j.1467-9965.2008.00359.x).
- [10] Louis P. Le Guyader and Thomas O. Meyer. “Employee Stock Options and the Flawed Use of the Black–Scholes Option Pricing Model”. In: *Journal of Corporate Accounting & Finance* 32.1 (2021), pp. 7–12. DOI: [10.1002/jcaf.22456](https://doi.org/10.1002/jcaf.22456).
- [11] Fischer Black and Myron S. Scholes. “The Pricing of Options and Corporate Liabilities”. In: *Journal of Political Economy* 81.3 (1973), pp. 637–654. DOI: [10.1086/260062](https://doi.org/10.1086/260062).
- [12] Ilona Babenko, Fangfang Du, and Yuri Tserlukevich. “Will I Get Paid? Employee Stock Options and Mergers and Acquisitions”. In: *Journal of Financial and Quantitative Analysis* 56.1 (2021), pp. 29–64. DOI: [10.1017/S0022109020000022](https://doi.org/10.1017/S0022109020000022).
- [13] Jennifer N. Carpenter. “The Exercise and Valuation of Executive Stock Options”. In: *Journal of Financial Economics* 48.2 (1998), pp. 127–158. DOI: [10.1016/S0304-405X\(98\)00006-3](https://doi.org/10.1016/S0304-405X(98)00006-3).
- [14] Kamil Kladvik and Mihail Zervos. “Valuation of Employee Stock Options (ESOs) by Means of Mean-Variance Hedging”. In: *arXiv preprint arXiv:1710.00897* (2017). DOI: [10.48550/arXiv.1710.00897](https://doi.org/10.48550/arXiv.1710.00897). arXiv: [1710.00897 \[q-fin.PR\]](https://arxiv.org/abs/1710.00897).
- [15] Andrew Pendleton and Andrew Robinson. “Why Walk Away from an Easy Gain in Wealth? Evidence from a UK Stock Option Plan”. In: *Journal of Behavioral and Experimental Finance* 31 (2021), p. 100539. DOI: [10.1016/j.jbef.2021.100539](https://doi.org/10.1016/j.jbef.2021.100539).

- [16] Jennifer N. Carpenter, Richard Stanton, and Nancy Wallace. “Employee Stock Option Exercise and Firm Cost”. In: *The Journal of Finance* 74.3 (2019), pp. 1175–1216. DOI: [10.1111/jofi.12752](https://doi.org/10.1111/jofi.12752).
- [17] John Hull and Alan White. “How to Value Employee Stock Options”. In: *Financial Analysts Journal* 60.1 (2004), pp. 114–119. DOI: [10.2469/faj.v60.n1.2596](https://doi.org/10.2469/faj.v60.n1.2596).