FINSEARCH (FINAL REPORT)

OPTION PRICING MODELS & THEIR ACCURACY

GROUP - E16

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1. Main Principles of Option Pricing: An In-Depth Analysis

Option pricing forms the cornerstone of modern finance, enabling individuals and institutions to navigate risk and capitalize on potential opportunities in the dynamic world of financial derivatives. At its core, option pricing seeks to determine the intrinsic and extrinsic value of these instruments, which grant the holder the right but not the obligation to buy or sell an underlying asset at a predetermined price within a specified timeframe.

Underlying Asset Price (S):

The first fundamental principle of option pricing hinges upon the current market price of the underlying asset, denoted as S. Whether it's a stock, index, currency, or commodity, the underlying asset's price serves as the linchpin upon which an option's potential profitability rests. As the underlying asset's price fluctuates, the value of the option ebbs and flows accordingly. This phenomenon encapsulates the essence of an option's intrinsic value, which is the immediate difference between the underlying asset's price and the option's strike price K.

Strike Price (K):

Central to the concept of option pricing is the strike price, also known as the exercise price. K represents the fixed price at which the option holder can buy (in the case of a call option) or sell (in the case of a put option) the underlying asset. The relationship between the asset's current market price S and the strike price K significantly influences an option's profitability and its intrinsic value. When S exceeds K for a call option or is below K for a put option, the option holds intrinsic value, as it allows for immediate profit.

Time to Expiration (T):

The third principle, time to expiration (T), serves as a pivotal factor in option pricing. All else being equal, the more time left until an option's expiration, the higher its value. This is because a longer time frame provides more opportunities for the underlying asset's price to move favorably for the option holder. Consequently, options with longer expiration dates command higher prices due to their increased potential for substantial market movements.

Volatility (σ):

Volatility, symbolized by σ, encapsulates the extent of price fluctuations of the underlying asset over time. A higher volatility denotes larger price swings, which can result in amplified profits or losses for option holders. Options on assets with higher volatility are generally priced higher to account for the increased risk and reward potential.

Risk-Free Interest Rate (r):

Lastly, the risk-free interest rate r plays a pivotal role in option pricing by discounting future cash flows back to their present value. The risk-free rate represents the return an investor can earn from a risk-free investment, often tied to government bonds. As the risk-free rate rises, the present value of future option payoffs decreases, leading to lower option prices. This principle emphasizes the time value of money, acknowledging that money available in the future is worth less than the same amount today due to the opportunity cost of not investing it elsewhere.

In conclusion, the main principles of option pricing revolve around the intricate interplay between the current market price of the underlying asset, the predetermined strike price, the remaining time until expiration, the asset's price volatility, and the risk-free interest rate. These principles lay the foundation for various option pricing models, providing traders, investors, and analysts with the tools to assess the fair value of financial derivatives and make informed decisions in the complex landscape of the financial markets.

2. Studying 2 Different Option Pricing Models: An In-Depth Analysis

Option pricing models are the bedrock of quantitative finance, offering systematic frameworks to estimate the fair value of options. Among the myriad models available, two prominent ones stand out: the Black-Scholes model and the Binomial model. Each model approaches option pricing from a distinct perspective, capturing unique aspects of the market's dynamics.

Black-Scholes Model:

The Black-Scholes model, introduced in 1973 by Fischer Black, Myron Scholes, and Robert Merton, revolutionized the field of option pricing by presenting a closed-form formula for calculating option prices. It is specifically tailored for European-style options, which can only be exercised at the expiration date. The Black-Scholes formula elegantly blends mathematical sophistication with financial intuition, taking into account the following key factors:

Continuous Model:

The Black-Scholes model operates under the assumption of continuous trading, making it well-suited for liquid markets where trading occurs without interruption. This continuous time framework allows for the incorporation of the risk-free interest rate, the continuous compounding of returns, and the smooth incorporation of volatility.

Log-Normal Asset Price Distribution:

The model assumes that the distribution of asset price returns follows a log-normal distribution, which effectively captures the tendency of financial asset prices to exhibit asymmetric growth patterns with occasional large moves.

Closed-Form Solution:

The most distinctive feature of the Black-Scholes model is its closed-form formula, which calculates option prices without iterative calculations. The formula involves cumulative normal distribution functions and provides a clear relationship between the option price and the underlying asset's price, strike price, time to expiration, volatility, and risk-free rate.

Binomial Model:

In contrast, the Binomial model takes a more discrete approach, dividing time into a series of discrete periods and creating a tree-like structure of possible asset price movements. Proposed by Cox, Ross, and Rubinstein in 1979, this model can accommodate both European and American-style options, making it versatile in assessing a broader range of options. Key aspects of the Binomial model include:

Discrete Steps:

Unlike the continuous time assumption of the Black-Scholes model, the Binomial model breaks time into discrete intervals. This approach allows for a more intuitive representation of price movements over time.

Two-Step Price Movement:

The model considers only two potential price movements: up and down. The asset price evolves as a result of these movements, allowing for a simplified but effective representation of the underlying asset's behavior.

Risk-Neutral Valuation:

The Binomial model employs a risk-neutral valuation framework, where option prices are calculated based on the probabilities of different price movements. These probabilities are derived to match the risk-free rate, ensuring that the model produces consistent results.

While the Black-Scholes model offers a streamlined and mathematically elegant solution for European options, the Binomial model's discrete nature and versatility make it applicable to a broader spectrum of option types, including American options. Both models, in their respective ways, contribute significantly to the understanding of option pricing dynamics, guiding investors and analysts in valuing options and managing risk in the complex world of financial markets.

3. Asian vs American Options: A Comprehensive Analysis

In the realm of options, diversity abounds in the form of various option types tailored to different risk profiles and market conditions. Two intriguing options in this landscape are Asian options and American options. While both provide avenues for managing risk and profiting from market movements, they do so through distinct mechanisms, each with its own set of advantages and intricacies.

Asian Options:

An Asian option, sometimes referred to as an average option, deviates from the standard path of option pricing by incorporating an averaging mechanism. The value of an Asian option is determined not solely by the underlying asset's price at expiration, but by the average price of the asset over a specified period. This averaging feature endows Asian options with unique characteristics:

Smoothing Effect: The averaging mechanism imparts a smoothing effect to Asian options. This means that short-term price fluctuations in the underlying asset have a diminished impact on the option's value. As a result, Asian options can be enticing to risk-averse investors seeking to mitigate the influence of abrupt price swings.

Reduced Volatility Impact: The averaging process inherently reduces the influence of extreme price movements. This can be advantageous in markets with high volatility, as Asian options could potentially offer more stable outcomes than their European or American counterparts.

Complex Valuation: The calculation of the average price introduces complexities in the valuation process. Various averaging methods, such as arithmetic or geometric averages, can impact the final option price. Consequently, the valuation of Asian options may necessitate more sophisticated mathematical approaches.

American Options:

In contrast to Asian options, American options adhere to the conventional model of option exercise. These options grant the holder the freedom to exercise the option at any point before or on the expiration date. This flexibility gives American options a distinct edge:

Strategic Flexibility: The ability to exercise an American option at any time offers strategic flexibility to investors. They can optimize their returns by capitalizing on favorable price movements even before the option's predetermined expiration date.

Higher Premiums: Due to the additional feature of early exercise, American options typically command higher premiums than European options. This higher cost reflects the increased potential for the option holder to capture advantageous market conditions.

Complex Valuation: The valuation of American options involves intricate calculations, often requiring the use of numerical methods or lattice-based models due to the potential for early exercise. This complexity adds an extra layer of sophistication to the pricing process.

In summary, Asian and American options showcase the versatility of options as financial instruments. Asian options introduce a novel averaging mechanism that offers stability in the face of volatility, though their valuation can be intricate. American options embrace strategic flexibility and early exercise potential, commanding higher premiums and necessitating advanced valuation techniques. Understanding the intricacies of these two option types equips investors with additional tools for effective risk management and targeted market participation.

4. Empirical Research on Option Pricing Models: An Extensive Exploration

Empirical research forms the bridge between theoretical concepts and real-world market dynamics. In the context of option pricing models, empirical research seeks to validate the efficacy of these models in predicting option prices and capturing market behavior. This empirical exploration involves data analysis, statistical tests, and the assessment of model accuracy under various market conditions.

Data Collection and Preparation:

Empirical research begins with the collection of historical data relevant to the option being studied. This data includes historical prices of the underlying asset, implied volatilities, risk-free interest rates, and actual option prices. The data should cover a diverse range of market scenarios to ensure the research's comprehensiveness.

Comparative Analysis:

Empirical research involves comparing the option prices generated by a chosen pricing model, such as the Black-Scholes or Binomial model, with the actual market prices. By quantifying the differences between model-calculated prices and observed prices, researchers can evaluate the accuracy of the model under different circumstances.

Accuracy Metrics:

To quantify the model's accuracy, researchers use statistical metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), or percentage error. These metrics provide insights into how closely the model's predictions align with the actual market prices. Smaller values of MAE or RMSE indicate higher accuracy.

Market Scenarios:

Empirical research should encompass a variety of market scenarios, including periods of high and low volatility, trending markets, and choppy or sideways movements. This diverse analysis helps researchers understand how well the model performs across different market conditions.

Statistical Testing:

Statistical tests can be employed to assess the significance of the differences between model-calculated prices and actual market prices. Techniques like t-tests or ANOVA can help determine if any observed differences are statistically significant or if they could be due to random chance.

Model Validation:

Empirical research serves as a crucial validation process for option pricing models. If a model demonstrates consistent accuracy across different scenarios and passes statistical tests, it is more likely to be reliable for practical applications.

Limitations and Insights:

Empirical research also sheds light on the limitations of the chosen pricing model. Researchers can identify scenarios where the model may underperform or overestimate option prices, leading to valuable insights into its applicability and potential improvements.

Continuous Improvement:

Empirical research is not a one-time endeavor. As market dynamics evolve and new data becomes available, researchers can refine and adjust models to better capture changing market conditions.

In conclusion, empirical research plays a pivotal role in validating option pricing models and understanding their real-world effectiveness. By systematically comparing model-calculated prices with actual market prices under various scenarios, researchers can gain insights into the models' strengths, limitations, and potential applications. This research ensures that option pricing models remain robust tools for risk management, investment decision-making, and financial analysis in a constantly evolving financial landscape.

5. **Building a Code to Backtest the Model in Different Markets: A Comprehensive Guide**

Building a code to backtest option pricing models in various markets involves combining quantitative techniques, programming skills, and financial domain knowledge. This process enables the assessment of how well a pricing model performs in capturing real market dynamics. Here's a step-by-step guide to building such a code:

1. **Data Collection and Preparation:**

Gather historical data for the underlying asset's prices, implied volatilities, and risk-free interest rates. Ensure the data covers diverse market conditions and time periods for accurate backtesting.

2. **Model Implementation:**

Choose a specific option pricing model, such as the Black-Scholes or Binomial model, to implement in your code. This involves coding the mathematical equations that define the chosen model.

3. Coding Parameters:

Define the input parameters required for the model, including the underlying asset's price, strike price, time to expiration, volatility, and risk-free interest rate. Allow for flexibility in altering these parameters for different backtesting scenarios.

4. Option Price Calculation:

Implement the calculations for option prices using the selected model and the provided input parameters. Ensure accuracy in the mathematical computations to achieve reliable results.

5. Looping Through Data:

Iterate through the historical data, feeding it into the code to calculate option prices for each data point. This loop helps generate a series of model-calculated prices over time.

6. Comparison with Market Prices:

Compare the model-calculated option prices with actual market prices for the same time periods. Calculate the differences between the two sets of prices to quantify the accuracy of the model.

7. Accuracy Metrics:

Compute accuracy metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), or percentage error to measure the discrepancy between the model's predictions and actual market prices.

8. Visualization:

Visualize the results using graphs or charts that display the model-calculated prices alongside the actual market prices. This visual representation enhances the understanding of how well the model performs across different market conditions.

9. Sensitivity Analysis:

Conduct sensitivity analysis by altering one or more input parameters at a time and observing the impact on the model's accuracy. This analysis provides insights into which parameters have the most significant influence on the model's performance.

10. Market Scenario Testing:

Apply the code to different market scenarios, such as periods of high volatility, trending markets, and stable conditions. This step helps assess the model's robustness and ability to adapt to changing market dynamics.

11. Documentation and Reporting:

Thoroughly document the code, including explanations of the implemented model, input parameters, and any assumptions made. Summarize the backtesting results in a comprehensive report that outlines the model's performance in different scenarios.

12. Continuous Refinement:

Iteratively refine the code as needed, incorporating feedback and insights gained from the backtesting process. Continuously updating the code ensures its accuracy and relevance as market conditions evolve.

In conclusion, building a code to backtest option pricing models requires a blend of quantitative skills, programming expertise, and financial acumen. This process facilitates a thorough evaluation of how well the selected model aligns with real market behavior, enabling practitioners to make more informed decisions in their investment strategies. By following these steps and ensuring the accuracy of the code, analysts and traders can harness the power of quantitative analysis to enhance their understanding of option pricing dynamics in different markets.

6. Checking the Accuracy of Option Pricing Models: A Comprehensive Evaluation

The accuracy of option pricing models is paramount for effective risk management and informed decision-making in financial markets. While these models offer valuable insights, their real-world performance can differ due to various factors. Validating the accuracy of these models involves a rigorous process of comparison, statistical analysis, and a deep understanding of market dynamics.

1. <u>Data Collection and Preprocessing</u>:

Begin by collecting historical data on option prices, underlying asset prices, implied volatilities, risk-free interest rates, and other relevant variables. Ensure the data is accurate, comprehensive, and spans various market conditions.

2. <u>Model Calibration</u>:

Calibrate the chosen option pricing model to fit the collected historical data. This step involves fine-tuning model parameters to ensure that the model's theoretical prices closely align with actual market prices.

3. <u>Comparison with Market Data</u>:

Calculate option prices using the calibrated model and compare them with the actual market prices. This step provides a direct assessment of how well the model predicts option prices under different scenarios.

4. <u>Accuracy Metrics</u>:

Utilize accuracy metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), or percentage error to quantify the differences between model-calculated prices and actual market prices. Smaller values of these metrics indicate a higher level of accuracy.

5. <u>Statistical Testing</u>:

Employ statistical tests such as t-tests or chi-squared tests to determine whether the differences between model predictions and market prices are statistically significant. These tests help assess if any observed discrepancies can be attributed to random chance.

6. <u>Sensitivity Analysis</u>:

Conduct sensitivity analysis by varying input parameters one at a time and observing the impact on model accuracy. This analysis provides insights into which parameters have the most significant influence on the model's performance.

7. <u>Market Scenario Testing</u>:

Evaluate the model's accuracy across different market scenarios, including periods of high volatility, trending markets, and stable conditions. This assessment helps determine the model's robustness and its ability to handle diverse market dynamics.

8. Overfitting and Generalization:

Beware of overfitting, where a model performs exceptionally well on historical data but fails to generalize to new data. To mitigate this, consider using out-of-sample testing, where the model is tested on data it hasn't been calibrated with.

9. Continuous Model Improvement:

Use insights gained from the accuracy assessment to refine the model. Adjust model parameters, incorporate new data, or explore alternative models if necessary to enhance accuracy across various scenarios.

10. Model Validation and Documentation:

Summarize the results of the accuracy assessment in a comprehensive report. Highlight the model's strengths, limitations, and performance across different scenarios. Provide detailed documentation of the validation process, including assumptions made and methodologies employed.

11. Regular Model Monitoring:

Accuracy is not a static attribute; market conditions change over time. Continuously monitor the model's performance and recalibrate it as needed to ensure that its predictions remain accurate and relevant.

In conclusion, checking the accuracy of option pricing models involves a meticulous process of comparing model predictions with actual market data, statistical analysis, and a deep understanding of market intricacies. This assessment ensures that the chosen model provides reliable insights for risk management, investment decisions, and financial analysis in the ever-evolving landscape of financial markets.