Executive Summary

The reporting period from **Day 42 to Day 47** of the Portfolio Management and Optimization modules focused on the integration of **option pricing theory**, **quantitative financial modeling**, and **risk management applications**. The week's work advanced progressively from conceptual understanding to computational implementation, emphasizing the translation of theoretical finance into actionable portfolio strategies.

The activities covered four core areas:

1. **Foundational Theory:** Understanding the role of derivatives and the Option Greeks in quantifying and managing portfolio risk.

2. **Quantitative Modeling:** Implementing the **Black-Scholes-Merton (BSM)** and **Binomial (CRR)** models to estimate theoretical prices, compare with live market data, and identify mispricing opportunities.

3. **Market Analysis:** Developing a **Python-based market scanner** to analyze pricing deviations in **NIFTY** and **M&M** options, generating systematic buy/sell insights.

4. **Applied Risk Management:** Conducting a **Delta-hedging simulation** to demonstrate real-time risk neutralization and volatility control in a self-financing framework.

The findings revealed that while **BSM and Binomial models remain indispensable benchmarks**, real-world deviations due to **volatility smiles**, **illiquidity**, and **stale quotes** necessitate more sophisticated stochastic extensions. Moreover, the **application of Greeks** provided a quantitative foundation for **dynamic hedging**, **volatility trading**, and **portfolio optimization**, significantly reducing exposure to directional market risks.

Overall, the week consolidated theoretical knowledge with data-driven analytics, highlighting how **quantitative tools enhance portfolio resilience, identify inefficiencies, and optimize risk-adjusted returns**.

Summary of Weekly Work

Day 42: Missing Content

The provided materials did not include specific outputs or documentation for Day 42.

Day 43: Derivatives Foundations and the Importance of Greeks

File: `D43_Derivatives_Foundations.ipynb`

Day 43 established the conceptual foundation for options and introduced the **Option Greeks**, key metrics used for sensitivity analysis and risk control.

Key Highlights:

- **Role of Options:** Options serve as powerful instruments for **risk management**, **income generation**, and **strategic portfolio construction**, extending investment flexibility beyond traditional equity holdings.
- **Flexibility and Leverage:** By offering high notional exposure for limited capital, options enable efficient capital deployment and sophisticated strategies like **spreads**, **collars**, and **covered positions**.
- **Portfolio Management Use Cases:**
  - **Protective Puts** act as downside insurance.
  - **Covered Calls** and **Cash-Secured Puts** enhance portfolio yields.
  - **Volatility Trading:** Options allow volatility to be treated as a tradable asset class (e.g., via **VIX options**).
- **Introduction to Greeks:**
  - **Delta (Δ):** Sensitivity to underlying price.
  - **Gamma (Γ):** Sensitivity of Delta; vital for dynamic hedging.
  - **Theta (Θ):** Measures time decay of option value.
  - **Vega (v):** Sensitivity to volatility.
  - **Rho (ρ):** Sensitivity to interest rate changes.
- **Risk Management:** Aggregated Greeks across positions provide insight into total portfolio exposures, enabling **dynamic hedging** and compliance with **risk limits**.

Day 44: Black-Scholes Model (Closed Form) and Market Scanning

File: `D44_Black_Scholes_Model_(Closed_Form)[ModelVSMarket].ipynb`

Day 44 focused on implementing the **Black-Scholes-Merton (BSM)** model for European options and applying it to live **NSE market data** for pricing validation and mispricing detection.

Key Components:

- **Model Overview:** The BSM model offers a closed-form pricing solution for European options, enabling efficient computation of theoretical prices and Greeks.
- **Limitations:** Assumes constant volatility and risk-free rate, excludes transaction costs, and applies only to European options.
- **Market Scanner:**
  - Collected live data (NIFTY and M&M options).
  - Computed **At-The-Money (ATM)** implied volatility.
  - Generated **Buy/Sell/Hold** signals based on pricing deviations using a configurable **Decision Threshold (0.03)**.

Key Findings:

- **NIFTY:** Significant mispricing observed — **Puts undervalued (up to -84%)**, likely due to illiquidity; **Calls mildly overvalued (+16.7%)**.
- **M&M:** Smaller deviations; **OTM puts undervalued (10–23%)**, **calls slightly overvalued (3–4%)**.

Day 45: BSM vs. Binomial (CRR) Option Pricing Comparison

File: `D45_Black_Scholes_Model_vs_Binomial_(CRR)_Option_Pricing.ipynb`

This day extended pricing analysis by comparing **Black-Scholes (BSM)** and **Binomial Tree (Cox–Ross–Rubinstein, CRR)** models.

Highlights:

- **Model Comparison:**
  - **BSM:** Continuous-time, closed-form analytical model.

- **Binomial (CRR):** Discrete-time, numerical model suitable for **American options** (supports early exercise).
- Binomial prices **converge to BSM** as the number of steps increases.

- **Pipeline Output:** Computed and compared:
  - BSM analytical price.
  - Binomial European price.
  - Binomial American price.
- **Findings:**
  - Reinforced **undervalued puts** and **overvalued calls** in NIFTY.
  - M&M options also reflected mild put undervaluation.
- **Strategic Implications:** Suggested potential **downside exposure (Buy PUT / Sell CALL)** and anticipation of **volatility uptick**.
- **Modern Context:** While BSM and CRR remain foundational, real-world markets require **Stochastic Volatility** and **Jump-Diffusion** extensions to capture volatility smiles and fat tails.

Day 46: In-Depth Greek Analysis

File: `D46_Option_Greeks.ipynb`

Day 46 deepened the understanding of Greeks through quantitative visualization of **Delta, Gamma, Vega, Theta, and Rho** across strike prices.

Observations:

- **Delta:** Increases (calls) or decreases (puts) monotonically with moneyness.
- **Gamma:** Peaks near ATM — critical for hedge adjustment sensitivity.
- **Vega:** Highest near ATM — indicates maximum sensitivity to volatility.

- **Theta:** Negative for long options, with steepest decay near ATM.
- **Rho:** Most significant for deep ITM calls and OTM puts.

Applications:

- Informs **hedging**, **volatility trading**, **time decay management**, and **portfolio optimization**.
- Enables structured, quantitative decision-making beyond directional speculation.

Day 47: Greeks in Practice (Delta Hedging Simulation)

File: `D47_Greeks_in_Practice_(Delta_Hedging).ipynb`

The final day implemented a **Delta-Hedging Simulator** to demonstrate real-world application of Greeks for **risk neutralization** and **volatility management**.

Methodology:

- Simulated 2000 price paths under risk-neutral conditions.
- Applied daily rebalancing with a **self-financing constraint** (realistic capital allocation).
- Compared **unhedged vs. delta-hedged PnL** performance.

Key Results:

- **Variance Reduction:**
  - M&M Call PnL volatility reduced by ~4.69x.
  - M&M Put PnL volatility reduced by ~4.02x.
- **Directional Neutrality:** Mean terminal PnL ≈ 0 — confirms effective delta hedging.
- **Residual Risks:** Persist due to **Gamma**, **Vega**, and **Theta** effects, particularly from discrete rebalancing and assumed constant volatility.

- **Visualizations:** Included histograms (hedged vs. unhedged PnL), MTM volatility decay curves, and sensitivity plots over time.

Key Insights

1. **Option Greeks are indispensable** for quantifying and managing multi-dimensional risk exposures in portfolios.

2. **Model-driven mispricing detection** can identify potential arbitrage or structural inefficiencies, though liquidity factors must be carefully considered.

3. **Dynamic hedging strategies**, especially Delta hedging, significantly stabilize returns by mitigating directional exposure.

4. **Black-Scholes and Binomial models**, while foundational, must be supplemented by modern stochastic and jump models to address real-world complexities.

5. **Visualization-driven analysis** enhances intuition about option sensitivity, aiding both traders and risk managers in decision-making.

Conclusion

Days 42–47 marked a significant advancement in integrating **theoretical finance**, **quantitative modeling**, and **practical application**. The work bridged the gap between academic option theory and applied portfolio management.
Through modeling, market scanning, and dynamic hedging simulations, the week's exercises highlighted how quantitative tools can **enhance portfolio resilience, identify inefficiencies**, and **control risk dynamically**.

This phase concludes with a strong foundation for further exploration into **stochastic volatility modeling**, **volatility surface analysis**, and **multi-asset hedging frameworks**.