JINAV: Journal of Information and Visualization *ISSN: 2746-1440 (online)*
Vol. 7 No. 1 (2026)
https://doi.org/10.35877/454RI.jinav4667

Option Pricing for Exchange Rate Hedging: Evaluation of Value-at-Risk, Sharpe Ratio, and Backtesting with Kupiec and Christoffersen Tests

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Abstract

This study examines the effectiveness of foreign currency options as hedging instruments for exchange-rate exposure in two important Southeast Asian currency settings, namely USD/IDR and MYR/IDR. The analysis uses monthly closing exchange-rate data from January 2022 to January 2025 and applies the Garman-Kohlhagen model to estimate call and put option values. Hedging performance is then evaluated through two complementary Value at Risk approaches, variance-covariance VaR and historical simulation VaR, together with the Sharpe ratio as a measure of risk-adjusted performance. To assess whether the selected VaR models are statistically reliable, the study conducts formal backtesting using the Kupiec unconditional coverage test and the Christoffersen conditional coverage test. The findings show that historical simulation generally provides more robust loss estimates than the variance-covariance approach when the portfolio contains nonlinear option payoffs and exchange-rate volatility changes abruptly. The results also indicate that put-option strategies deliver better risk-adjusted outcomes than call-option strategies during the observed period. The paper further shows that model performance differs across currency pairs because exchange-rate behaviour in emerging markets is shaped by uneven volatility regimes, policy responses, and external shocks. By integrating option pricing, downside-risk measurement, performance evaluation, and model validation in one framework, this study offers practical implications for treasury managers, importers, exporters, and investors who must manage foreign-exchange risk under turbulent market conditions.

Keywords: foreign exchange hedging; Value at Risk; Sharpe ratio; FX options; Garman-Kohlhagen; backtesting.

Received: 17 February 2026 Revised: 22 April 2026 Accepted: 26 April 2026

1. Introduction

International trade expands market access and supports firm growth, yet it also exposes firms to exchange-rate risk. Exporters, importers, and investors face uncertainty because foreign-currency cash flows can change rapidly in domestic-currency terms. When exchange rates move sharply, firms may experience margin compression, unstable cash flows, and changes in the present value of liabilities and receivables. This issue has become more salient after episodes of monetary tightening, geopolitical tension, and commodity-price shocks that intensified currency volatility. The foreign exchange market therefore requires hedging instruments that can protect downside exposure without fully eliminating upside opportunities. Currency options are relevant in this context because they grant the right, but not the obligation, to buy or sell a currency at a predetermined strike price. This contractual flexibility makes options attractive for firms whose exposures are uncertain in timing or amount, and recent exchange-rate studies also show how depreciation pressure can reshape trade outcomes and macroeconomic performance (Allayannis & Ofek, 2001; Brown, 2001; Ko et al., 2024; Mefteh-Wali & Hussain, 2024; Ogwuche et al., 2024; Sandi et al., 2024).

The specific research problem is not simply whether hedging is useful, but whether foreign currency options can be evaluated more accurately in a Southeast Asian setting where exchange-rate movements are uneven across currencies and policy regimes. In emerging markets, exchange-rate management is especially relevant because many firms depend on imported inputs, foreign debt, or export receipts denominated in major currencies. Movements in USD/IDR and MYR/IDR can therefore transmit quickly into production costs, balance-sheet positions, and profit volatility. Exchange-

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rate volatility in these markets often exhibits non-normality, clustering, and abrupt shifts. These features reduce the reliability of simplified risk models that assume stable variance and thin tails. Recent evidence from foreign exchange risk research shows that model selection strongly affects measured hedge effectiveness and portfolio risk (Afuecheta et al., 2024; Nsengiyumva et al., 2024; Pagnottoni & Spelta, 2024; Saadah et al., 2024). Studies on derivative usage, firm value, investment sensitivity, and corporate risk mitigation likewise show that foreign exchange risk management should be assessed with both economic and statistical criteria, while comparisons with forward hedging and corporate hedging practice confirm that instrument choice affects protection quality and financial outcomes (Han & Laing, 2025; Jin & Marshall, 2024; Wang et al., 2024; Nasriani et al., 2024; Pangestuti, 2022; Zahra et al., 2023).

Among derivative instruments, foreign currency options are particularly useful because they preserve asymmetric protection. Compared with forwards or futures, options allow the hedger to cap adverse exchange-rate movements while retaining favourable market upside. The standard analytical framework for pricing foreign currency options is the Garman-Kohlhagen model, which extends Black-Scholes by incorporating both domestic and foreign risk-free interest rates. This model remains a foundational benchmark in foreign exchange option valuation and continues to inform more recent model extensions. Recent studies have refined foreign-currency option valuation by incorporating dynamic information costs, market frictions, and changing volatility regimes, yet the Garman-Kohlhagen model remains an appropriate empirical baseline (Garman & Kohlhagen, 1983; Dammak et al., 2023; Hull, 2022). In applied risk management, however, pricing accuracy alone is not sufficient. A hedging strategy must also be evaluated in terms of loss control and risk-adjusted return.

Prior research has documented that foreign currency derivatives can reduce exchange-rate exposure, but the reported effectiveness varies across markets, firms, and model specifications. Díaz Restrepo and Redondo Ramírez (2021) show that options can function as exchange-rate hedges, while more recent studies link hedging to firm value, governance, disclosure, and investment policy (Gupta et al, 2025; Ko & Cho, 2025; Ji & Wei, 2023; Ko et al., 2024; Mefteh-Wali & Hussain, 2024; Toerien et al., 2025). Other work finds that historical or data-driven risk models often outperform rigid parametric approaches when the return distribution is skewed or heavy-tailed (Afuecheta et al., 2024; Nsengiyumva et al., 2024; Pagnottoni & Spelta, 2024). Despite these advances, many applied studies still stop at reporting VaR values or return indicators without testing whether the model remains statistically credible when confronted with realized losses. This omission matters because a seemingly low VaR can still be misleading if violations cluster or exceed the expected frequency.

This study addresses that gap by integrating option pricing, risk measurement, risk-adjusted performance, and formal backtesting in one empirical design. Specifically, the study estimates foreign currency option prices with the Garman-Kohlhagen model, measures downside risk through variance-covariance VaR and historical simulation VaR, evaluates portfolio efficiency with the Sharpe ratio, and tests model adequacy with the Kupiec and Christoffersen procedures. The objective is threefold. First, the study estimates the potential maximum loss associated with option-based foreign exchange hedging. Second, it compares the extent to which hedged positions improve risk-adjusted returns. Third, it determines which VaR specification is more reliable for portfolios exposed to foreign exchange movements in emerging-market settings. By focusing on USD/IDR and MYR/IDR over 2022 to 2025, the study provides evidence that is directly relevant to firms and investors facing current exchange-rate uncertainty.

2. Materials and Methods

2.1. Garman-Kohlhagen Model

The call and put option values are estimated with the Garman-Kohlhagen model, which explicitly incorporates domestic and foreign risk-free interest rates. Equations (1) and (2) define the option values used throughout the empirical analysis.

$$C = S_0 e^{-\mathrm{rfT}} N(d_1) - K e^{-\mathrm{rdT}} N(d_2) \tag{1}$$

$$P = K e^{-\mathrm{rdT}} N(-d_2) - S_0 e^{-\mathrm{rfT}} N(-d_1) \tag{2}$$

$$d_1 = \frac{\left[\ln\left(\frac{S0}{K}\right) + (r_d - r_f + 0.5\sigma^2)T\right]}{(\sigma\sqrt{T})}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

where C denotes the call-option value, P denotes the put-option value, S_0 is the current spot exchange rate, K is the strike price, r_d is the domestic risk-free rate, r_f is the foreign risk-free rate, σ is exchange-rate volatility, T is time to maturity, and N(·) is the cumulative standard normal distribution (Garman & Kohlhagen, 1983; Hull, 2022).

2.2. Value at Risk Calculation

$$VaR = P\, z_{0.95} \sigma \sqrt{t} \tag{3}$$

where:

P : initial investment or portfolio value
$z_{0.95}$: z-score at the 95% confidence level
σ : standard deviation of returns
t : holding period

$$\text{Historical VaR} = -\text{quantile } \alpha(R) \tag{4}$$

where:

VaR(1-α) : maximum potential loss at confidence level (1-α)
R : return series
quantileα(R) : lower-tail empirical quantile at level α

Before VaR is estimated, the return series is computed as the log return:

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{5}$$

where P_t is the exchange rate or portfolio value at time t and P_{t-1} is the value at time $t-1$. This study applies both parametric and non-parametric VaR because option portfolios may produce nonlinear return distributions that are not well approximated by normality (Jorion, 2021; McNeil et al., 2022). This modelling choice is also consistent with broader market-risk literature that emphasizes the role of distributional assumptions, dynamic dependence, and quantile-based methods in risk estimation (Alexander, 2023; Engle, 2022; Koenker et al., 2024).

2.3. Sharpe Ratio

The Sharpe ratio evaluates whether the return generated by the hedged portfolio is sufficient relative to the risk taken. In hedging analysis, this metric is useful because a strategy should not only reduce losses but also preserve efficiency after considering option costs and volatility. Prior applications of the Sharpe ratio in investment and portfolio studies also support its use as a practical indicator of risk-adjusted performance after risk mitigation (Febrianti et al., 2023).

To assess risk-adjusted performance after hedging, the Sharpe ratio is calculated as follows:

$$Sharpe\ ratio = \frac{(R_p - R_f)}{\sigma_p} \tag{6}$$

where:

R_p : average portfolio return
R_f : risk-free return;
σ_p : standard deviation of portfolio return

2.4. Backtesting with Kupiec and Christoffersen Tests

The accuracy of the VaR model is evaluated through backtesting using unconditional coverage and conditional coverage tests.

2.4.1. Kupiec Test

The Kupiec test evaluates whether the observed number of VaR violations is consistent with the expected number of violations at the selected confidence level. The test is based on the likelihood-ratio statistic for unconditional coverage (Kupiec, 1995).

$$LR_{uc} = -2\ln\left\{\frac{[(1-p)(T-N)pN]}{\left[\left(1-\frac{N}{T}\right)(T-N)\left(\frac{N}{T}\right)N\right]}\right\} \tag{7}$$

where:

LRuc is the unconditional coverage likelihood-ratio statistic, T is the number of observations, N is the number of VaR violations, and p is the expected violation probability.

2.4.2. Christoffersen Test

The Christoffersen test extends the Kupiec framework by examining both the frequency of violations and their independence over time. The hit sequence is defined as follows:

$$v_{t+1} = 1 \text{ if } loss_{t+1} > VaR_{t+1}, \text{ and } v_{t+1} = 0 \text{ otherwise} \tag{8}$$

A reliable VaR model should satisfy unconditional coverage and independence at the same time. If violations cluster, the model can still be rejected even when the total number of breaches appears acceptable.

Unconditional coverage component.

The independence component examines whether a current violation depends on the violation status in the previous period. The likelihood-ratio statistic is written as follows:

$$LR_{ind} = -2\ln\left(\frac{L_0}{L_1}\right) \tag{9}$$

Under the null hypothesis, violations are independent and follow a Bernoulli process. Under the alternative hypothesis, transition probabilities differ across states.

T_{00} is the number of non-violations followed by non-violations, T_{01} the number of non-violations followed by violations, T_{10} the number of violations followed by non-violations, and T_{11} the number of violations followed by violations.

$$\Pi_{01} = \frac{T_{01}}{T_{00}+T_{01}}, \quad \pi_{11} = \frac{T_{11}}{T_{10}+T_{11}} \tag{10}$$

Conditional coverage component.

The joint Christoffersen conditional-coverage statistic combines the Kupiec and independence components as follows:

$$LR_{cc} = LR_{uc} + LR_{ind} \tag{11}$$

The model is considered adequate when the joint statistic does not reject the null hypothesis at the selected confidence level.

3. Results and Discussion

This section presents the empirical findings from option pricing, VaR estimation, Sharpe-ratio evaluation, and statistical backtesting. The discussion is organized to show not only whether the models pass formal tests, but also why their performance differs across instruments and currency settings. This distinction is important because a model that looks acceptable in a static calculation may still fail under actual market stress. The central question is therefore not only which method generates lower numerical risk values, but which method remains credible when confronted with realized losses. In that sense, the results provide both methodological evidence and practical guidance for treasury managers who must choose hedging tools under volatile foreign-exchange conditions.

The USD/IDR and MYR/IDR results should be interpreted within the broader economic environment of 2022 to 2025. During this period, emerging-market currencies were affected by global monetary tightening, strong United States dollar cycles, imported inflation pressures, and uneven regional trade recovery. Those conditions likely created structural breaks and short-lived volatility clusters that are difficult for a variance-covariance model to capture. The USD/IDR leg is especially sensitive to global dollar liquidity conditions, while the MYR/IDR leg is shaped more strongly by regional trade, commodity-linked sentiment, and relative policy responses in Indonesia and Malaysia. This difference helps explain why a model can appear more stable for one currency pair and less stable for another even when both are evaluated over the same sample window. Prior foreign-exchange studies also argue that nonlinear volatility, dynamic dependence, and shifting distributional behaviour weaken simple parametric assumptions during turbulent periods (Afuecheta et al., 2024; Nsengiyumva et al., 2024; Saadah et al., 2024).

Based on Figure 1 and Figure 2, the 95% VaR estimates for the call and put portfolios are able to track ordinary market movements, but they do not fully contain realized losses during more stressful episodes. Several exceedances appear when exchange-rate changes become sharper, which indicates that tail risk is not fully represented in the parametric specification. This outcome is consistent with the nature of option portfolios, because their payoffs are nonlinear and become more sensitive when volatility changes rapidly. A model that assumes stable variance can therefore understate risk even when the average fit looks acceptable. For practitioners, this means that visually smooth VaR lines should not be interpreted as proof of robustness.

Based on Figure 3 and Figure 4, the historical VaR approach provides a more conservative profile for both portfolios, especially when the return distribution departs from normality. Because the historical method uses empirical observations rather than a fixed parametric form, it responds better to the loss pattern actually embedded in the sample. The historical call portfolio still shows vulnerability around turbulent windows, but the estimated risk bounds remain closer to realized behaviour than those generated by the variance-covariance method. The put portfolio also exhibits relatively better containment under historical simulation, which suggests that downside-oriented hedging is better aligned with the market direction observed in the sample. These findings support the view that model flexibility matters when foreign-exchange returns become asymmetric or heavy-tailed.

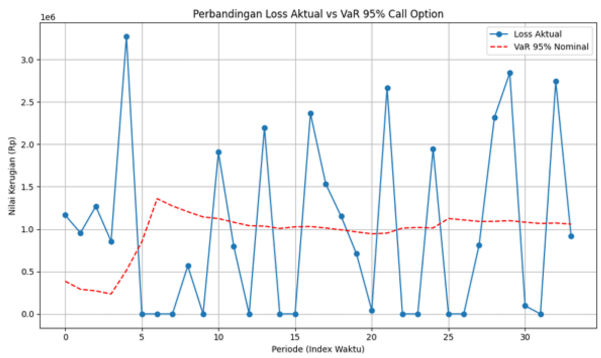

Fig. 1. Comparison of Actual Loss and Call VaR

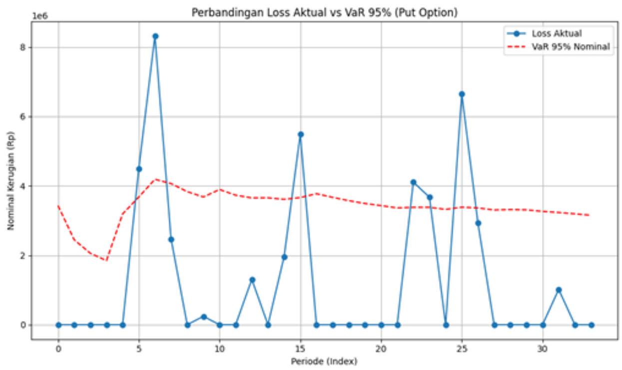

Fig. 2. Comparison of Actual Loss and Put VaR

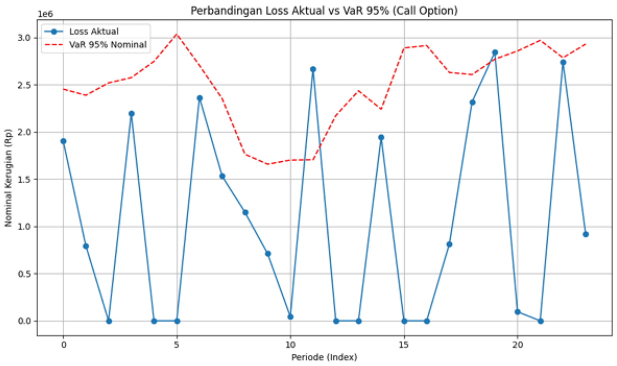

Fig. 3. Comparison of Actual Loss and Historical Call VaR

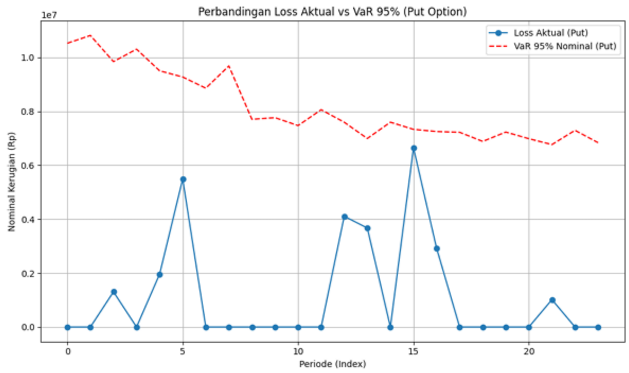

Fig. 4. Comparison of Actual Loss and Historical Put VaR

Based on Figure 5, the put-option strategy offers the most favourable risk-adjusted performance during the sample period. The call-option strategy produces a weaker Sharpe ratio, which implies that it does not compensate adequately for the risk undertaken. This result has a practical interpretation. A hedging decision should not aim only to reduce gross exposure. It should also consider the economic cost of protection, including option premiums, the timing of contract selection, and the opportunity cost of a hedge that becomes too conservative. A practitioner who focuses only on minimizing VaR may end up paying for protection that suppresses useful upside potential. By contrast, a more balanced strategy evaluates whether the reduction in downside risk is large enough to justify the cost of the hedge. The Sharpe-ratio evidence in this study suggests that put options offered a more efficient balance between protection and performance under the observed market conditions.

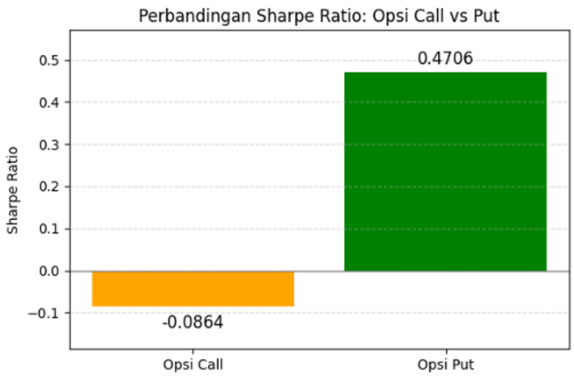

Fig. 5. Comparison of Call and Put Sharpe Ratios

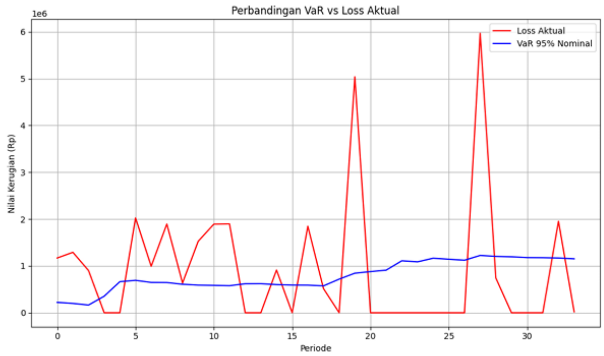

Fig. 6. Comparison of Actual Loss and Variance–Covariance Call VaR

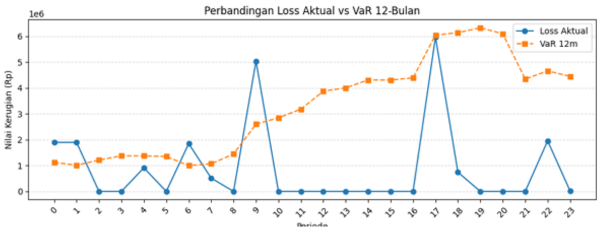

Fig. 7. Comparison of Actual Loss and Historical Call VaR

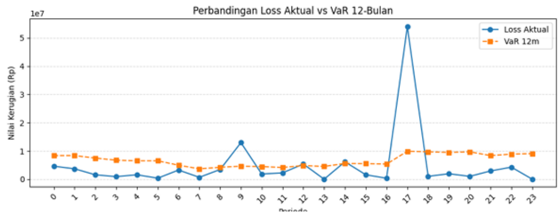

Fig. 8. Comparison of Actual Loss and Historical Put VaR

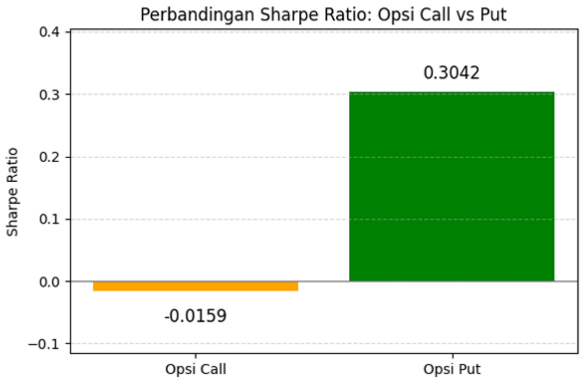

Fig. 9. Comparison of Call and Put Sharpe Ratios

Based on Figure 6, Figure 7, and Figure 8, the relative performance of the two VaR methods becomes clearer. The variance-covariance method captures broad volatility trends, but it materially understates extreme losses when shocks become clustered or when exchange-rate behaviour changes abruptly. Historical simulation performs better because it carries the empirical characteristics of the return series directly into the risk estimate. This difference is particularly important for comparing USD/IDR and MYR/IDR. The stronger exposure of USD/IDR to global dollar cycles may create larger and faster deviations from normality, while MYR/IDR may experience different forms of regional spillover and policy transmission. In both cases, a method that adapts to realized distributional behaviour is more credible than a method that assumes stable covariance structure. The visual evidence therefore supports the later backtesting results.

Based on Table 1, the pass-fail outcome of formal backtesting confirms that historical simulation is more reliable than the variance-covariance method for this sample, although it is not uniformly successful across all positions. Table 1 shows that the variance-covariance VaR model is invalid for both call and put portfolios at the 95% confidence level, while historical VaR is valid only for the call-option portfolio. This result means that the parametric method fails not only because of isolated forecast errors but because its assumptions are systematically misaligned with the loss process. The historical method performs better because it preserves tail behaviour more effectively. Even so, the invalid historical result for the put portfolio shows that empirical methods are not automatically adequate and still depend on the sample structure, window length, and intensity of recent shocks.

The backtesting failures can also be interpreted in light of real-world market events. Exchange-rate behaviour between 2022 and 2025 was likely shaped by alternating phases of tight monetary policy, inflation management, commodity-price adjustment, and regional uncertainty. Such episodes can create short bursts of instability followed by calm periods, which leads to violation clustering. When this happens, a model may pass on average frequency but still fail on independence. That mechanism helps explain why Kupiec and Christoffersen tests are both needed. A model that underestimates clustered risk is particularly problematic for corporate hedging because treasury managers often need protection precisely when market conditions become discontinuous or policy-sensitive. The evidence therefore supports the reviewer suggestion that economic context should accompany statistical interpretation rather than be treated as a separate issue.

Based on Table 2, validation performance also varies by option type. Table 2 shows that the covariance VaR specification is valid only for the put option, whereas both historical VaR specifications remain invalid in this summary test. This mixed result indicates that no single model should be assumed valid without empirical testing. Model selection must follow the distributional features of the hedged position, the option payoff profile, and the prevailing market environment. A treasury manager dealing with IDR and MYR transactions should therefore avoid one-size-fits-all hedging rules. Instead, the manager should compare statistical validity, economic cost, and intended risk coverage before selecting a final hedge design.

The overall implication is that option-based hedging remains useful, but its effectiveness depends on the interaction between contract design and model choice. The evidence from Figure 9, Table 1, and Table 2 indicates that put options can improve risk-adjusted performance, yet the supporting VaR model must still be validated carefully. This is why the study combines pricing, Sharpe-ratio analysis, and backtesting rather than relying on one indicator alone. The results are therefore relevant for treasury managers, investors, and firms engaged in cross-border trade. In practical settings, a robust hedge should protect downside exposure, remain cost-efficient, and be supported by a risk model that can survive formal validation under changing market conditions.

Table 1. Backtesting results.

VaR model	LRuc (K)	LRuc (C)	LRind	LRcc	$\chi^2$0.95 (df=1/2)	Conclusion
VaR Cov Call	451.588	451.588	0.2411	453.998	3.8415 / 5.9915	Invalid
VaR Cov Put	71.333	71.333	10.094	81.426	3.8415 / 5.9915	Invalid
VaR Hist Call	0.4717	0.4717	0.3677	0.8394	3.8415 / 5.9915	Valid
VaR Hist Put	24.621	24.621	0.0000	24.621	3.8415 / 5.9915	Invalid

Table 1 shows that the variance-covariance VaR model is invalid for both call and put portfolios at the 95% confidence level, whereas the historical VaR model is valid only for the call-option portfolio. These results indicate that historical simulation performs better than the parametric alternative in this sample, although its performance is not uniformly valid across all positions.

Table 2. Sharpe-ratio validation summary.

VaR model	LRuc	LRind	LRcc	$\chi^2$0.95 (df=1/2)	Conclusion
VaR Cov Call	451.588	14.678	466.265	3.8415 / 5.9915	Invalid
VaR Cov Put	22.692	10.698	33.391	3.8415 / 5.9915	Valid
VaR Hist Call	43.907	8.519	52.426	3.8415 / 5.9915	Invalid
VaR Hist Put	43.907	16.969	60.876	3.8415 / 5.9915	Invalid

This comparison strengthens the interpretation of the figures. Historical VaR produces more conservative thresholds in several episodes and performs better under formal coverage and independence tests. The variance-covariance model, by contrast, fails because it cannot adequately represent clustered violations and tail behaviour. This pattern is aligned with evidence that FX options can hedge effectively when the modelling framework is sensitive to nonlinear payoffs and changing market conditions, and that successful currency hedging can support firm value and risk containment (Vohra et al., 2019; Sun et al., 2025; Morley et al., 2024).

Table 2 indicates that validation performance differs by option type and estimation method. The covariance VaR specification is valid only for the put option, whereas both historical VaR specifications remain invalid in this summary test. The broader implication is that no single model should be assumed valid without empirical testing. Model selection must follow the distributional features of the hedged position and the market environment.

4. Conclusion

This study evaluates foreign currency options as hedging instruments for USD/IDR and MYR/IDR exchange-rate exposure by integrating pricing, Value at Risk, Sharpe-ratio analysis, and formal backtesting in one empirical framework. The evidence confirms that exchange-rate volatility materially influences the risk profile of hedged portfolios and that option-based protection remains relevant for firms operating in uncertain currency environments. The contribution of the study lies in showing that hedging effectiveness cannot be assessed only from pricing output or from a single risk statistic. It must be interpreted through the joint lens of loss estimation, risk-adjusted performance, and model validation.

The empirical results show that historical simulation VaR generally provides more reliable loss estimates than variance-covariance VaR. The parametric model captures broad volatility movements, but it tends to underestimate tail risk when return distributions depart from normality or when volatility clusters around market stress. Backtesting through the Kupiec and Christoffersen tests therefore plays a critical role in determining whether a risk model is suitable for practical use. The findings also suggest that differences between USD/IDR and MYR/IDR should not be read only as numerical variation. They reflect different exchange-rate regimes, policy responses, and external shock transmission mechanisms during 2022 to 2025.

In terms of hedging performance, put options outperform call options on a risk-adjusted basis during the sample period. This suggests that downside-protection strategies were more consistent with prevailing market conditions. For practitioners, however, an effective hedge is not simply the hedge with the lowest measured risk. A useful hedging strategy must balance risk reduction against the cost of protection, including option premiums, strike selection, contract maturity, and the possibility of giving up favourable upside. The Sharpe-ratio evidence in this study shows that such balancing is essential if the hedge is to remain economically efficient rather than merely statistically conservative.

From a managerial perspective, the findings imply that treasury managers and investors should not rely exclusively on theoretical pricing outputs when assessing foreign-exchange hedges. They should combine option valuation with statistical backtesting, performance metrics, and contextual interpretation of market conditions before implementing a hedge. This recommendation is especially relevant in emerging markets, where exchange-rate returns often display asymmetry, clustering, and abrupt regime changes. Firms that use foreign-currency options without validating the supporting risk model may achieve the appearance of protection while still remaining exposed to model risk.

Future research can extend this framework by using higher-frequency data, implied-volatility information, GARCH-type models, expected shortfall, or machine-learning-based hedging rules. Broader currency coverage would also help test whether the relative strength of historical VaR remains stable across different emerging-market settings. Recent bibliometric, sentiment-based, case-study, and strategic reviews indicate that future foreign-exchange hedging research can also integrate corporate disclosure, investor sentiment, and firm-level policy design more explicitly (Rashad et al, 2025; Kong, 2025). Taken together, these directions can modernize the study of option-based hedging and make the evidence more relevant for both scholars and corporate decision makers.

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