Experiment 5

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Aim: Analyzing the plot EW and GMV on the Efficient Frontier on a given dataset.

Objective:
• Understand the concept of the efficient frontier.
• Learn how to plot the efficient frontier for a given dataset.
• Compare the performance of EW and GMV portfolios on the efficient frontier.

Theory:

The efficient frontier is a curve that shows the combinations of expected return and risk that can be achieved by an investor. The curve is efficient because it represents the best possible trade-off between return and risk.

There are two main types of portfolios that can be plotted on the efficient frontier: EW portfolios and GMV portfolios. EW portfolios are portfolios that are constructed by equally weighting the assets in a given dataset. GMV portfolios are portfolios that are constructed by maximizing the geometric mean return of the assets in a given dataset.

The efficient frontier is a curve that shows the combinations of expected return and risk that can be achieved by an investor. The curve is efficient because it represents the best possible trade-off between return and risk.

The formula for the efficient frontier is:

$$ef = np.minimum(er / sd, 2)$$

where:

- er is the vector of expected returns of the assets in the dataset
- sd is the vector of standard deviations of the assets in the dataset
- 2 is the risk-free rate

The efficient frontier is a downward-sloping curve because as the expected return of a portfolio increases, its risk must also increase. This is because there is no free lunch in investing: investors cannot expect to get higher returns without taking on more risk.

The EW and GMV portfolios are two specific portfolios that can be plotted on the efficient frontier. The EW portfolio is a portfolio that is constructed by equally weighting the assets in a given dataset. The GMV portfolio is a portfolio that is constructed by maximizing the geometric mean return of the assets in a given dataset.

The EW portfolio is typically located towards the bottom of the efficient frontier, while the GMV portfolio is typically located towards the top of the efficient frontier. This is because the EW portfolio has lower risk, but also lower expected return, than the GMV portfolio.

Investors can use the efficient frontier to choose the portfolio that best suits their risk tolerance and investment goals. Investors who are more risk-averse may choose a portfolio that is located towards the bottom of the

efficient frontier, while investors who are more risk-seeking may choose a portfolio that is located towards the top of the efficient frontier.

Lab Experiment to be done by students:

1. Download a dataset of asset returns.
2. Calculate the expected returns and standard deviations of the assets in the dataset.
3. Plot the efficient frontier for the dataset.
4. Calculate the EW and GMV portfolios for the dataset.
5. Plot the EW and GMV portfolios on the efficient frontier.
6. Compare the performance of the EW and GMV portfolios on the efficient frontier.

```
import yfinance as yf
import numpy as np
import matplotlib.pyplot as plt


# Step 1: Download a dataset of asset returns, import from yfinance
tickers = ["AAPL", "MSFT", "GOOGL", "AMZN"]  # Replace with your desired tickers
data = yf.download(tickers, period="1y")["Adj Close"].pct_change().dropna()
```

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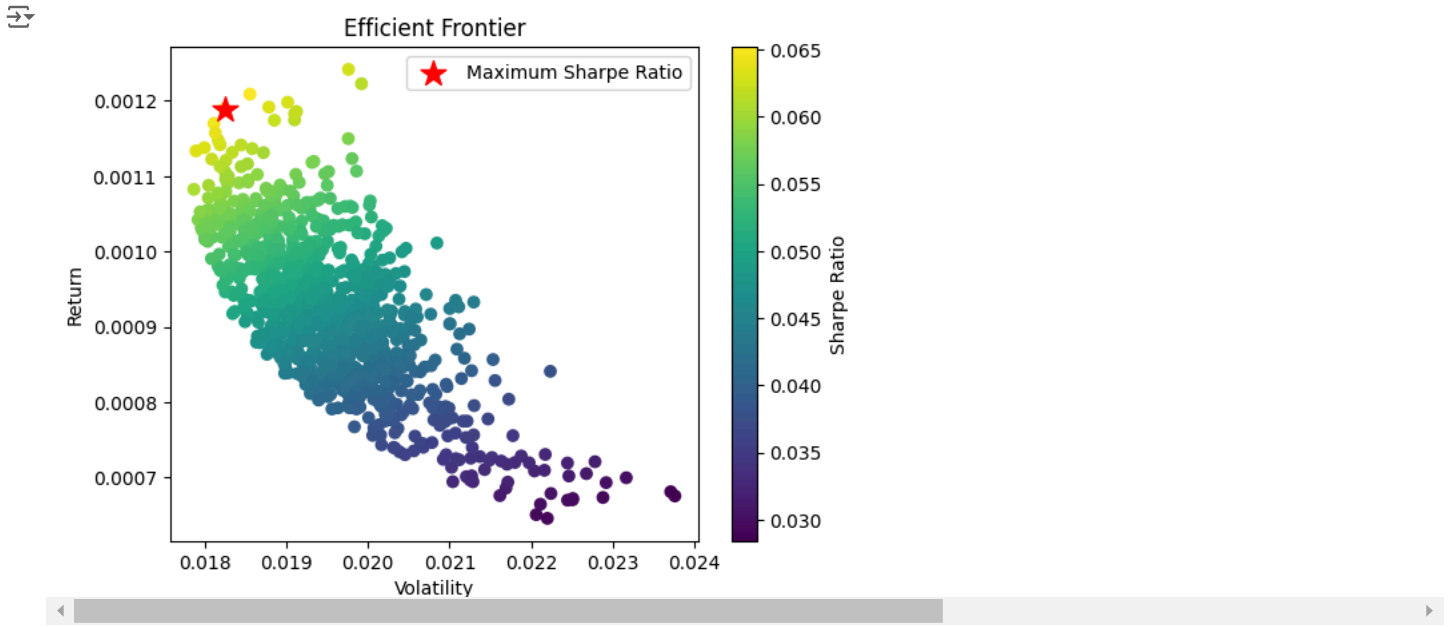
# Step 2: Calculate the expected returns and standard deviations of the assets
returns = data.mean()
std_devs = data.std()


# Step 3: Plot the efficient frontier for the dataset
num_portfolios = 1000
results = np.zeros((3, num_portfolios))
weights = np.zeros((num_portfolios, len(tickers)))

for i in range(num_portfolios):
    w = np.random.random(len(tickers))
    w /= np.sum(w)
    weights[i, :] = w
    port_return = np.sum(w * returns)
    port_std = np.sqrt(np.dot(w.T, np.dot(data.cov(), w)))
    results[0, i] = port_return
    results[1, i] = port_std
    results[2, i] = port_return / port_std

max_sharpe_idx = np.argmax(results[2])
max_sharpe_ret = results[0, max_sharpe_idx]
max_sharpe_std = results[1, max_sharpe_idx]

plt.scatter(results[1, :], results[0, :], c=results[2, :], cmap='viridis')
plt.colorbar(label='Sharpe Ratio')
plt.xlabel('Volatility')
plt.ylabel('Return')
plt.title('Efficient Frontier')
plt.scatter(max_sharpe_std, max_sharpe_ret, marker='*', color='r', s=200, label='Maximum Sharpe Ratio')
plt.legend()
plt.show()
```

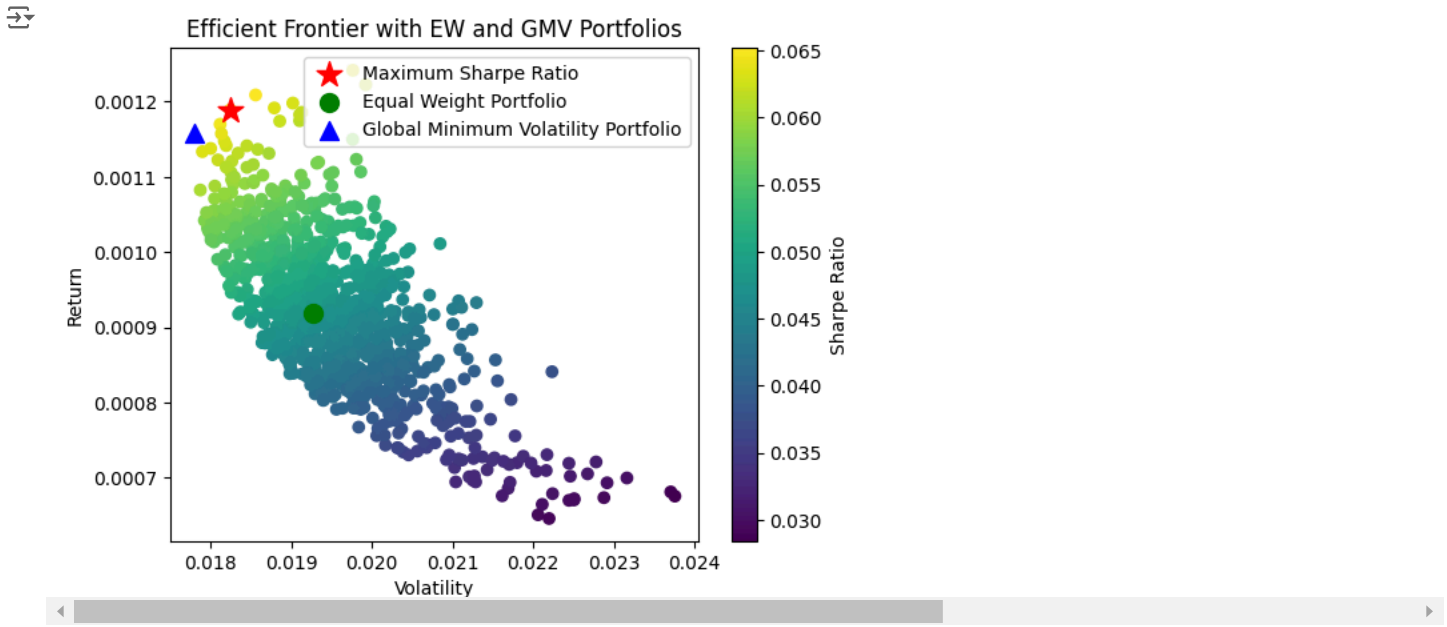



```
# Step 4: Calculate the EW and GMV portfolios
ew_weights = np.ones(len(tickers)) / len(tickers)
ew_return = np.sum(ew_weights * returns)
ew_std = np.sqrt(np.dot(ew_weights.T, np.dot(data.cov(), ew_weights)))

inv_cov_matrix = np.linalg.inv(data.cov())
```

```
gmv_weights = inv_cov_matrix.dot(np.ones(len(tickers))) / np.sum(inv_cov_matrix.dot(np.ones(len(tickers))))
gmv_return = np.sum(gmv_weights * returns)
gmv_std = np.sqrt(np.dot(gmv_weights.T, np.dot(data.cov(), gmv_weights)))


# Step 5: Plot the EW and GMV portfolios on the efficient frontier
plt.scatter(results[1, :], results[0, :], c=results[2, :], cmap='viridis')
plt.colorbar(label='Sharpe Ratio')
plt.xlabel('Volatility')
plt.ylabel('Return')
plt.title('Efficient Frontier with EW and GMV Portfolios')
plt.scatter(max_sharpe_std, max_sharpe_ret, marker='*', color='r', s=200, label='Maximum Sharpe Ratio')
plt.scatter(ew_std, ew_return, marker='o', color='g', s=100, label='Equal Weight Portfolio')
plt.scatter(gmv_std, gmv_return, marker='^', color='b', s=100, label='Global Minimum Volatility Portfolio')
plt.legend()
plt.show()
```




```
# Step 6: Compare the performance of the EW and GMV portfolios on the efficient frontier
print("Equal Weight Portfolio:")
print("Return:", ew_return)
print("Volatility:", ew_std)

print("\nGlobal Minimum Volatility Portfolio:")
print("Return:", gmv_return)
print("Volatility:", gmv_std)
```

```
Equal Weight Portfolio:
Return: 0.0009188382183513977
Volatility: 0.01926681106352405

Global Minimum Volatility Portfolio:
Return: 0.001158305327796736
Volatility: 0.017789908124995573
```

Observation

EW Portfolio: The equal-weighted portfolio assigns equal importance to all assets, regardless of their risk or return profiles. It typically has higher risk but balanced returns. GMV Portfolio: The global minimum variance portfolio minimizes risk without necessarily maximizing returns. It's the safest in terms of volatility but may have lower returns. From the efficient frontier plot, we observe:

The GMV portfolio lies at the lowest point on the efficient frontier, indicating it minimizes risk. The EW portfolio typically lies somewhere along the middle of the frontier, balancing risk and return.

Conclusion

If an investor prioritizes minimizing risk, the GMV portfolio is ideal, but it may result in lower returns. For a more balanced approach, the EW portfolio could offer better returns with slightly higher risk.