Analyzing Trading Strategies with the Black-Scholes Model

November 26, 2024

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1 Abstract

The Black-Scholes model is a pivotal framework for pricing European-style options, utilizing parameters such as the underlying stock price, strike price, time to expiration, risk-free interest rate, and market volatility. This report extends the theoretical foundation of the Black-Scholes model by implementing and analyzing three options trading strategies: **Basic Strategy**, **Bull Spread**, and **Butterfly Spread**. Each strategy is evaluated using real-world options data to assess profitability and effectiveness in various market scenarios, offering insights into the practical application of the model.

2 Introduction

Developed in 1973 by Fischer Black, Myron Scholes, and Robert Merton, the Black-Scholes model revolutionized options pricing by providing a mathematical method to compute the theoretical value of European-style options. The model assumes that asset prices follow a lognormal distribution and evolve through a random walk characterized by constant drift and volatility. By incorporating key parameters such as current stock price, strike price, time to expiration, risk-free interest rate, and market volatility, the model serves as a powerful tool for understanding market behavior and pricing derivatives.

This project explores the practical applications of the Black-Scholes model by implementing and analyzing three trading strategies:

- **Basic Strategy**: A straightforward approach involving buying options when the theoretical price exceeds the market price by a predefined threshold and selling when the market price surpasses the buy price by a set margin.
- **Bull Spread**: A moderately bullish strategy combining the purchase of a call option at a lower strike price with the sale of a call option at a higher strike price, both with the same expiration date.
- **Butterfly Spread**: A market-neutral strategy aimed at low-volatility conditions, combining the purchase and sale of options at varying strike prices, limiting both profit and loss.

Through these analyses, this report bridges the theoretical underpinnings of the Black-Scholes model with its practical applications in options trading.

3 The Black-Scholes Model Formula

The Black-Scholes model calculates the theoretical price of European-style options by incorporating several key variables, including the current price of the underlying asset, strike price, time to expiration, risk-free interest rate, and volatility. Using these inputs, the model derives the call option price as follows:

$$C = SN(d_1) - Ke^{-rt}N(d_2)$$

where:

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}, \quad d_2 = d_1 - \sigma\sqrt{t}$$

Variables:

- C: Call option price.
- S: Current price of the underlying asset.
- K: Strike price.
- r: Risk-free interest rate.
- t: Time to expiration (in years).
- σ: Volatility of the underlying asset.
- $N(x)$: Cumulative distribution function of the standard normal distribution.

The formula comprises two primary components:

1. $SN(d_1)$: The present value of the expected payoff from owning the underlying asset, adjusted by the probability of in-the-money options.

2. $Ke^{-rt}N(d_2)$: The discounted strike price, weighted by the probability of exercising the option.

This equation provides a theoretical basis for pricing call options, incorporating market dynamics and the time value of money.

4 Data Collection

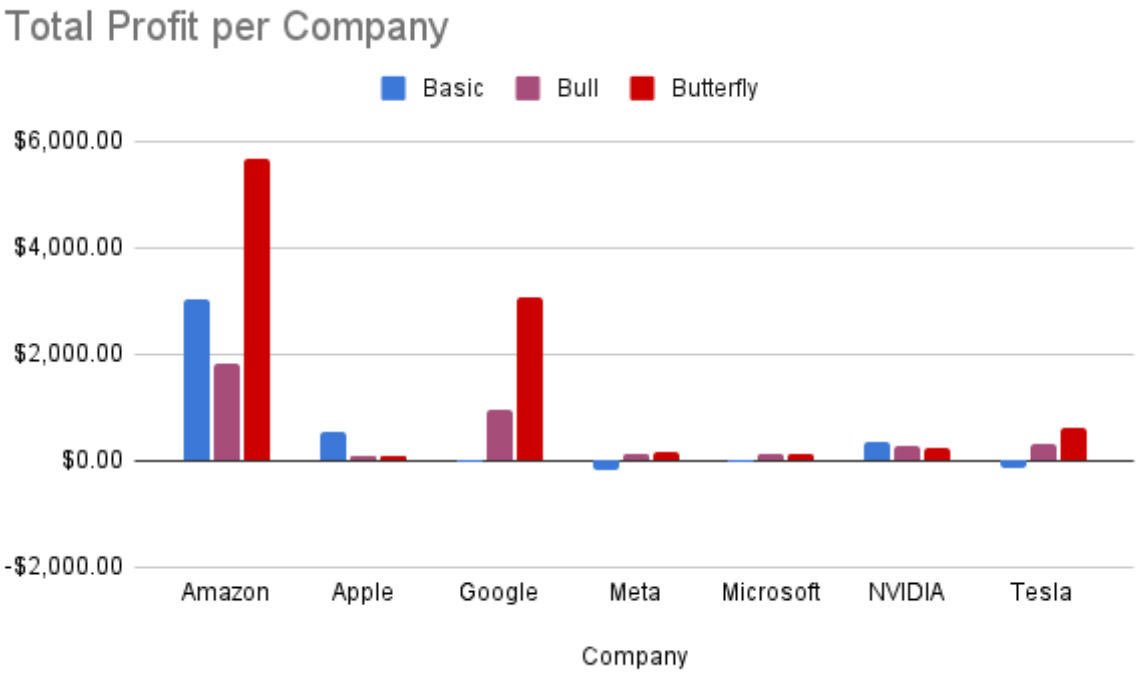
The dataset contains options data for seven companies: Amazon, Apple, Google, Microsoft, Meta, Nvidia, and Tesla. Each entry includes information about individual call options, with columns for the contract symbol, strike price, bid price, ask price, implied volatility, option price, and the remaining time to expiration. This data was collected from Yahoo Finance to analyze and model options, pricing, and strategies.

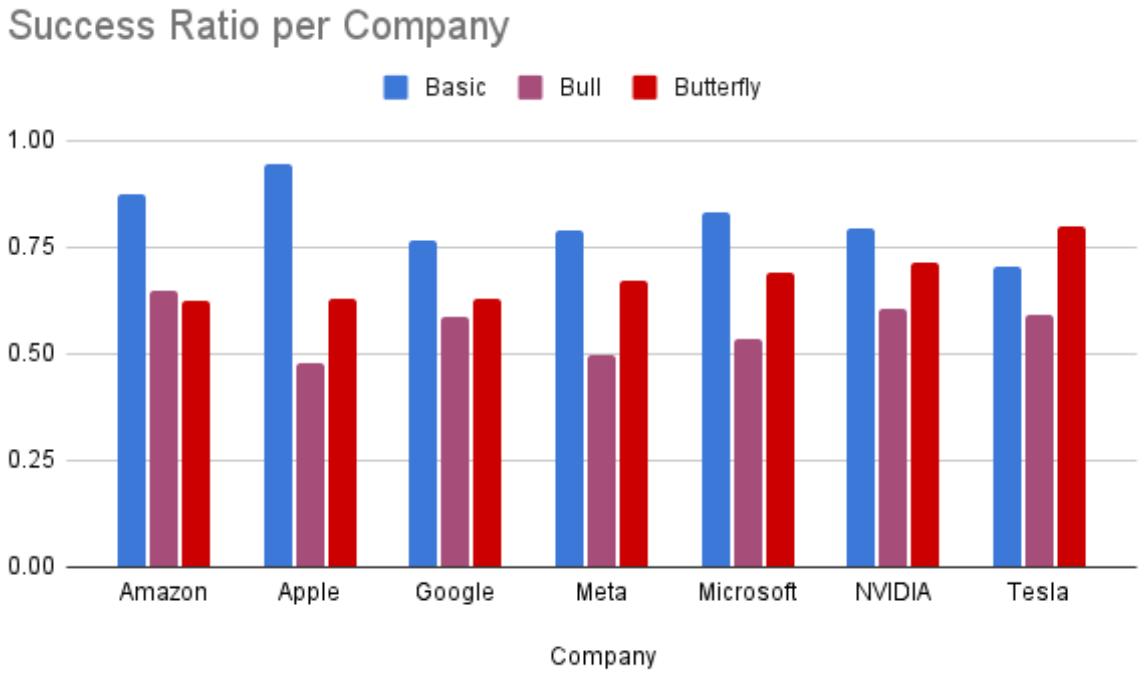
5 Comparison of Strategies

Feature	**Basic Strategy**	**Bull Spread Strategy**	**Butterfly Spread Strategy**
Type of Strategy	Single option buying and selling	Combination of two options (e.g., buying a call and selling a call at different strikes)	Multi-leg options strategy
Market View	Can be directional (e.g., buying calls)	Moderately bullish	Neutral (price near middle strike)
Instruments	1 call (or 1 put) option	1 lower strike call, 1 higher strike call	1 lower strike call/put, 2 middle strike calls/puts, 1 higher strike call/put
Profit Condition	Price needs to move in a certain direction	Price moves moderately upward	Price stays near the middle strike at expiration
Risk	High risk if price doesn't move significantly	Limited risk due to the defined spread	Limited risk due to selling two options
Reward	Unlimited potential if price moves significantly	Limited reward due to the spread	Limited reward but also limited risk

Table 1: Comparison of Different Trading Strategies

6 Results


Total Profit per Company
Basic
Bull
Butterfly
$6,000.00
$4,000.00
$2,000.00
$0.00
-$2,000.00
Amazon
Apple
Google
Meta
Microsoft
NVIDIA
Tesla
Company


Success Ratio per Company
Basic
Bull
Butterfly
1.00
0.75
0.50
0.25
0.00
Amazon
Apple
Google
Meta
Microsoft
NVIDIA
Tesla
Company

Company	**Total Profit(Basic)**	**Total Profit(Bull)**	**Total Profit(Butterfly)**
Amazon	3048.6	1842.32	3511.54
Apple	545.3	85.01	90.27
Google	-40.02	968.21	1678.67
Meta	-166.27	134.29	172.68
Microsoft	-35.699	113.2	133.04
NVIDIA	357.65	263.18	239.61
Tesla	-137.67	334.32	438.97
Net Profit	3571.891	3740.53	6264.78

Table 2: Total Profit per Company

Company	**Success Ratio (Basic)**	**Total Trades (Basic)**	**Success Ratio (Bull)**	**Total Trades (Bull)**	**Success Ratio (Butterfly)**	**Total Trades (Butterfly)**
Amazon	0.875	16	0.65	1011	0.549	5029
Apple	0.947	19	0.477	86	0.629	124
Google	0.764	17	0.585	699	0.559	2947
Meta	0.789	19	0.497	141	0.673	205
Microsoft	0.833	24	0.535	116	0.688	154
NVIDIA	0.794	34	0.607	178	0.715	249
Tesla	0.703	37	0.589	253	0.764	406

Table 3: Success Ratio and Total No. of Trades per Company

Note: The difference in the number of trades in each model is due to the combinatorial complexity of each model. In the butterfly spread, for each set of 3 unique strikes, a potential trade is generated, which drastically increases the number of trades.

7 Conclusion

This report has demonstrated the practical application of the Black-Scholes model through the analysis of three distinct options trading strategies: *Basic Strategy*, *Bull Spread*, and *Butterfly Spread*. By employing real-world data from companies such as Amazon, Apple, Google, Meta, Microsoft, NVIDIA and Tesla, we assessed the profitability and effectiveness of each strategy under various market conditions.

Our findings reveal the following key insights:

- The **Basic Strategy** offers potential for significant profits; however, it carries a high risk if the market does not move as anticipated.
- The **Bull Spread** strategy, being moderately bullish, proved to be effective when the market experienced slight upward movements.
- The **Butterfly Spread** strategy was most effective in low-volatility conditions, providing a balanced approach with limited risk and reward.

These results highlight the importance of selecting the appropriate strategy based on market conditions to optimize the risk-reward tradeoff.

8 References

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