FIN42020 Derivative Securities

Option Pricing and Hedging Project 2024

Research Company: MRK

Group 18

1) Mahek Kathuria- 24201835
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Submission Date: 04 December 2024

Assessment Submission Form

Peer Marks

Project Number	Student Name	Student Number (id card)	Total Peer Mark (/30)
18	Mahek Kathuria	24201835	30
	Tejas Landge	24218694	30
	Yuxin Yang	23207969	30
	Sanaathan Sridhar	24296640	30
	Ivaylo Ivanov	24209428	30

e-Signatures:

Signed: Mahek Kathuria Date: 4th December 2024

Signed: Tejas Landge Date 4th December 2024

Signed: Yuxin Yang Date 4th December 2024

Signed: Sanaathan Sridhar Date 4th December 2024

Signed: Ivaylo Ivanov Date 4th December 2024

Appendix

Number to Name Key Table

Student #	Name
1.	Mahek Kathuria
2.	Tejas Landge
3.	Yuxin Yang
4.	Sanaathan Sridhar
5.	Ivaylo Ivanov

Grids for Peer marking

Evaluator	**Evaluatee**	Peer Mark Effort (/10)	Peer Attitude (/10)	Peer Contribution (/10)	Total Peer Mark (/30)
2. Tejas Landge	1. Mahek Kathuria	10	10	10	30
3. Yuxin Yang	1. Mahek Kathuria	10	10	10	30
4. Sanaathan Sridhar	1. Mahek Kathuria	10	10	10	30
5. Ivaylo Ivanov	1. Mahek Kathuria	10	10	10	30
				Total Average:	30
1. Mahek Kathuria	2. Tejas Landge	10	10	10	30
3. Yuxin Yang	2. Tejas Landge	10	10	10	30
4. Sanaathan Sridhar	2. Tejas Landge	10	10	10	30
5. Ivaylo Ivanov	2. Tejas Landge	10	10	10	30
				Total Average:	30
1. Mahek Kathuria	3. Yuxin Yang	10	10	10	30
2. Tejas Landge	3. Yuxin Yang	10	10	10	30
4. Sanaathan Sridhar	3. Yuxin Yang	10	10	10	30
5. Ivaylo Ivanov	3. Yuxin Yang	10	10	10	30
				Total Average:	30
1. Mahek Kathuria	4. Sanaathan Sridhar	10	10	10	30
2. Tejas Landge	4. Sanaathan Sridhar	10	10	10	30
3. Yuxin Yang	4. Sanaathan Sridhar	10	10	10	30
5. Ivaylo Ivanov	4. Sanaathan Sridhar	10	10	10	30
				Total Average:	30

1. Mahek Kathuria	5. Ivaylo Ivanov	10	10	10	30
2. Tejas Landge	5. Ivaylo Ivanov	10	10	10	30
3. Yuxin Yang	5. Ivaylo Ivanov	10	10	10	30
4. Sanaathan Sridhar	5. Ivaylo Ivanov	10	10	10	30
				Total Average:	30

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Executive Summary

This project analyses the pricing and hedging of Merck & Co. (MRK) options, focusing on four key areas: **Put-Call Parity**, **Implied Volatility**, **Delta Hedging** and **Volatility Trade**. The objective is to evaluate the adherence of observed option prices to theoretical models, assess market expectations through volatility patterns, and explore trading strategies.

Data collected from November 5 to November 15, 2024, was utilized for this study, leveraging daily closing prices of MRK options and its underlying stock. Using tools like Excel, Python, and Bloomberg Terminal, key insights were derived:

1. **Put-Call Parity**: Minor deviations from theoretical parity were identified, suggesting limited arbitrage opportunities due to transaction costs and market frictions.

2. **Implied Volatility**: Calculations using the Black-Scholes model revealed a skew pattern, indicative of market expectations for price movements. A volatility smile highlighted greater uncertainty at deep in-money and out-of-money options.

3. **Delta Hedging**: Comparisons of hedging strategies using implied and historical volatility underscored the importance of dynamic adjustments. Implied volatility strategies proved more effective in high-volatility conditions.

4. **Volatility Trade**: Straddle strategies demonstrated differing risk-reward profiles, with the long straddle suited for volatile markets and the short straddle favourable for stability, depending on volatility expectations.

The findings from this project provide actionable insights into the Merck and Co. options pricing and market behaviour.

Furthermore, the critical role of volatility and parity concepts in pricing and hedging decisions are defined. Practical limitations, such as transaction costs and liquidity constraints, were noted as challenges to theoretical arbitrage strategies. This analysis provides actionable insights for traders, portfolio managers, and risk analysts in optimizing strategies based on market dynamics and volatility trends.

By integrating theoretical models with real-world data, the project contributes valuable knowledge to understanding option pricing mechanisms and effective hedging approaches.

Introduction

Merck & Co, a well-known leader in the American pharmaceutical Industry and widely recognized for publishing the Merck Manual has shown consistent financial growth.

Options pricing plays a crucial role in modern finance, providing investors and traders with insights into market expectations and risk management strategies.

This project focuses on analyzing Merck and Co. options to evaluate their adherence to theoretical pricing models and to explore market dynamics through implied volatility patterns.

The project was divided into four key components: **Put-Call Parity**, **Implied Volatility**, **Delta Hedging**, and **Volatility Trading**. For the Put-Call Parity analysis, deviations were calculated using theoretical and market prices. Implied Volatility was estimated using the Black-Scholes model, with Solver in Excel used for iterative calculations. Delta Hedging strategies were simulated to assess their profitability under different volatility assumptions. Lastly, a Volatility Spread was constructed to analyze differences between implied and historical volatilities, identifying potential trading opportunities.

Analysis

1. Put-Call Parity Analysis

1.1. Overview:

Put-Call Parity is a cornerstone concept in option pricing, deriving an important relationship between the prices of European put and call options with the same underlying asset, strike price, and expiration date *(John C Hull Book)*. This relationship safeguards that when the parity condition holds, the market remain arbitrage-free. It relies on the concept that the value of put option and the underlying asset (Merck and Co) should be equal to the call option and the discounted value of strike price. The principle is mathematically expressed as:

$$S + P = C + K \cdot e^{-r(T-t)}$$

where:

- S : Current price of the underlying stock as of November 5th.
- P : Last traded price of the put option.
- C : Last traded price of the call option.
- K : Strike price of the option.
- r : Risk-free rate i.e. (4.6975%, based on the average yield of Treasury bills from November 5th to 15th, sourced from the FRED database).
- T : Time to expiration
- $e^{-r(T-t)}$: discount factor for the strike price over the remaining time to expiration.

Key assumptions included the use of constant risk-free rate based on the US Treasury yields and efficient market conditions. This methodology provided a robust framework for evaluating options pricing and hedging strategies.

1.2. Importance of Put Call Parity and Strategy

The concept of put-call parity is essential as it ensures that overall efficiency of our market. It is a critical reference point for analysing whether our stocks are under-priced or over-priced. It helps to detect any mispricing that can create potential arbitrage opportunity which gives traders a chance to earn profits. It helps traders to create a trading strategy for their synthetic positions. (Long or short hedges or limit order pricing)

The put call parity concept assures a theoretical relationship among the values of options, thereby helping to determine their fair prices and maintaining market efficiency by equating market prices with the theoretical expectations. Arbitrage opportunity may develop when market prices differ from the relationship, which gives the traders an advantage to make profit without taking any risks.

Nevertheless, economic factors such as transaction costs, bid-ask spreads, and liquidity issues often act as constraints which limit the real- world utilization of such tactic which significantly reduces and often eliminates the arbitrage opportunities, particularly for small variables.

There is a relationship between put-call parity anticipated to remain constant across all levels of strike prices. If any possible deviations occur for specific strikes, it indicates potential market mispricing. Key indicators such as supply and demand mismatches, liquidity discrepancies, and volatility skew all of these can contribute to market mispricing.

- **Volatility Skew**: It refers to the variations in implied volatility among strike prices, which can cause such pricing anomalies for options.
- **Supply and Demand**: Discrepancies between supply and demand arise when some options are not evenly supplied or preferred, contributing to price discrepancies.
- **Liquidity Differences**: Less liquid options are harder to be priced with accuracy, variances impact effective pricing and execution.

  A trader can take leverage of these market inefficiencies as these differences offer them risk-free arbitrage opportunities. For instance, if the value of the put option plus the underlying asset is greater than the call option plus the present value of strike price a trader can buy a less costly option and sell the overpriced put option along with the underlying asset. This brief inefficiency in the market helps the trader profit until prices adjust, this disparity defies the put call parity concept.

1.3. Methodology

To prove the put-call parity principle, a thorough analysis was conducted using the options data for Merck and Co (MRK) as of 5th Nov,2024. The inputs used were current stock price (S=101.65), the risk-free rate (r=4.6975%) options with an expiration date on 15th November 2024 which correspond to a time expiration of 9 trading days divide by 252 trading days (T-t) =0.035714 years. With an aim to concentrate on contracts that are actively traded, zero trading volume options were not included in our analysis.

We methodically calculated both sides of the put-call parity equation. For each strike price the sum of the spot price (S) and the price of put option (P) was added (LHS). This signifies the cost of building a synthetic portfolio comparable to a long call option. On the other hand (RHS) the price of the call option (C) was added to the discounted present value of the of the strike price, using the formula

$$\text{PV(K)}= K \cdot e^{r(T-t)}$$

This was done for each strike price and the violation for every strike was identified. However, the strike (102) closest to closing price (101.65) was closely evaluated and an arbitrage strategy was created.

Figure 1: **Option Arbitrage Strategies- Steps for Overpriced and Underpriced Scenarios**

Scenario	Step and Description
Overpriced Stock: $S+P\ >\ C+K\cdot e^{r(T-t)}$	1. Identify Mispricing: Compare market and theoretical values to confirm mispricing
	2. Short the stock: Benefit from the expected price drop
	3. Sell overpriced put: Lock in inflated premiums
	4. Buy a call option: Hedge against unexpected price increases
	5. Invest discounted strike price: Secure future obligations
	Expiration Outcomes: If Stock Price > K: Call exercised, short position covered; If Stock Price < K: Put exercised, stock acquired, short repurchased
Underpriced Stock: $S+P<C+K\cdot e^{r(T-t)}$	1. Spot Opportunity: Observe put price undervaluation relative to theoretical pricing
	2. Buy a put: Secure the right to sell at strike price K
	3. Sell the call option: Capitalize on the overpricing
	4. Purchase the stock: Benefit from undervaluation
	5. Borrow PV(K) to fund purchase: Fund the purchase with borrowed amount equal to PV(K)
	Expiration Outcomes: If Stock Price > K: Call exercised, stock sold for K, borrowed amount repaid; If Stock Price < K: Put exercised, stock sold at K, borrowed amount repaid

1.3.1. Arbitrage Scenarios:

a. For Overvalued Put Options:

$$S+P\ >C+K\cdot e^{-r(T-t)}$$

or

$$C-P\,(Observed)\ <\ S-K*e^{-r(T-t)}(Theoretical)$$

Strategy: In general, but for all our underlying asset's case

For instance, at strike 102 the put call deviation was 0.206,

- **Buy a call option (-1.63)**,
- **Sell a put option (2.015)**,
- **Short the stock (101.65)**,
- Investing in bonds equivalent to the present value of the strike price (−101.83)
- **Lend money** at the risk-free rate.

- This results in a net initial cashflow of **0.205980**.
- When my Stock price (S) < Strike Price (K), we can exercise the put and sell the at K (102). This strategy allows us to cover the short position (96.31). The bonds will mature to K (102), ensuring sufficient funds are maintained to cover all liabilities. Thus, the call expires worthless, avoiding additional costs.

Focus: The goal is to profit from the higher combined value of the stock and put option when compared to the theoretical parity price.

Outcome: There is guaranteed profit since the as the synthetic portfolio replicates the payoff of the overpriced portfolio, while the hedged positions and invested funds ensure no exposure to adverse market movements.

b. For Undervalued Put Options:

$$S + P \ < \ C + K \cdot e^{-r(T-t)}$$

Strategy: Establish a portfolio by purchasing

- **Buy a put option**
- **Sell a call option**
- **Buy the stock**
- **Borrow money** at the risk-free rate.

Focus: Exploit the undervaluation of the stock and put combination compared to the call and discounted strike price.

Hedged Portfolio Approach for Undervalued Put Options

Form a hedged portfolio by buying the underpriced put option, selling the overpriced call option, purchasing the stock, and borrowing funds at the risk-free rate.

Outcome: Any pricing discrepancy guarantees a net gain upon exercise or expiry.

These strategies ensure that any mispricing is leveraged until the market realigns to maintain equilibrium.

Table. 1. Option Valuation Analysis.

Strike Price (K)	S+P	C+K*e^-rt	Difference	Theoretical Value of Put Option P=C+K*e^-rt-S	S+P>C+K·e ^−r(T−t) (OVERVALUED)	S+P<C+K·e ^−r(T−t) (UNDERVALUED)
95	101.8200	101.6408	0.1792	-0.0092	YES	NO
98	102.2600	102.0607	0.1993	0.4107	YES	NO
99	102.5300	102.3090	0.2210	0.6590	YES	NO
100	102.7800	102.6174	0.1626	0.9674	YES	NO
101	103.2000	102.9907	0.2093	1.3407	YES	NO
102	103.6650	103.4590	0.2060	1.8090	YES	NO
103	104.2350	104.0223	0.2127	2.3723	YES	NO
104	104.9250	104.6707	0.2543	3.0207	YES	NO
105	105.6500	105.4140	0.2360	3.7640	YES	NO
106	106.5000	106.2273	0.2727	4.5773	YES	NO
107	107.3750	107.0856	0.2894	5.4356	YES	NO
110	110.2500	109.9206	0.3294	8.2706	YES	NO
114	114.2000	113.8789	0.3211	12.2289	YES	NO
130	130.5500	129.8021	0.7479	28.1521	YES	NO

1.4. Observations

The analysis of MRK options data validates that there holds a general put-call parity relationship, with deviations observed at extreme strike prices. For example, at K, a deviation of 0.206 was calculated, caused likely by market inefficiencies like lower liquidity and implied volatility skew. Whereas near-the-money options showed minimum deviations due to higher trading volumes and narrower bid-ask spreads, on the contrary, far-strike options exhibited greater mispricing due to time decay and intrinsic value dominance as expiration approached.

1.5. Result

The findings confirm that the put-call parity for MRK Co.'s options is strong. Thus, providing an accurate framework to assess option prices and detect potential arbitrage opportunities. Although, variances at extreme strike prices of In-the-money and out-the-money were observed due to liquidity constraints and volatility biases, these were consistent and spread across the dataset. This indicates a strong parity relationship, and it showcases important factors that depend on the changes in option pricing while considering for real world issues when implementing trading strategies.

Risks and Considerations:

While arbitrage opportunities based on Put-Call Parity appear risk-free in theory, practical limitations can impact execution and profitability:

1. **Accuracy of Market Data**: For arbitrage to be effective, stock and option prices must be accurate and updated in real-time. Any delay. In obtaining the result would lead to miscalculation and missed opportunities.
2. **Changing Interest Rates**: The interest rates are always fluctuating, arbitrage models assume constant interest rates however, which causes changes in calculations.
3. **Trading Costs**: The profit we obtain from arbitrage might be influenced by cost such as taxes tied to the bid-ask spread and commission.
4. **Market Liquidity**: It can be difficult to buy and sell at the right price when there is low activity in trade in the stock or options market, particularly when buying and selling on a large scale.
5. **Market Imperfections**: In arbitrage strategy, there is an assumption that market is efficient, because of which any real-world market inefficiencies such irrational behaviour would cause deviations from the theoretical values
6. **Option Types**: European options are those which can be exercised only at the time expiration, whereas American options, can be exercised at any time, violates the assumption of put-call parity.
7. **Settlement Risks**: Risks associated with settlement: In certain agreements, counterparty risk the possibility that the other party won't fulfil their end of the bargain may exist. In this sense, certain markets that are less regulated are more vulnerable to this danger.
8. **Regulatory and Technical Issues**: The implementation of new regulations or policies, as well as system failures or order routing mistakes, may serve as unforeseen obstacles to the effective implementation of your strategy.

2. Implied Volatility

Implied Volatility (IV) is calculated from option pricing using models like the Black-Scholes formula and it is considered a forward-looking measure of market expectations for future price volatility. IV analyzes market emotions, highlighting potential risk and price fluctuations. Interestingly the higher the IV greater is our uncertainty, whereas lower IV suggests stability.

IV is vital in options trading and strategy analysis, as it facilitates accessing not just profitability, but also risk and fair pricing. In terms of Merck & Co., an examining IV gives an overview of a trader's sentiments and fluctuations in the market, meanwhile it also ensures that pricing evaluations are accurate and aims at improving the reliability of strategies like Delta Hedging and Volatility Spread, that rely on robust calculations of IV.

2.1. Models to Calculate Implied Volatility

In option pricing implied volatility (IV) plays a vital role, since it directly impacts on the option's premium by signifying the market's anticipation of future price variations. To calculate IV, several models can be applied based on certain assumptions about market performance. The **Black-Scholes Model (BSM)** is frequently utilized in this analysis, it provides a foundational framework for pricing options by assuming a lognormal distribution of asset prices and constant volatility. A lattice structure that calculates prices with the help of lattice structure that simulates multiple price paths. On the contrary, to manage complex scenarios under uncertainty the **Monte Carlo Simulation** utilizes random sampling. For assets with time-dependent risks, complex models like the **Heston Model** incorporate stochastic volatility. While the **SABR Model** is designed for interest rate derivatives, which successfully captures the volatility smile. For this paper, the BSM model is used to calculate IV, offering a robust method for assessing market expectations and pricing accuracy.

2.2. How Black-Scholes is Used for Implied Volatility:

The Black-Scholes formula along with the market price of the option is utilized to calculate the implied volatility. Since IV is a parameter of the Black-Scholes model it cannot be calculated completely on its own.

The Black-Scholes formula:

For a call option price is:

$$C = S \times N(d_1) - K \times e^{(-rt)} \times N(d_2)$$

For a put option price is:

$$P = K \times e^{(-rt)} \times N(d_2) - S \times N(d_1)$$

where:

- S: Current price of the underlying asset
- K: Strike price of the option
- T: Time to expiration (in years)
- r: Risk-free interest rate (continuously compounded)
- σ: Implied volatility
- N(d): Cumulative distribution function of the standard normal distribution

Calculating d1 and d2

$$d_1 = (\ln(S/K) + (r + 0.5 \times \sigma^2) \times T) / \left(\sigma\sqrt{T}\right),$$

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

Given that our trade was only 10 days long, no dividends were declared or paid for the underlying stock (MRK), we can assume a null value for the dividend component within the BSM formula. This made the BSM framework even more fitting, as it remains effective for dividend-paying stocks like MRK while providing flexibility for scenarios without dividends.

Methodology for Implied Volatility

The implied volatility (IV) for MRK options as of November 5, 2024, with the expiry of November 15, 2024, was derived using the Black-Scholes Model and the Goal Seek function in Excel as well using the scipy.optimize.minimize function on Python to ensure consistency. Implied Volatility, not being observable directly, was calculated by matching the theoretical option prices to their market mid-prices. The analysis focused on options with active trading volumes, ensuring accuracy by excluding inactive contracts.

The calculation relied on key inputs such as the mid-price of the options, the underlying spot price (S = 101.65), strike prices (K), time to maturity (9 trading days or T−t = 0.035714 years), and the risk-free interest rate (r=4.6975%). Using the Black-Scholes Model formula, an initial IV estimate of 20% was derived, and the theoretical prices were calculated based on the result. A pricing error column was introduced to capture the difference between theoretical and observed mid-prices.

The Goal Seek function was applied iteratively to optimize and refine IV values. For each option considered in the analysis, the IV was iteratively adjusted until the pricing error, i.e., the difference between the theoretical price and the mid-price, was minimized to zero. This iterative approach ensured that the theoretical Black-Scholes price aligned precisely with the market price, providing an accurate IV estimate and the same was aligned with Python results. The results for the IV values are quite crucial for understanding market sentiment and assessing the pricing dynamics of MRK and Co's options during the specified period.

Table 2: Goal Seek result for Call Option

SPOT Price	STRIKE Price	Risk Free Interest Rate	Mid Price	BSM d1	BSM d2	Trading Volume	Model Implied Volatility (Calculated)	Theo. Call Price (Black-Scholes)	Market Implied Volatility	Pricing Error
101.65	95	4.6975%	6.80	0.1288	0.0480	12.00	42.79%	6.80	28.58%	0.00
101.65	98	4.6975%	4.23	0.0945	0.0387	2.00	29.55%	4.23	27.17%	0.00
101.65	99	4.6975%	3.48	0.0850	0.0348	10.00	26.51%	3.48	26.83%	0.00
101.65	100	4.6975%	2.79	0.0759	0.0301	55.00	24.23%	2.79	26.36%	0.00
101.65	101	4.6975%	2.16	0.0669	0.0239	28.00	22.76%	2.16	25.73%	0.00
101.65	102	4.6975%	1.63	0.0573	0.0148	41.00	22.47%	1.63	25.29%	0.00
101.65	103	4.6975%	1.20	0.0469	0.0029	89.00	23.30%	1.19	24.96%	0.00
101.65	104	4.6975%	0.84	0.0362	-0.0112	56.00	25.10%	0.84	24.64%	0.00
101.65	105	4.6975%	0.59	0.0257	-0.0271	660.00	27.96%	0.59	24.60%	0.00
101.65	106	4.6975%	0.41	0.0160	-0.0436	107.00	31.57%	0.40	24.68%	0.00
101.65	107	4.6975%	0.27	0.0073	-0.0600	36.00	35.60%	0.26	24.60%	0.00
101.65	110	4.6975%	0.11	-0.0139	-0.1086	114.00	50.15%	0.10	27.05%	0.00
101.65	114	4.6975%	0.07	-0.0358	-0.1682	30.00	70.06%	0.07	33.87%	0.00
101.65	130	4.6975%	0.02	-0.1115	-0.3673	10.00	135.35%	0.02	59.25%	0.00

Figure. 1.1. Implied Volatility Graph for Call Option

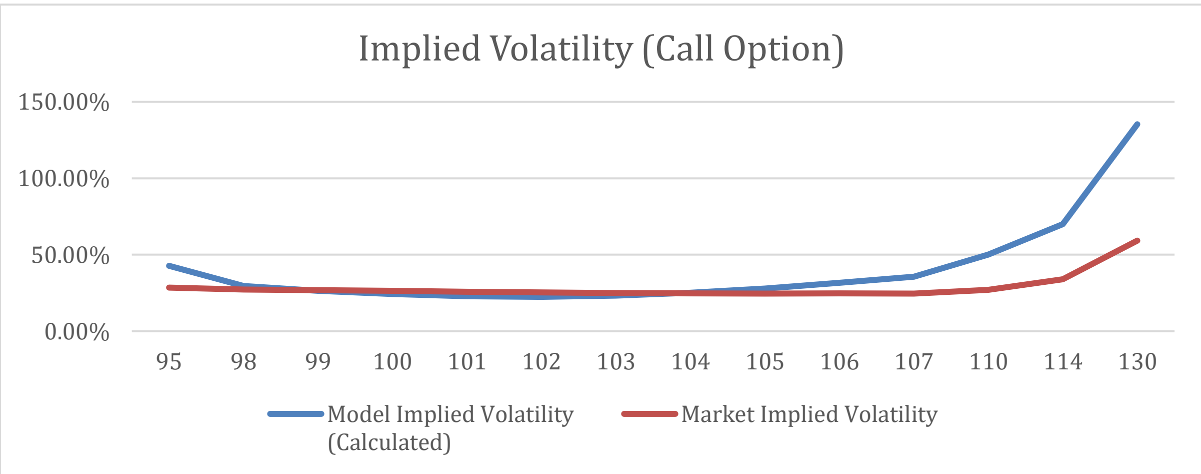
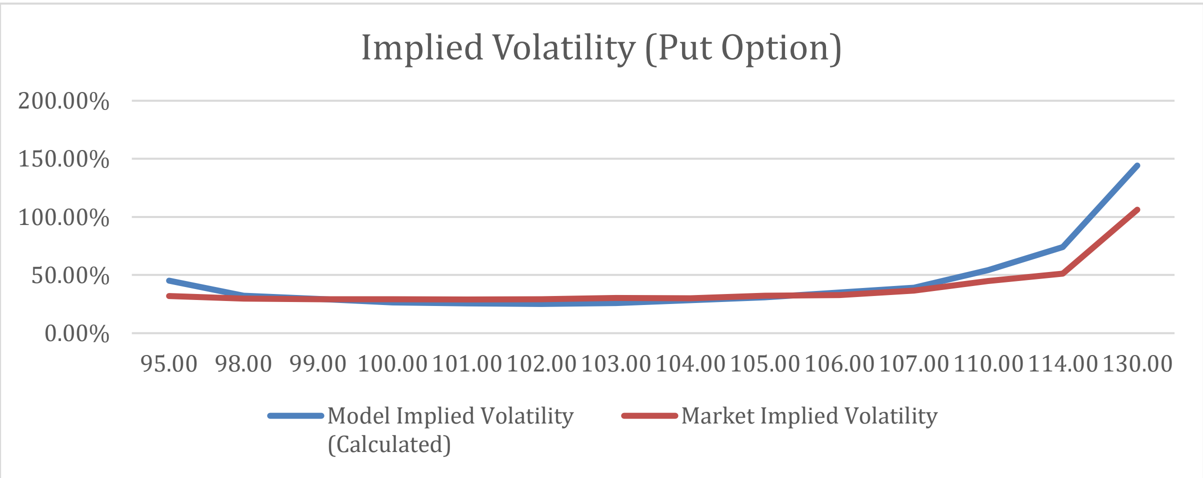


Table 2: Goal Seek result for Put Option

SPOT Price	STRIKE Price	Risk Free Interest Rate	Mid-Price	BSM d1	BSM d2	Trading Volume	Model Implied Volatility (Calculated)	Theo. Put Price (Black-Scholes)	Market Implied Volatility	Pricing Error
101.65	95	4.6975%	0.17	0.1300	0.0445	24	45.25%	0.17	31.93%	0.00
101.65	98	4.6975%	0.61	0.0946	0.0336	124	32.25%	0.61	29.79%	0.00
101.65	99	4.6975%	0.88	0.0844	0.0287	56	29.49%	0.88	29.25%	0.00
101.65	100	4.6975%	1.13	0.0749	0.0250	84	26.40%	1.13	29.10%	0.00
101.65	101	4.6975%	1.55	0.0653	0.0171	100	25.52%	1.55	29.00%	0.00
101.65	102	4.6975%	2.01	0.0556	0.0081	65	25.15%	2.01	29.08%	0.00
101.65	103	4.6975%	2.59	0.0455	-0.0037	28	26.03%	2.58	30.40%	0.00
101.65	104	4.6975%	3.28	0.0352	-0.0183	29	28.34%	3.27	30.13%	0.00
101.65	105	4.6975%	4.00	0.0255	-0.0330	69	30.95%	4.00	32.18%	0.00
101.65	106	4.6975%	4.85	0.0165	-0.0496	11	35.00%	4.85	32.69%	0.00
101.65	107	4.6975%	5.73	0.0084	-0.0657	6	39.22%	5.72	36.52%	0.00
101.65	110	4.6975%	8.60	-0.0113	-0.1138	143	54.24%	8.60	44.78%	0.00
101.65	114	4.6975%	12.55	-0.0327	-0.1726	30	74.01%	12.55	51.22%	0.00
101.65	130	4.6975%	28.90	-0.1035	-0.3761	4	144.24%	28.90	106.25%	0.00

Figure. 1.2. Implied Volatility Graph for Put Option



Observations on Volatility Smile for MRK and Co.’s Options:

For options MRK the graph plots a **volatility smile curve** which illustrates the implied volatility trends against strike prices. The key findings from our analysis state that:

1. **For Put Options**:
   The implied volatility curve for put options forms a near-perfect smile shape graph. **At-the-money (ATM)** strike price we observe the lowest implied volatility, while for both **out-of-the-money (OTM)** and **in-the-money (ITM)** options the implied volatility rises, resulting in higher market uncertainty and risk premiums.
2. **For Call Options**:
   Call options just like the put options demonstrate a smile-like structure, with the lowest implied volatility at the ATM strike price and increasing volatility for both ITM and OTM strikes. This pattern is consistent with market expectations for higher risks at extreme strike prices.
3. **Mean Reversion Effect**:
   The curve demonstrates mean reversion tendencies, where volatility is downward-sloping in high-volatility regions and upward-sloping in low-volatility regions. This reflects the market's expectation of returning to a long-term volatility equilibrium.
4. **Market Sentiment and Deviations**:
   Some inconsistencies in implied volatility stem from deviations in put-call parity, investor sentiment, and recent market activity. For MRK, stock price fluctuations and macroeconomic uncertainty likely amplified implied volatility, highlighting the interconnectedness of market dynamics.

2.3. High model-implied volatility

During most of 2024 there quite a few significant global events that have contributed to heightened market volatility, which could possibly explain the elevated model implied volatility when compared to the market implied volatility observed in your analysis.

Between November 5th and November 15th, 2024, Merck & Co. (MRK) experienced stock price fluctuations that were directly influenced by both company specific events and broader market dynamics.

Company Specific Developments:

- On November 14, Merck announced its Q3 2024 earnings. They reported a 4% increase in global sales to $16.7 billion compared to Q3 2023. Due to an increase in R&D, development, and acquisitions-related expenses, GAAP net income decreased by 33% to 3.2b. On the same day, Merck spearheaded a strategic move aimed at bolstering its oncology department by entering a licensing deal worth up to $3.3b with LaNova Medicines for an experimental cancer drug, LM-299.

- During October 2024 we saw France facing nationwide instability with the possibility of bringing its government down, this could potentially affect most sectors including the pharmaceutical sector.

These events have collectively heightened market uncertainty, leading to increased volatility. Such conditions can cause model-implied volatility, which often relies on historical data and assumes market stability, to diverge from market-implied volatility, which rapidly adjusts to current market sentiments. The dynamic nature of these geopolitical and economic developments underscores the importance of incorporating real-time data and market conditions into volatility models to enhance their accuracy.

2.4. Result:

To conclude, the IV graphs offer an elaborate view of market emotions along with the risk perceptions. While the lower IV at-the-money suggests comparative confidence in stable price movements near the spot price, the greater the IV at deep end strike prices (for both calls and puts) depicts the volatility to price extremes. Based on expected market behaviours these trends can facilitate traders and portfolio managers refine their strategies

Using the Black-Scholes model along with the goal seek in excel allowed to calculate the implied volatility precisely which can be seen with pricing error of zero. The graphs provide detailed analysis of the market expectations and the risk perception which help the investors in pricing option and thus helping them manage risk efficiently.

2.5. Limitations:

As IV depends heavily on market prices to find its fair value we cannot fully rely on Black-Scholes model and Goal Seek tool as they have too many limitations and due to its static nature make it far less reliable for real world market conditions. IV fails to predict which way the price could swing and struggles with varying strike prices. The main flaw with Black-Scholes model is that it assumes that volatility is constant, and it fails to consider volatility smile and skew and is only limited to European options limiting its purpose as it cannot handle exotic options due to transaction costs, changes in interest rates and taxes. Although Goal Seek can be useful its major limitations lie within the fact that it’s restricted to solving for a single variable and is unsuited for larger scale dynamic models. To circumvent that all those tools need to be used in conjunction to address their inherent limitations.

3. Delta Hedging

Delta hedging is a dynamic risk management strategy designed to neutralize the sensitivity of an option's price to changes in the underlying asset's price. For Call options, $0 < \Delta < 1$, while for Put options, $-1 < \Delta < 0$. In this case study, only ATM Call options would be considered in this part.

3.1. Methodology

Each trade is thought to represent 100 shares. Therefore, if 10 contracts are sold short, the risk is equal to 1 lot of shares (10×100). The theoretical volatility of 22.47% is considered constant the (Ticker- MRK11/15/24C102) at all the trade dates. This belief stems from the lack of information on the values of these contracts. The information from the excel sheets allows you to calculate the number of shares required for hedging each day by referencing the delta value and the "Stocks to Buy" section to assess if the hedged position aligns with the price movement of the underlying asset. The change in Delta shows how the delta adjusts dynamically over time – if there are changes here, you'll need to update your hedge portfolio more frequently. Analysing profits and losses can be done by looking at the Profit and Loss and Cumulative Profit and Loss sections – the P&L gives a short-term view while the cumulative P&L reflects the strategies long term performance. To check the accuracy of a model's implied volatility versus the market's view of volatility, the model's implied volatility can be compared to market volatility. Moreover, Pricing Error column indicates how differences, between market prices affect hedge effectiveness. "Stocks Bought/sold" indicates the daily stock position adjustment quantity, that is, the number of stocks that need to be bought or sold on the day. Cumulative cost including interest includes the cumulative cost of equity and the daily interest cost of finance equity holdings. A value close to zero or positive indicates that the hedging approach was effective in mitigating risk and managing losses.

Table. 3. Results for Delta Hedging using calculated values

Date	SPOT Price	Time to Maturity (Trading days)	Mid-Price	BSM d1	Contracts Sold (Assumed)	Short call Options	Delta	Cost of shares ('000s)	Cumulative cost including interest	Interest cost
11/5/24	101.65	3.17%	1.63	-0.0286	10	1000	0.49	49.67	49.67	0.009258
11/6/24	100.73	2.78%	0.82	-0.2810	10	1000	0.39	-10.00	39.68	0.007396
11/7/24	101.17	2.38%	1.19	-0.1861	10	1000	0.43	3.73	43.41	0.008092
11/8/24	102.92	1.98%	1.86	0.3290	10	1000	0.63	20.87	64.29	0.011983
11/11/24	100.73	1.59%	0.46	-0.4021	10	1000	0.34	-28.72	35.58	0.006632
11/12/24	98.58	1.19%	0.09	-1.3562	10	1000	0.09	-25.26	10.32	0.001924
11/13/24	98.50	0.79%	0.04	-1.7159	10	1000	0.04	-4.38	5.95	0.001108
11/14/24	98.36	0.40%	0.02	-2.5473	10	1000	0.01	-3.70	2.24	0.000418
11/15/24	96.31	0.00%	0.01	0.0000	10	1000		-0.52	1.72	0.000321

Table. 4. Payoff Analysis.

	(in 000's)
Cumulative cost including interest	1.71983215
Option Payoff	0.00
Total option payoff	0.00
Final Hedge Portfolio Value	0
Premium received	1.69
Profit/(Loss)	**-0.03**

Table. 5. Results for Delta Hedging using Historical values

Date	SPOT Price	Time to Maturity (Trading days)	Mid Price	BSM d1	22 Day Implied Volatility (Yahoo)	Delta	Stocks to Buy	∆ Stocks Bought/ sold	Cost of shares ('000s)	Cumulative cost including interest	Interest cost
11/5/24	101.65	3.17%	1.63	-0.05	16.53%	0.48	479.53	479.53	48.74	48.74	0.01
11/6/24	100.73	2.78%	0.82	-0.40	16.16%	0.34	343.36	-136.17	-13.72	35.04	0.01
11/7/24	101.17	2.38%	1.19	-0.27	16.08%	0.39	392.88	49.52	5.01	40.05	0.01
11/8/24	102.92	1.98%	1.86	0.44	16.26%	0.67	671.53	278.65	28.68	68.74	0.01
11/11/24	100.73	1.59%	0.46	-0.56	16.42%	0.29	288.01	-383.52	-38.63	30.12	0.01
11/12/24	98.58	1.19%	0.09	-1.75	17.46%	0.04	39.92	-248.09	-24.46	5.67	0.00
11/13/24	98.50	0.79%	0.04	-2.12	18.24%	0.02	17.11	-22.81	-2.25	3.42	0.00
11/14/24	98.36	0.40%	0.02	-3.14	18.23%	0.00	0.84	-16.27	-1.60	1.82	0.00
11/15/24	96.31	0.00%	0.01	0.00	16.70%		0.00	-0.84	-0.08	1.74	0.00

Table. 6. Payoff Analysis.

	(in 000's)
Cumulative cost including interest	1.743272156
Option Payoff	0.00
Total option payoff	0.00
Final Hedge Portfolio Value	0
Premium received	1.69
Profit/(Loss)	**-1.74**

3.2 Analysing the Strategy of Delta Hedging

3.2.1 Implied Volatility Strategy Performance

The strategy of implied volatility proves to be an effective hedge in the short run as evidenced by its performance on November 8th in 2024 – The number of shares adjusted increased to 628.92 shares and the cumulative cost of shares rose to 64.29 accompanied by a higher daily trading adjustment (+202.74 shares). This was because the price of the underlying asset jumped from 101.17 to 102.92 on the same day, resulting in a significant change in the delta value (from 0.43 to 0.63).

This showcases that during times of reduced market volatility implied volatility can accurately mirror market expectations and enhance hedging effectiveness. On 12 November 2024, as the price of the Underlying Asset falls to 98.58, the delta falls significantly to 0.09 and the required stock adjustment is significantly reduced (-256.27 shares), reducing the cumulative cost to 10.32.

3.2.2 Historical Volatility Strategy Performance

The Historical Volatility strategies performance was not as good overall because it relies on data and cannot adjust quickly to market shifts. On 8 November 2024, because of the lagged adjustment in Delta (from 0.39 to 0.67), the number of shares adjusted reaches 278.65 and the cumulative cost rises to 68.74, which is significantly higher than the implied volatility strategy.

In the subsequent period from 12 November to 14 November, as the underlying asset price continues to fall, the delta drops to 0.04, the number of shares required plummets to 39.92, and the cumulative cost decreases rapidly. However, this adjustment lag could lead to the accumulation of hedging errors.

Implied volatility strategies have frequented and large stock adjustments but are more reflective of short-term market movements and have more stable cumulative costs. Historical volatility strategies have slower adjustments but lower transaction costs and are suited to environments with lower or more stable market volatility.

Implied volatility strategies perform better in short-term high volatility markets, allowing positions to be adjusted on time with the market changes. Historical volatility strategies can lead to greater hedging error due to the lag in adjustments, especially during rapid market changes.

3.3. Error Analysis of Theoretical and Market Prices

3.3.1 Sources of error

When the implied volatility is higher, or the market volatility is more intense the gap between value and market price becomes more pronounced. Theoretical prices are calculated using the Black Scholes model while market prices are subject to external factors like supply and demand sentiment and other influences leading to an unavoidable disparity between them.

3.3.2 Delta Sensitivity Analysis

Delta represents how the option price reacts to shifts in the spot price. The greater the spot price variations are the often adjustments to delta must be made to maintain a neutral position. The existence of Gamma adds complexity to modifying Delta posing a challenge to keeping the hedge stable.

3.4. Improvement suggestions

3.4.1 Dynamically update implied volatility

Use a fast response of implied volatility to adjust the hedge size in real time and reduce the error caused by lag.

3.4.2 Optimize delta and gamma management

Trade off by resorting to gamma-neutral products when the cost of frequent adjustment might be too high, or is not feasible, during increased turmoil in the market.

3.4.3 Make term structure considerations

Adjust long-run tendencies of volatility in hedging to reduce long-term hedging mistakes.

3.4.4 Diversify by using hedging instruments

Incorporate a mix of hedging instruments, for instance, spot, futures, forwards, and options, toward the goal of reducing a single-instrument dependence for a hedging strategy that turns out inflexible.

4. Volatility Trade

4.1. Overview

Straddle is a strategy that takes place when European call and put are bought at the same strike price and expiration date.

This strategy is more suited for an investor with a higher risk appetite that is looking for a significant change in the underlying stock price but is unclear as to which way the price will move.

We carried out an analysis of both Long and Short Straddle payouts by utilizing historical volatility, implied volatility and their respective payouts as parameters to determine which is the more optimal of the two strategies.

When comparing the historical volatility and implied volatility we found that the annualized historical volatility of MRK is 31.97% showing the price fluctuations over the last 22 days, in contrast the call and put options were at 22.47% and 25.15% respectively. The discrepancy indicates that the market might be undervaluing future price movements. Therefore, the difference might have a significant impact on the pricing and profitability of both strategies.

4.2. Methodology

The Long Straddle strategy consists of buying a call and a put option at the same strike price. The strategy generates a profit from price fluctuations in either direction.

Parameters:

- Strike Price: $102
- Call Option Cost: $1.63
- Put Option Cost: $2.02
- Total Cost: $3.65

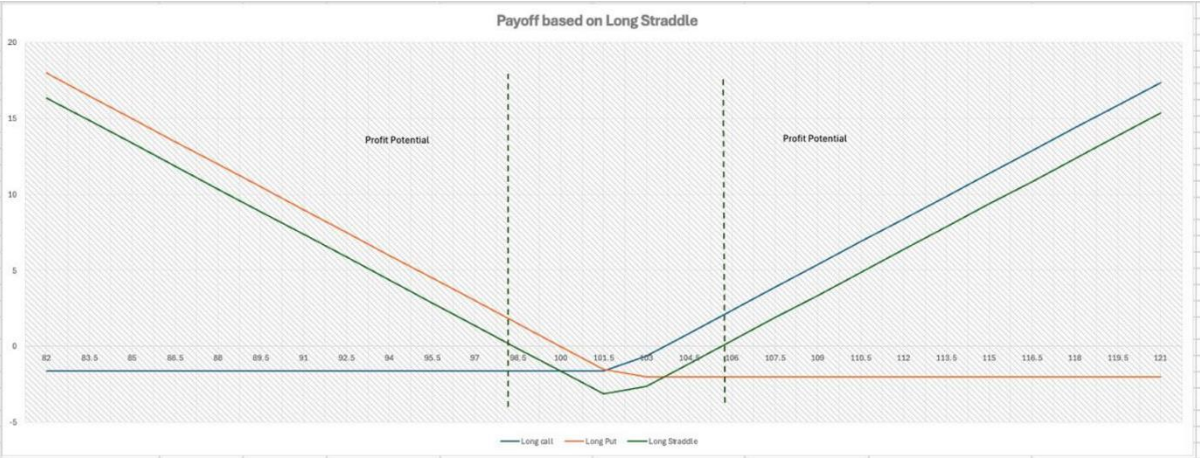
Break even points are as follows:

- Lower: $98.36
- Upper: $105.64

Potential Long Returns:

- Maximum loss caps out at $3.65 which takes place if the stock closes exactly on the strike price.
- Profit potential does not have a ceiling if the stock moves significantly above $105.64 or below $98.36.

Figure. 2. Payoff based on Long Straddle



The Short Straddle strategy consists of selling a call and a put option at the same strike price. This strategy generates a profit when MRK remains close to stable and with very minor fluctuations in the price.

Parameters:

- Strike Price: $102
- Call Option Cost: $1.63
- Put Option Cost: $2.02
- Total Cost: $3.65

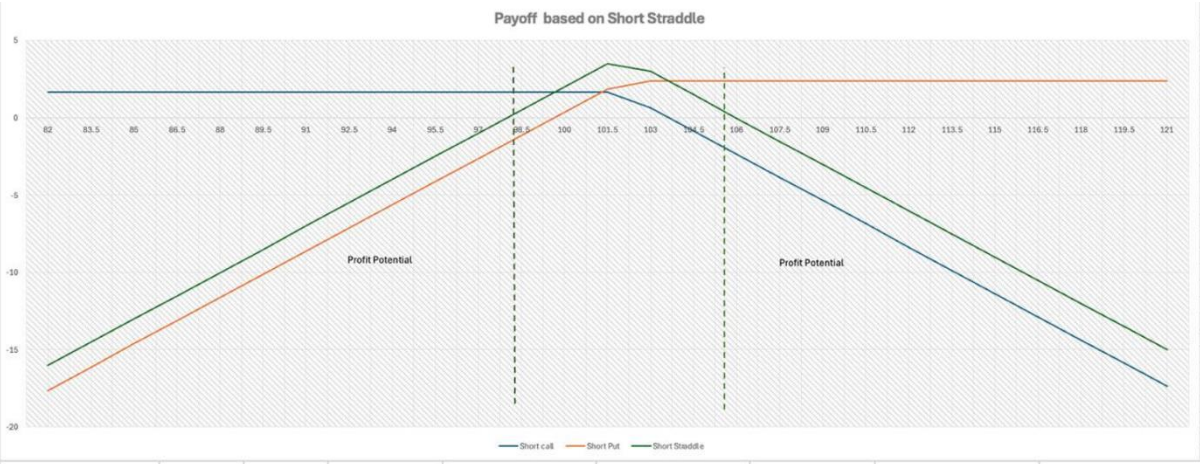
Break even points are as follows:

- Lower: $98.36
- Upper: $105.64

Potential Short Returns:

- Maximum loss caps out at $3.65 which takes place if the stock closes exactly on the strike price
- Profit potential does not have a ceiling if the stock moves significantly above $105.64 or below $98.36

Figure. 3. Payoff based on Short Straddle



4.3. Analysis:

Parameter	Long Straddle	Short Straddle
Cost / Premium	$3.65 (cost)	$3.65 (premium received)
Break-even Points	$98.36 - $105.64	$98.36 - $105.64
Profit Potential	Unlimited (price movement)	Limited (premium received)
Risk	Limited (cost)	Unlimited (price movement)
Volatility Context	High volatility expected	Low volatility expected

4.4. Result:

- **Strategy Choice**: The long straddle benefits from significant price movements, while the short straddle profits from stable prices.
- **Implied Volatility**: Comparing historical and implied volatility is critical in selecting the appropriate strategy. If implied volatility is lower than expected future volatility, a **long straddle** may be favourable.
- **Cost Effectiveness**: While the short straddle provides an immediate credit, it carries unlimited risk, making it less favourable under uncertain conditions.

5. Conclusion:

The analysis of long and short-straddle strategies indicate their disparity in terms of payoff structures and risk-return profiles. A **long straddle**, established by purchasing both a call and put option at the same strike price, offers *unlimited profit potential* for significant price movements in either direction. However, this strategy involves a high margin of capital upfront, and a maximum loss limited to the net premium paid if the underlying price remains in close proximity to the strike price at expiry.

In contrast, a **short straddle**, established by selling a call and put option at the same strike price, earns from minimal price movement and offers a *limited profit potential* equal to the net premium received. However, it exposes the seller to unlimited losses if the underlying price diverges significantly from the strike price.

When comparing the implied volatility on the trade date (05.11.2024) with historical volatility, the choice of strategy can be impacted by perceived mispricing. Higher implied volatility indicates an advantageous situation for short volatility spreads (i.e. short straddles) to capitalise on potential mean reversion, while lower implied volatility may encourage long volatility strategies (i.e. long straddle) to exploit expected volatility increases.

From the cost analysis, the **long straddle** proves to be a more expensive investment due to the purchase of two options albeit it provides greater protection against significant price fluctuations. Au contraire, **the short straddle,** whilst cheaper to implement, carries substantial risk, particularly during periods of high market uncertainty or unexpected volatility spikes.

Conclusively, the choice between these strategies pivots on the investor’s market outlook, risk appetite, and volatility expectations. Long straddles align with a directional bet on volatility, whilst short straddles align with a neutral market view and a belief in declining or stable volatility.

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7. Appendix – Python Script

```
import pandas as pd
import numpy as np

# Load the Excel or CSV file
file_path = 'C:\\Users\\TEJAS\\Downloads\\Put-Call Parity Data.xlsx'  # Update
with your file path
data = pd.read_excel(file_path)

# Display the first few rows
print(data.head())
# Add a column for LHS (C - P)
data['LHS (C - P)'] = data['Call Price ©'] - data['Put Price (P)']

# Add a column for RHS (S - K * exp(-r * T))
data['RHS (S - Ke^(-rt))'] = data['Spot Price (S)'] - data['Strike Price (K)']
* np.exp(-data['Risk-Free Rate (r)'] * data['Time to Maturity (T)'])

# Calculate the deviation (LHS - RHS)
data['Deviation'] = data['LHS (C - P)'] - data['RHS (S - Ke^(-rt))']

# Display the first few rows
print(data[['LHS (C - P)', 'RHS (S - Ke^(-rt))', 'Deviation']])
import matplotlib.pyplot as plt

# Plot Deviations
plt.figure(figsize=(10, 6))
plt.plot(data['Strike    Price    (K)'],    data['Deviation'],    marker='o',
label='Deviation')
plt.axhline(0, color='red', linestyle='--', label='Zero Line')
plt.title('Put-Call Parity Deviation Across Strike Prices')
plt.xlabel('Strike Price (K)')
plt.ylabel('Deviation (LHS - RHS)')
plt.legend()
plt.grid(True)
plt.show()
output_path    =    'C:\\Users\\TEJAS\\Downloads\\Put-Call    Parity    Python
Results.xlsx'
data.to_excel(output_path, index=False)
print(f"Results saved to {output_path}")
```

```python
import pandas as pd
import numpy as np

# Load the formatted data from Excel
file_path = 'C:\\Users\\TEJAS\\Downloads\\Put-Call Parity Python Results.xlsx'
# Replace with your file path
data = pd.read_excel(file_path)

# Calculate theoretical Call - Put (C - P) using Put-Call Parity
data['Theoretical_C_minus_P'] = data['Spot Price (S)'] - (data['Strike Price
(K)'] * np.exp(-data['Risk-Free Rate (r)'] * data['Time to Maturity (T)']))

# Calculate actual Call - Put (C - P) from market data
data['Actual_C_minus_P'] = data['Call Price (C)'] - data['Put Price (P)']

# Calculate arbitrage difference
data['Arbitrage_Difference'] = data['Actual_C_minus_P'] -
data['Theoretical_C_minus_P']

# Identify arbitrage opportunities (where the difference is significant)
# Define a threshold for "significant" arbitrage
threshold = 0.01
data['Arbitrage_Opportunity'] = np.abs(data['Arbitrage_Difference']) >
threshold

# Save the results to a new Excel file
output_file = 'C:\\Users\\TEJAS\\Downloads\\Put-Call Parity Python Results
Final.xlsx'
data.to_excel(output_file, index=False)

print(f"Arbitrage analysis completed. Results saved to {output_file}.")
```

```
import numpy as np
import pandas as pd
from scipy.stats import norm
from scipy.optimize import minimize

# Black-Scholes Call Option Pricing Formula
def black_scholes_call_price(S, K, T, r, sigma):
    d1 = (np.log(S / K) + (r + 0.5 * sigma ** 2) * T) / (sigma * np.sqrt(T))
    d2 = d1 - sigma * np.sqrt(T)
    call_price = S * norm.cdf(d1) - K * np.exp(-r * T) * norm.cdf(d2)
    return call_price, d1, d2

# Function to Calculate Implied Volatility
def implied_volatility(S, K, T, r, market_price):
    def objective_function(sigma):
        theoretical_price, _, _ = black_scholes_call_price(S, K, T, r, sigma)
        return (theoretical_price - market_price) ** 2

    # Use minimize to find the implied volatility
    result = minimize(objective_function, x0=0.2, bounds=[(1e-5, 5)])
    return result.x[0] if result.success else np.nan

# Load the Data from Excel
file_path = 'C:\\Users\\TEJAS\\Downloads\\Implied Volatility Data.xlsx'  #
Replace with the path to your Excel file
data = pd.read_excel(file_path)

# Add Calculations
data["Mid Price"] = (data["Bid"] + data["Ask"]) / 2  # Calculate Mid Price
data["Model Implied Volatility (Calculated)"] = data.apply(
    lambda row: implied_volatility(
        row["Spot Price (S)"],
        row["Strike Price (K)"],
        row["Time to Maturity (T)"],
        row["Risk-Free Rate (r)"],
        row["Mid Price"]
    ),
    axis=1
)

# Calculate Theoretical Call Price, BSM d1, and BSM d2
data["Theoretical Call Price"], data["BSM d1"], data["BSM d2"] =
zip(*data.apply(
    lambda row: black_scholes_call_price(
        row["Spot Price (S)"],
        row["Strike Price (K)"],
```

```
        row["Time to Maturity (T)"],
        row["Risk-Free Rate (r)"],
        row["Model Implied Volatility (Calculated)"]
    ),
    axis=1
))

# Calculate Pricing Error
data["Pricing Error"] = data["Theoretical Call Price"] - data["Mid Price"]

# Save the Updated Data to Excel
output_file = 'C:\\Users\\TEJAS\\Downloads\\Implied Volatility Python Result.xlsx'
data.to_excel(output_file, index=False)
print(f"Updated data saved to {output_file}")


import pandas as pd
import numpy as np
from scipy.stats import norm

# Load the data from the Excel file
file_path = 'C:\\Users\\TEJAS\\Downloads\\Delta Hedging Data.xlsx'  # Replace with your file path
data = pd.read_excel(file_path)

# Ensure necessary columns are numeric
numeric_columns = [
    "SPOT Price", "STRIKE Price", "Time to Maturity (Trading days)",
    "Risk Free Interest Rate", "Model Implied Volatility (Calculated)", "Mid Price", "BSM d1", "Contracts Sold", "Short call Options"]
data[numeric_columns] = data[numeric_columns].astype(float)

# Calculate Delta
data["Delta"] = data["BSM d1"].apply(norm.cdf)

# Calculate Stocks to Buy/Sell
data["Stocks to Buy/Sell"] = data["Delta"] * data["Short call Options"]

# Calculate Change in Stocks to Buy/Sell
# Add "Change in Stocks to Buy/Sell" column
data["Change in Stocks to Buy/Sell"] = data["Stocks to Buy/Sell"].diff().fillna(data["Stocks to Buy/Sell"].iloc[0])

# Calculate Cost of Shares
```

```python
data["Cost of Shares ('000s)"] = data["Change in Stocks to Buy/Sell"] * data["Mid Price"] / 1000

# Calculate Cumulative Cost Including Interest
data["Cumulative Cost Including Interest"] = data["Cost of Shares ('000s)"].cumsum()

# Calculate Interest Cost (Assume daily compounding at risk-free rate)
data["Interest Cost"] = data["Cumulative Cost Including Interest"] * (data["Risk Free Interest Rate"] / 252)

# Add Option Payoff (for call options)
data["Option Payoff"] = (data["SPOT Price"] - data["STRIKE Price"]).clip(lower=0)

# Save the updated data to a new Excel file
output_file = 'C:\\Users\\TEJAS\\Downloads\\Delta Hedging Python Results.xlsx'
data.to_excel(output_file, index=False)
print(f"Delta Hedging results saved to {output_file}")



import pandas as pd
import numpy as np
from scipy.stats import norm

# Load the data from the Excel file
file_path = 'C:\\Users\\TEJAS\\Downloads\\Delta Hedging Data.xlsx'  # Replace with your file path
data = pd.read_excel(file_path)

# Ensure necessary columns are numeric
numeric_columns = [
    "SPOT Price", "STRIKE Price", "Time to Maturity (Trading days)",
    "Risk Free Interest Rate", "Model Implied Volatility (Historical)", "Mid Price", "BSM d1"
]
data[numeric_columns] = data[numeric_columns].astype(float)

# Calculate Delta
data["Delta"] = data["BSM d1"].apply(norm.cdf)

# Calculate Stocks to Buy/Sell
data["Stocks to Buy/Sell"] = data["Delta"] * data["Short call Options"]

# Add "Change in Stocks to Buy/Sell" column
```

```
data["Change in Stocks to Buy/Sell"] = data["Stocks to Buy/Sell"].diff().fillna(data["Stocks to Buy/Sell"].iloc[0])

# Calculate Cost of Shares
data["Cost of Shares ('000s)"] = data["Change in Stocks to Buy/Sell"] * data["SPOT Price"] / 1000

# Calculate Cumulative Cost Including Interest
data["Cumulative Cost Including Interest"] = data["Cost of Shares ('000s)"].cumsum()

# Calculate Interest Cost (Assume daily compounding at risk-free rate)
data["Interest Cost"] = data["Cumulative Cost Including Interest"] * (data["Risk Free Interest Rate"] / 252)

# Add Option Payoff (for call options)
data["Option Payoff"] = (data["SPOT Price"] - data["STRIKE Price"]).clip(lower=0)

# Add Options Payoff (No Hedging)
data["Options Payoff (No Hedging)"] = -data["Option Payoff"]

# Calculate Net Off (Hedging)
data["Net Off (Hedging)"] = data["Options Payoff (No Hedging)"] + data["Cumulative Cost Including Interest"]

# Save the updated data to a new Excel file
output_file = 'C:\\Users\\TEJAS\\Downloads\\Delta Hedging Historical Python Results.xlsx'
data.to_excel(output_file, index=False)
print(f"Delta Hedging results saved to {output_file}")



import numpy as np
import matplotlib.pyplot as plt

def analyze_short_straddle(current_price=96.31):
    """Analyze short straddle strategy and its characteristics"""

    # ATM strike
    strike = 102.0

    # Updated prices from the table
    call_price = 1.63  # Premium received for selling the call
    put_price = 2.015  # Premium received for selling the put
```

```
    total_premium = call_price + put_price  # Total premium received

    # Break-even points from data
    lower_breakeven = strike - total_premium  # Lower break-even point
    upper_breakeven = strike + total_premium  # Upper break-even point

    # Calculate payoff profiles
    spot_range = np.linspace(95, 110, 1000)

    short_straddle_payoffs = np.array([
        total_premium - (max(0, s - strike) + max(0, strike - s))
        for s in spot_range
    ])

    # Plot payoffs with enhanced visualization
    plt.figure(figsize=(15, 8))

    # Main payoff line
    plt.plot(spot_range, short_straddle_payoffs, 'b-', label='Short Straddle',
linewidth=2)

    # Reference lines
    plt.axhline(y=0, color='k', linestyle='--', alpha=0.5)
    plt.axvline(x=current_price,  color='g',  linestyle='--',  label='Current
Price', alpha=0.7)
    plt.axvline(x=strike,  color='r',  linestyle='--',  label='Strike  Price',
alpha=0.7)

    # Break-even points
    plt.axvline(x=lower_breakeven, color='gray', linestyle=':', alpha=0.5)
    plt.axvline(x=upper_breakeven, color='gray', linestyle=':', alpha=0.5)

    # Formatting
    plt.title('Short Straddle Payoff Profile', fontsize=12, pad=20)
    plt.xlabel('Stock Price ($)', fontsize=10)
    plt.ylabel('Profit/Loss ($)', fontsize=10)
    plt.legend(fontsize=10)
    plt.grid(True, alpha=0.3)

    # Add text box with strategy information
    text_info = f'Strike Price: ${strike:.2f}\n'
    text_info += f'Call Premium: ${call_price:.2f}\n'
    text_info += f'Put Premium: ${put_price:.2f}\n'
    text_info += f'Total Premium: ${total_premium:.2f}\n'
    text_info += f'Lower Breakeven: ${lower_breakeven:.2f}\n'
```

```
    text_info += f'Upper Breakeven: ${upper_breakeven:.2f}\n'

    plt.text(0.02, 0.98, text_info,
             transform=plt.gca().transAxes,
             bbox=dict(facecolor='white', alpha=0.8),
             verticalalignment='top',
             fontsize=10)

    plt.tight_layout()
    plt.show()

    # Print detailed analysis
    print("\nDetailed Short Straddle Analysis:")
    print(f"Sell 1 {strike} Call @ ${call_price:.2f}")
    print(f"Sell 1 {strike} Put @ ${put_price:.2f}")
    print(f"Total Premium Received: ${total_premium:.2f}")

    print("\nBreak-even Points:")
    print(f"Lower Break-even: ${lower_breakeven:.2f}")
    print(f"Upper Break-even: ${upper_breakeven:.2f}")

    print("\nPotential Returns:")
    print(f"Maximum Profit: ${total_premium:.2f} (if stock price = strike at
expiration)")
    print(f"Maximum Loss: Unlimited (if stock price moves significantly away
from strike)")

    print("\nStrategy Characteristics:")
    print("1. Benefits from low volatility and minimal price movement.")
    print("2. Maximum profit occurs if stock closes at strike price.")
    print("3. Unlimited risk if stock price moves significantly in either
direction.")
    print("4. Time decay works in favor of the position.")

# Run the analysis
analyze_short_straddle()

import numpy as np
import matplotlib.pyplot as plt

def analyze_short_straddle(current_price=96.31):
    """Analyze short straddle strategy and its characteristics"""

    # ATM strike
    strike = 102.0
```

```
    # Updated prices from the table
    call_price = 1.63  # Premium received for selling the call
    put_price = 2.015  # Premium received for selling the put
    total_premium = call_price + put_price  # Total premium received

    # Break-even points from data
    lower_breakeven = strike - total_premium  # Lower break-even point
    upper_breakeven = strike + total_premium  # Upper break-even point

    # Calculate payoff profiles
    spot_range = np.linspace(95, 110, 1000)

    short_straddle_payoffs = np.array([
        total_premium - (max(0, s - strike) + max(0, strike - s))
        for s in spot_range
    ])

    # Plot payoffs with enhanced visualization
    plt.figure(figsize=(15, 8))

    # Main payoff line
    plt.plot(spot_range, short_straddle_payoffs, 'b-', label='Short Straddle',
linewidth=2)

    # Reference lines
    plt.axhline(y=0, color='k', linestyle='--', alpha=0.5)
    plt.axvline(x=current_price,  color='g',  linestyle='--',  label='Current
Price', alpha=0.7)
    plt.axvline(x=strike,  color='r',  linestyle='--',  label='Strike  Price',
alpha=0.7)

    # Break-even points
    plt.axvline(x=lower_breakeven, color='gray', linestyle=':', alpha=0.5)
    plt.axvline(x=upper_breakeven, color='gray', linestyle=':', alpha=0.5)

    # Formatting
    plt.title('Short Straddle Payoff Profile', fontsize=12, pad=20)
    plt.xlabel('Stock Price ($)', fontsize=10)
    plt.ylabel('Profit/Loss ($)', fontsize=10)
    plt.legend(fontsize=10)
    plt.grid(True, alpha=0.3)

    # Add text box with strategy information
    text_info = f'Strike Price: ${strike:.2f}\n'
```

```python
    text_info += f'Call Premium: ${call_price:.2f}\n'
    text_info += f'Put Premium: ${put_price:.2f}\n'
    text_info += f'Total Premium: ${total_premium:.2f}\n'
    text_info += f'Lower Breakeven: ${lower_breakeven:.2f}\n'
    text_info += f'Upper Breakeven: ${upper_breakeven:.2f}\n'

    plt.text(0.02, 0.98, text_info,
             transform=plt.gca().transAxes,
             bbox=dict(facecolor='white', alpha=0.8),
             verticalalignment='top',
             fontsize=10)

    plt.tight_layout()
    plt.show()

    # Print detailed analysis
    print("\nDetailed Short Straddle Analysis:")
    print(f"Sell 1 {strike} Call @ ${call_price:.2f}")
    print(f"Sell 1 {strike} Put @ ${put_price:.2f}")
    print(f"Total Premium Received: ${total_premium:.2f}")

    print("\nBreak-even Points:")
    print(f"Lower Break-even: ${lower_breakeven:.2f}")
    print(f"Upper Break-even: ${upper_breakeven:.2f}")

    print("\nPotential Returns:")
    print(f"Maximum Profit: ${total_premium:.2f} (if stock price = strike at expiration)")
    print(f"Maximum Loss: Unlimited (if stock price moves significantly away from strike)")

    print("\nStrategy Characteristics:")
    print("1. Benefits from low volatility and minimal price movement.")
    print("2. Maximum profit occurs if stock closes at strike price.")
    print("3. Unlimited risk if stock price moves significantly in either direction.")
    print("4. Time decay works in favor of the position.")

# Run the analysis
analyze_short_straddle()

def analyze_calendar_spread(current_price=101.65):

def analyze_butterfly_spread(current_price=101.65):
    """Analyze butterfly spreads and their characteristics"""
```

```python
    # ATM strike
    atm_strike = 102.0

    print("\nVolatility Analysis:")
    print(f"Historical Volatility: {31.97:.2f}%")

    # Create butterfly spreads with 1-point wings centered around ATM strike
    strikes = [101.0, 102.0, 103.0]

    # Get prices for each strike (adjusted for different strikes)
    # These should be different prices for different strikes
    call_prices = [1.85, 1.63, 1.45]  # Adjusted for strike differences
    put_prices = [2.25, 2.015, 1.80]   # Adjusted for strike differences

    # Calculate spread costs
    call_butterfly_cost = call_prices[0] - 2*call_prices[1] + call_prices[2]
    put_butterfly_cost = put_prices[0] - 2*put_prices[1] + put_prices[2]

    # Calculate payoff profiles
    spot_range = np.linspace(95, 110, 1000)

    call_payoffs = np.array([
        max(0, s - strikes[0]) -
        2*max(0, s - strikes[1]) +
        max(0, s - strikes[2]) -
        call_butterfly_cost for s in spot_range
    ])

    put_payoffs = np.array([
        max(0, strikes[0] - s) -
        2*max(0, strikes[1] - s) +
        max(0, strikes[2] - s) -
        put_butterfly_cost for s in spot_range
    ])

    # Plot payoffs with enhanced visualization
    plt.figure(figsize=(15, 8))

    # Main payoff lines
    plt.plot(spot_range,    call_payoffs,    'b-',    label='Call    Butterfly',
linewidth=2)
    plt.plot(spot_range, put_payoffs, 'r-', label='Put Butterfly', linewidth=2)

    # Reference lines
```

```
    plt.axhline(y=0, color='k', linestyle='--', alpha=0.5)
    plt.axvline(x=current_price,  color='g',  linestyle='--',  label='Current
Price', alpha=0.7)

    # Strike price markers
    for strike in strikes:
        plt.axvline(x=strike, color='gray', linestyle=':', alpha=0.3)

    # Formatting
    plt.title('Butterfly  Spread  Payoffs  (1-Point  Wing  Width)',  fontsize=12,
pad=20)
    plt.xlabel('Stock Price ($)', fontsize=10)
    plt.ylabel('Profit/Loss ($)', fontsize=10)
    plt.legend(fontsize=10)
    plt.grid(True, alpha=0.3)

    # Add text box with spread information
    text_info = f'Call Butterfly Cost: ${call_butterfly_cost:.2f}\n'
    text_info += f'Put Butterfly Cost: ${put_butterfly_cost:.2f}\n'
    text_info += f'Strikes: {strikes[0]}/{strikes[1]}/{strikes[2]}\n'
    text_info += f'Historical Vol: {31.97:.2f}%\n'
    text_info += f'Call Implied Vol: {22.47:.2f}%\n'
    text_info += f'Put Implied Vol: {25.15:.2f}%'

    plt.text(0.02, 0.98, text_info,
             transform=plt.gca().transAxes,
             bbox=dict(facecolor='white', alpha=0.8),
             verticalalignment='top',
             fontsize=10)

    plt.tight_layout()
    plt.show()

    # Print detailed analysis
    print("\nDetailed Spread Analysis:")
    print(f"\nCall Butterfly:")
    print(f"Buy 1 {strikes[0]} Call @ ${call_prices[0]:.2f}")
    print(f"Sell 2 {strikes[1]} Calls @ ${call_prices[1]:.2f}")
    print(f"Buy 1 {strikes[2]} Call @ ${call_prices[2]:.2f}")
    print(f"Net Cost: ${call_butterfly_cost:.2f}")

    print(f"\nPut Butterfly:")
    print(f"Buy 1 {strikes[0]} Put @ ${put_prices[0]:.2f}")
    print(f"Sell 2 {strikes[1]} Puts @ ${put_prices[1]:.2f}")
    print(f"Buy 1 {strikes[2]} Put @ ${put_prices[2]:.2f}")
    print(f"Net Cost: ${put_butterfly_cost:.2f}")
```

```python
    # Calculate maximum potential profit
    max_profit_call = 1 - call_butterfly_cost
    max_profit_put = 1 - put_butterfly_cost

    print("\nPotential Returns:")
    print(f"Max Profit Call Butterfly: ${max_profit_call:.2f}")
    print(f"Max Profit Put Butterfly: ${max_profit_put:.2f}")
    print(f"Maximum              Risk:              ${min(call_butterfly_cost,
put_butterfly_cost):.2f}")

    print("\nVolatility Information:")
    print(f"Historical Volatility: {31.97:.2f}%")
    print(f"Call Implied Volatility: {22.47:.2f}%")
    print(f"Put Implied Volatility: {25.15:.2f}%")

analyze_butterfly_spread()
```