Problem 1:

1. Arithmetic Returns (Last 5 Rows):

```
                 SPY      AAPL      EQIX
Date
2024-12-27 -0.011492 -0.014678 -0.006966
2024-12-30 -0.012377 -0.014699 -0.008064
2024-12-31 -0.004603 -0.008493  0.006512
2025-01-02 -0.003422 -0.027671  0.000497
2025-01-03  0.011538 -0.003445  0.015745
SPY     0.008077
AAPL    0.013483
EQIX    0.015361
```

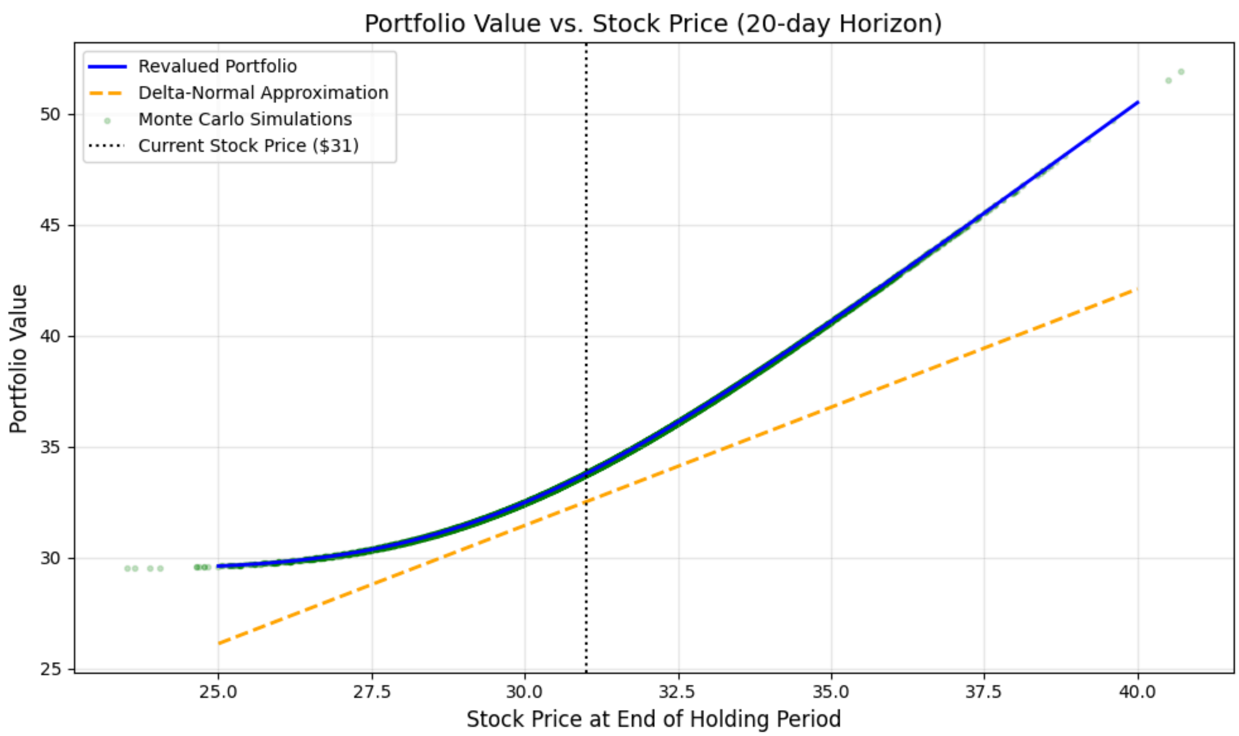
2. Log Returns (Last 5 Rows):

```
                 SPY      AAPL      EQIX
Date
2024-12-27 -0.011515 -0.014675 -0.006867
2024-12-30 -0.012410 -0.014696 -0.007972
2024-12-31 -0.004577 -0.008427  0.006602
2025-01-02 -0.003392 -0.027930  0.000613
2025-01-03  0.011494 -0.003356  0.015725
SPY     0.008078
AAPL    0.013446
EQIX    0.015270
```

Problem 2:

1. Current Value of Portfolio given today is 1/3/2025: $251862.50
2. VAR and ES
    a. *Method 2a (Normal EW Covariance):*
    b. VaR 5%: $3886.02
    c. ES 5%: $4873.23
    d. *Method 2b (Copula):*
    e. VaR (T-distribution with Gaussian Copula, 5%): $4379.51
    f. ES (T-distribution with Gaussian Copula, 5%): $6123.02
    g. *Method 2c (Historical):*
    h. VaR (Historical, 5%): $4575.03
    i. ES (Historical, 5%): $6059.39
3. The three VaR and ES estimation methods differ in their assumptions and risk sensitivity. Normal EW Covariance assumes normally distributed returns, making it computationally efficient but prone to underestimating extreme losses, resulting in the lowest VaR ($3,886.02) and ES ($4,873.23). T-distribution with Gaussian Copula captures fat tails and dependencies better, producing a higher VaR ($4,379.51) and the highest ES ($6,123.02), but is more complex. Historical Simulation relies on past market data, providing the highest VaR ($4,575.03) and ES ($6,059.39), though it assumes historical patterns persist. For accurate risk assessment, a combination of these methods is ideal.

Problem 3:

1. Implied Volatility: 0.3351
2. Delta: 0.6659, Vega: 5.6407, Theta: -5.5446
   Estimated Option Price Change for 1% Volatility Increase: $0.0564
3. Put Price (BSM Model): $1.2593 Put-Call Parity Difference: 0.0000; Given that the Put-Call Parity Difference is 0.0000, it confirms that the parity relationship holds exactly, as expected in a theoretically efficient market. This result indicates that the calculated put price aligns perfectly with the put-call parity condition, suggesting no arbitrage opportunities.
4. Delta-Normal Approximation (20-day, 5% level) [Standard ES]:
   VaR = 4.2717
   ES (Standard) = 5.2383
5. Monte Carlo Simulation (20-day, 5% level):
   VaR = 2.5964
   ES = 2.9147
6. 

7. The Delta-Normal method assumes a normal distribution of returns and linear sensitivity to stock price changes, which simplifies risk estimation but may underestimate risk in highly volatile or non-linear scenarios. The Monte Carlo simulation, in contrast, captures the full range of potential portfolio values by simulating thousands of possible price paths, reflecting non-linearity and tail risks more effectively. This difference is evident in the results: the Delta-Normal method estimates a higher Value at Risk (VaR) and Expected Shortfall (ES), indicating that it assumes a greater potential downside due to its reliance on a normal distribution. However, the Monte Carlo method, by incorporating non-linearity, provides a more accurate measure of extreme events, showing lower VaR and ES values. The portfolio value graph further illustrates this: while the Delta-Normal

approximation follows a straight-line assumption, the revalued portfolio from Monte Carlo simulations displays a more realistic curvature, accounting for convexity in option pricing. Thus, while Delta-Normal is computationally efficient, Monte Carlo provides a more robust risk estimation, particularly for portfolios with significant option exposure.