UCD Michael Smurfit Graduate Business School

Title:	**Capital Markets and Instruments Group Project**
Description:	**In this report the Boeing Company (BA) and Caterpillar Inc (CAT) were analysed from an investment perspective**
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Declaration

We certify that this submission is entirely our own work and has not been taken from the work of others, to the extent that such work has been cited and acknowledged within the text of our own work.

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  - Question 6
  - Question 7
- **Daniel Lewins**
  - Questions 1
  - Question 2
  - Question 4
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- **Jason O'Connor**
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  - Question 5
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Abstract

This report was completed as part of Continuous assessment for Capital Markets and Instruments Module, in UCD Michael Smurfit Graduate Business School. This report contains a detailed analysis of the risk and return associated with investing in the Boeing Company (CA) and Caterpillar Inc. (CAT) and the most appropriate investment opportunity between the companies.

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Nomenclature

$$r_t = Daily\ Log\ Return$$

$$P_t = Closing\ Stock\ Price\ on\ a\ selected\ day$$

$$P_{t-1} = Closing\ Stock\ price\ on\ day\ previous\ to\ selected\ day$$

$$\sigma = standard\ deviation$$

$$x_i = each\ daily\ log\ return$$

$$\mu = mean\ daily\ \log return\ of\ each\ stock$$

$$n = size\ of\ sample$$

$$r = correlation\ coefficient$$

$$\omega = weight\ of\ portfolio$$

$$\rho = correlation\ coefficient$$

$$E(r) = Expected\ Return$$

$$k = coefficient\ of\ risk\ aversion$$

$$R_f = Risk\ Free\ Return\ Rate$$

$$\beta_p = Beta\ Coeffiecient\ of\ Stock$$

$$R_m = Market\ Return\ Rate$$

$$\alpha = Jensen's\ Alpha$$

$$R(r)_i = Realised\ Return\ on\ Stock$$

Introduction

This report contains a detailed analysis of the risk and return associated with investing in the Boeing Company (CA) and Caterpillar Inc. (CAT), and the most appropriate investment opportunity between the companies. To identify the best investment opportunity, we analysed the following aspects of each stock over the between 1st July 2019 and 30th June 2024. The method section of this report shows how calculations were conducted and the results sections displays all results.

1.1 Boeing Company (BA)

1.1.1 Background Information

Boeing is a leading global company in the aerospace industry with over 170,000 employees across 65 countries with their products being used in over 150 countries. The company is broken into three business units: Commercial Airplanes (43.45% of revenue), Defense Space and Security (31.98% of revenue) and Global Services (24.53% of revenue). The company brought in a total revenue of $77.8 billion dollars in 2023. [1][2]

1.1.2 Stock Prices

Between 1st July 2019 and 30th June 2024 the Boeing stock price has fallen 48.61% as can be seen on the time series chart in Figure 1 below. The performance of Boeing across each of the last five years is explained by the following:

- **2020** – Stock price plummeted thanks to Covid-19 travel restrictions leading to little demand for new aircraft resulting in Boeing losing $12 billion across the year. [3]
- **2021** – Losses per share came in higher than expected for year resulting in slight decline across year. [4]
- **2022** – Shares fell 10% in May after disappointing delivery numbers were reported and fell again in September due to market slowdown. However, revenue rose towards end of year due to increasing demand for aircraft. [5][6]
- **2023** – Revenue rose from $66.6 billion to $77.8 billion as well as a huge demand for new aircraft resulted in rise in share value for Boeing. [7]
- **2024** – Accident on Alaskan Air flight involving cabin panel detaching in January and delays in production of new aircraft has led to decline in share value. [8]

Figure 1 – Boeing stock price between 1st July 2019 and 30th June 2024

1.2 Caterpillar Inc. (CAT)

1.2.1 Background Information

Caterpillar is the world's leading manufacturer of construction and mining equipment, industrial gas turbines and diesel-electric locomotives with over 110,000 employees across 6 continents with their products being used globally. The company brought in a total revenue of $67 billion dollars in 2023. [9]

1.2.2 Stock Prices

Between 1st July 2019 and 30th June 2024 the Caterpillar stock price has risen 145.20% as can be seen on the time series chart in Figure 2 below. The performance of Caterpillar across each of the last five years is explained by the following:

- **2020** – Despite poor Q4 performance, expectation for strong 2021 led to increase in share value. [10]
- **2021** – Sales and revenues up 23% led to increase in share value. [11]
- **2022** – Caterpillars stock value increased due to increased investment into infrastructure and mining sectors [24]
- **2023** – Caterpillar stock value increased again due to strong demand in energy and transportation sector. [12]
- **2024** – Caterpillar outperformed Q2 estimates again leading to strong start to year however deceleration of construction industry has led to slow start to second half of year.[13][14]

Figure 2 – Caterpillar stock price between 1st July 2019 and 30th June 2024

Method

1.3 Mean, Standard Deviation and Correlation

The first step in analysis of stocks is to obtain the daily log return of stocks. This is done by using the following equation:

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

These calculations were completed in excel and once completed were graphed as shown in Figure 3 and 4 below.

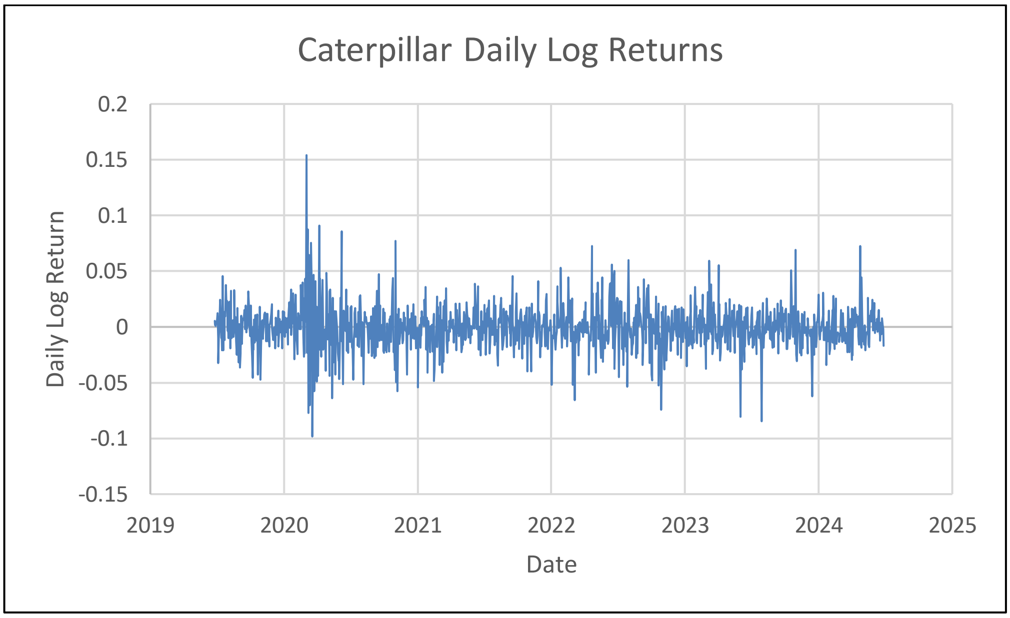

Figure 3 - Daily Log Returns of Caterpillar Stock

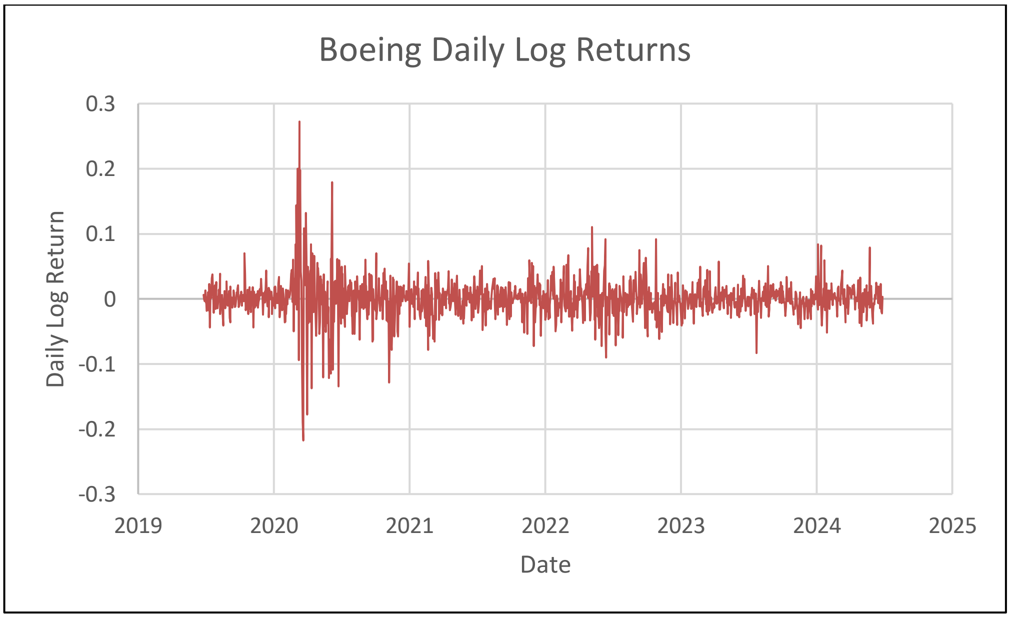

Figure 4 – Daily Log Returns of Boeing Stock

The equation used to compute the standard deviation is the following:

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{n}}$$

This calculation was carried out in Python with the code used shown in Appendix A below. The obtained results found the standard deviation of the Boeing stock to be 0.032 and the standard deviation of the Caterpillar Stock to be 0.0204

The following equation was used in order to calculate the standard deviation:

$$r = \frac{\sum(x_i - \bar{x})(y_i - \overline{y})}{(n-1)\sigma_x\sigma_y}$$

This calculation was also carried out using Python with the code used shown in Appendix A below. The obtained results found the correlation coefficient between the two stocks to be 0.4799.

1.4 Investment Opportunity Set and Efficient Frontier

In order to graph the opportunity set and plot the efficient frontier, two sets of values must be obtained; the standard deviation (x-axis) and mean return (y-axis) of varyingly weighted portfolios needed to be found.

The equation used to calculate the standard deviations of a portfolio containing two stocks is the following:

$$\sigma_p^2 = \omega_x^2\sigma_x^2 + \omega_y^2\sigma_y^2 + 2\omega_x\omega_y\sigma_x\sigma_y\rho_{xy}$$

The full list of results for the standard deviations can be seen in Appendix B below.

The equation used to calculate the mean return of a portfolio containing two stocks is the following:

$$E(r)_p = \omega_x E(r)_x + \omega_y E(r)_y$$

The full list of results for the standard deviations can be seen in Appendix B below. The opportunity set and efficient frontier could finally be plotted after these calculations were completed and can be seen in Figure 5 below.

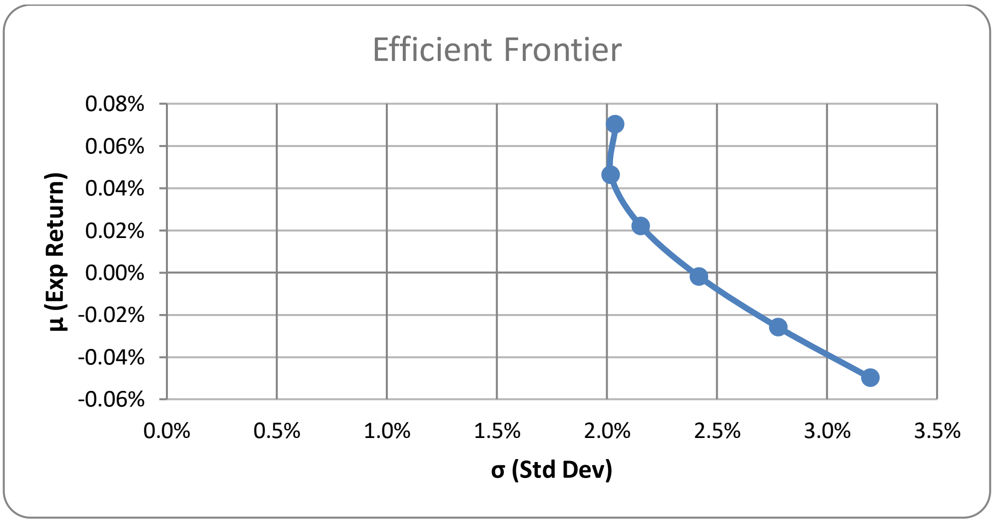

Figure 5 – Investment Opportunity Set and Efficient Frontier

1.5 Mean Returns of Varying Portfolio Weights

The number of portfolio weights being analysed was increased this analysis comes due to inclusion that either of the stocks could be shorted allowing for negative weights in the portfolio. The calculations were conducted in Python and can be seen in Appendix A below. The updated Efficiency Frontier can be seen in Figure 6 below.

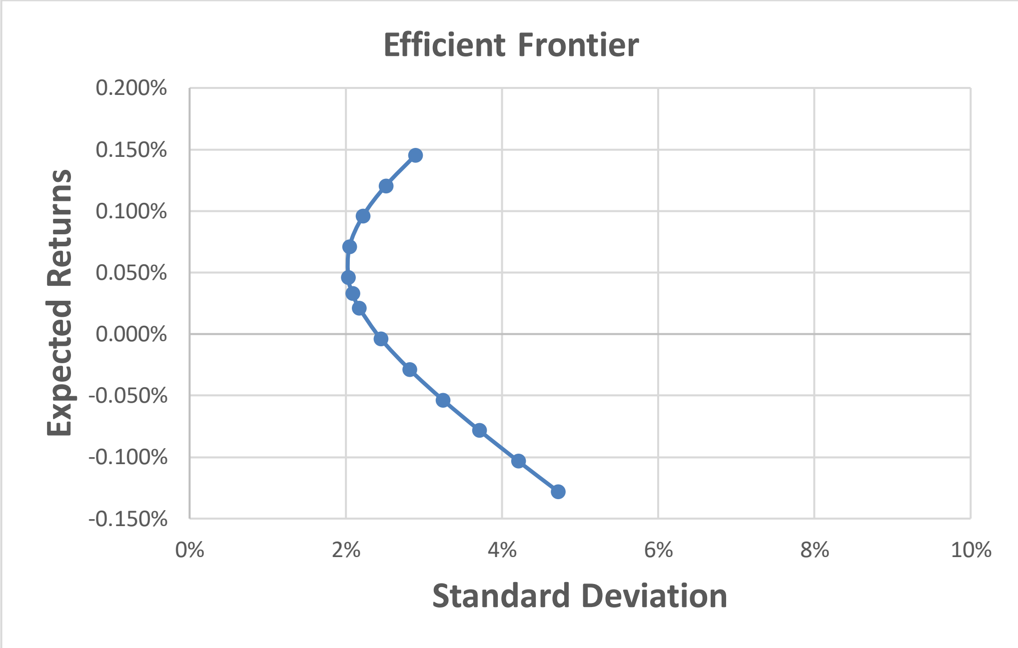

Figure 6 – Investment Opportunity Set and Efficient Frontier

1.6 Minimum Variance Portfolio

In order to find the minimum variance portfolio, the following formula was used:

$$\omega_x = \frac{\sigma_y^2 - \rho_{xy}\sigma_x\sigma_y}{\sigma_x^2 + \sigma_y^2 - 2\rho_{xy}\sigma_x\sigma_y}$$

This calculation was completed, and the minimum variance portfolio was found to be 69.39% weighted Caterpillar and 30.61% weighted Boeing. The minimum variance portfolio can be seen highlighted as the red data point on the efficient frontier graph shown in Figure 7 below.

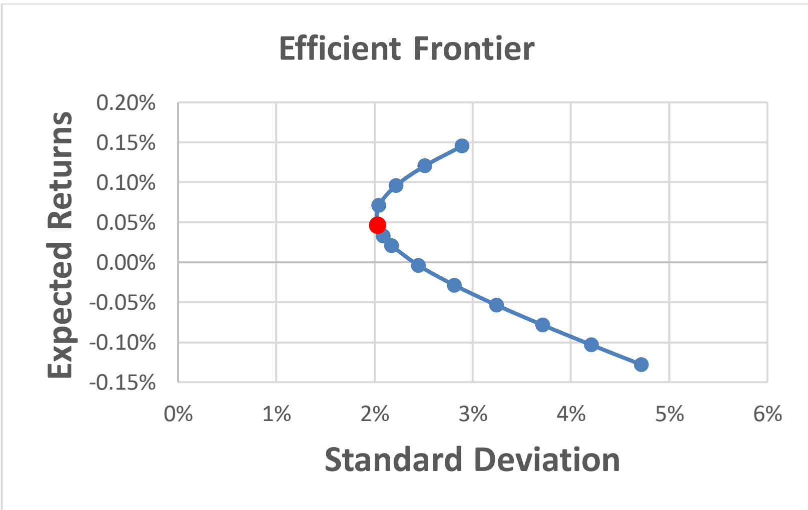

Figure 7 – Efficient Frontier Displaying Minimum Variance Portfolio

1.7 Risk Free Rates and Obtaining Tangency Portfolio

The risk-free rate used for these calculations is the 10-Year US Treasury Bill which has a daily rate of 0.010976%.

The optimal portfolio chosen to use as the tangential point on the Efficient Frontier was selected as the portfolio with the highest Sharpe Ratio. The equation used to calculate the Sharpe ratio is as follows:

$$Sharpe\ Ratio = \frac{E(r)_p - E(r)_f}{\sigma_P}$$

The Sharpe Ratio was calculated for every portfolio in previous sections of this report, it was found that the portfolio with the highest Sharpe ratio was 160% Caterpillar and -60% Boeing (this portfolio has an $E(r)_p$ = 0.146%) . From this we can draw the CAL line shown in red on Figure 7 below.

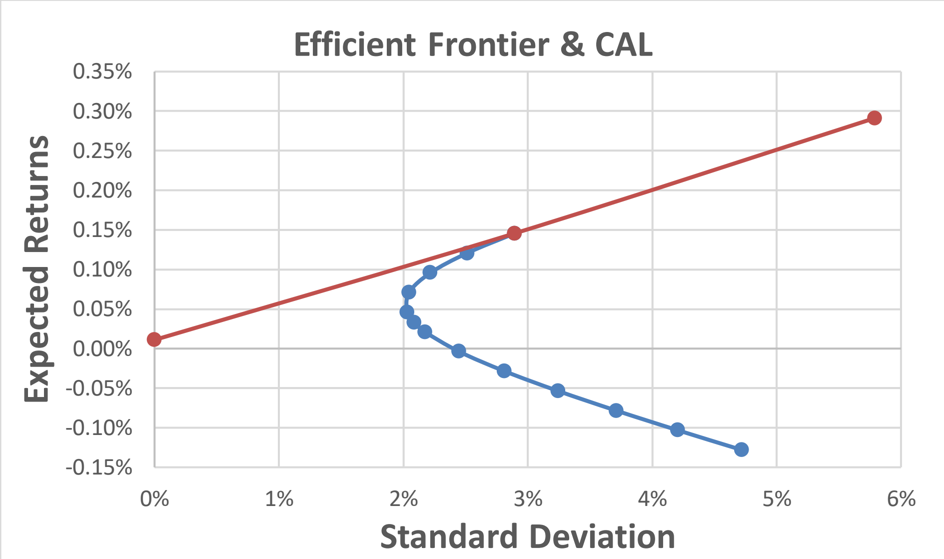

Figure 7 – Efficient Frontier with CAL line

1.8 Portfolio Optimization

The Utility function is given by the following equation:

$$U = E(r)_p - k \times \sigma_p^2$$

We know from earlier that:

$$E(r)_p = \omega_x E(r)_x + \omega_y E(r)_y$$

Subbing this back into the equation above where:

$$\omega_x = weight\ of\ risk\ free\ return$$

$$E(r)_x = return\ of\ risk\ free\ investment = 0.010976\%$$

$$\omega_y = weight\ of\ tangency\ portfolio$$

$$E(r)_y = return\ of\ tangency\ portfolio = 0.146\%$$

We obtain the following equation:

$$U = (0.00010976\omega_x + 0.00146\omega_y) - k \times \sigma_p^2$$

We know that the total weight of the portfolio must equal one therefore:

$$1 = \omega_y + \omega_x$$

Subbing this back into the equation above we get:

$$U = (0.00010976\omega_x + 0.00146(1 - \omega_x) - k \times \sigma_p^2$$

In order to maximise the function, we must differentiate the function with respect to x and set the derivative equal to zero. Solving this we obtain the following:

$$1 - \omega_x = 0.00951/(0.00137 * \mathrm{k})$$

This obtains the following formula which values allows us to maximise the Utility function depending on the k value.

$$X = 0.0013503/0.00167 * \mathrm{k}$$

1.9 Finding Beta Coefficients

The equation used to find the Beta Coefficient of each stock (β) is the CAPM formula shown below:

$$E(r)_i = R_f + \beta_i \times (R_m - R_f)$$

For the market return rate for this question, the SPX index was used and for the risk-free rate 10-year US Treasury Bills were used. Rearranging the CAPM equation above to get Beta on its own on one side we get the following:

$$\beta_p = \frac{E(r)_i - R_f}{R_m - R_f}$$

By using this formula at each day during the five-year period and plotting the daily returns of the market versus the stock and plotting a linear trendline the slope of that trendline is the daily Beta Coefficient. The plotted graph can be seen in Figure 10 and 9 below.

1.10 Prediction of Stock Returns

The expected return of each stock was calculated using the CAPM formula:

$$E(r)_i = R_f + \beta_i \times (R_m - R_f)$$

The expected returns were then plotted against the Beta coefficients (calculated in 2.7) and the expected returns were then compared against the realised returns shown on the SML graph shown in the in Figure 11 in the results section of this report.

The Jensen's Alpha was calculated by using the below formula:

$$\alpha = (r)_i - E(r)_i$$

Results

The following Table 1 displays the mean daily log return and standard deviation of Boeing and Caterpillar stocks between 1st July 2019 and 30th June 2024. From the table it is clear that Caterpillar was a far better performing stock over this period as it has a smaller standard Deviation and a higher return. The found correlation coefficient between Boeing and Caterpillar for the same period was 0.4799.

Table 1 – Mean Daily Returns and Standard Deviation of Boeing and Caterpillar Stocks

	Boeing	**Caterpillar**
Mean Daily Log Return (%)	-0.05	0.07
Standard Deviation (%)	3.2	2.04

The following Table 2 shows the mean return, standard deviation and Sharpe ratio calculated for varying portfolio weights assuming shorts can be sold on the stocks and the weights can go into negative. From this analysis it was found that the portfolios with a higher weight of Caterpillar stock had a better Sharpe ratio, this was expected due to caterpillar having a higher return and lower standard deviation.

Table 2 – Mean Return, Standard Deviation and Sharpe Ratio of Varying Weighted Portfolios

Portfolio (BA%, CAT%)	**Mean Return**	**Standard Deviation**	**Sharpe Ratio**
(160%, -60%)	-0.128%	4.72%	-0.02946485
(140%, -40%)	-0.103%	4.21%	-0.02715158
(120%, -20%)	-0.078%	3.71%	-0.02407395
(100%, 0%)	-0.053%	3.24%	-0.01988104
(80%, 20%)	-0.029%	2.81%	-0.01406577
(60%, 40%)	-0.004%	2.45%	-0.00600601
(40%, 60%)	0.021%	2.17%	0.004686435
(20%, 80%)	0.046%	2.03%	0.017267985
(0%, 100%)	0.071%	2.05%	0.029287645
(-20%, 120%)	0.096%	2.22%	0.038241372
(-40%, 140%)	0.121%	2.51%	0.043651381
(-60%, 160%)	0.146%	2.89%	0.046498945

The following graph 7 displays the efficient frontier graph with the CAL line running through the risk-free return and the tangential portfolio (portfolio with highest Sharpe ratio on Table 2 above). The minimum variance portfolio was found to be 30.61% Boeing (BA) and 69.36% Caterpillar (CAT) and can be seen highlighted as the green data point on the efficient frontier in Figure 8 below.

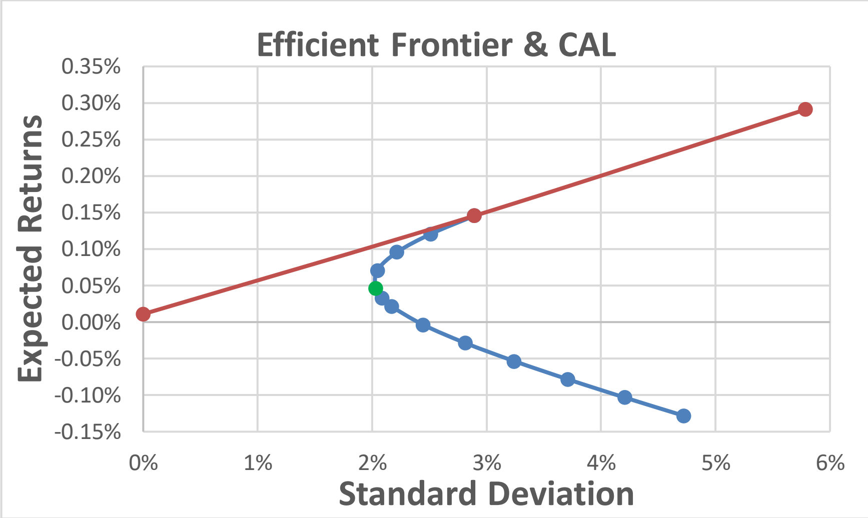

Figure 8 - Efficient Frontier & CAL Graph

The following table 3 displays the weights of the risk free and risky asset at different risk aversion coefficients. As the risk aversion coefficient increases (k) the weight of the risk-free investment increases, this decreases the risk and return of the chosen portfolio, reflecting the investors preference for lower risk.

Table 3 - weights of the risk free and risky asset at different risk aversion coefficients

k	Weights				
	Risk free asset(x)	**Asset A + Asset B(1-x)**	**Portfolio return r_p**	**Portfolio Variance σ_p^2**	**Utility (Portfolio return) - (k*portfolio variance)**
1	0.19	0.81	0.119784%	0.05476%	0.000650
2	0.60	0.40	0.065380%	0.01369%	0.000380
3	0.73	0.27	0.047245%	0.00608%	0.000290
4	0.80	0.20	0.038178%	0.00342%	0.000245
5	0.84	0.16	0.032737%	0.00219%	0.000218
6	0.87	0.13	0.029110%	0.00152%	0.000200
7	0.88	0.12	0.026520%	0.00112%	0.000187
8	0.90	0.10	0.024577%	0.00086%	0.000177

The Daily regression graphs used to find the daily Beta coefficients of the two stocks being compared can be seen in Figure 8 and 9 below. From these graphs the found Betas have been inserted in the table 4 below. From this we can see that Boeing has a Beta closer to 1 meaning it acted more in line with the market across the recorded period.

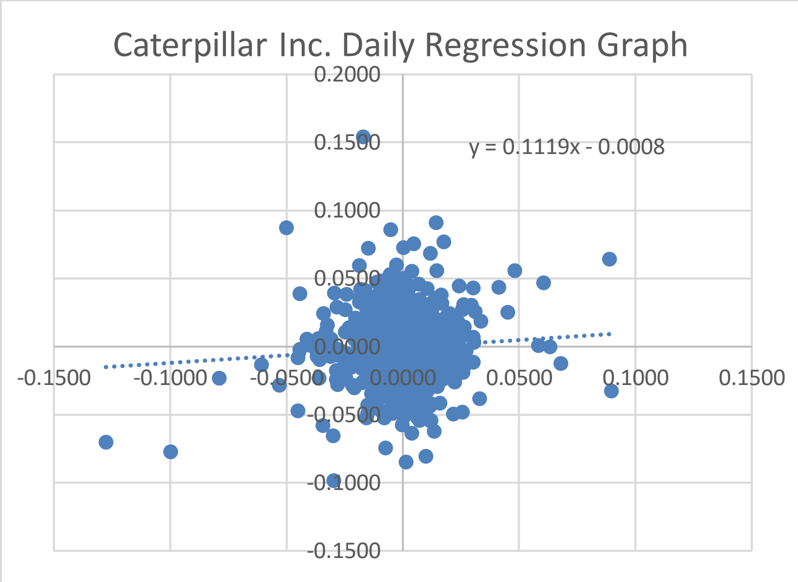

Figure 9 - Caterpillar Daily Regression Graph

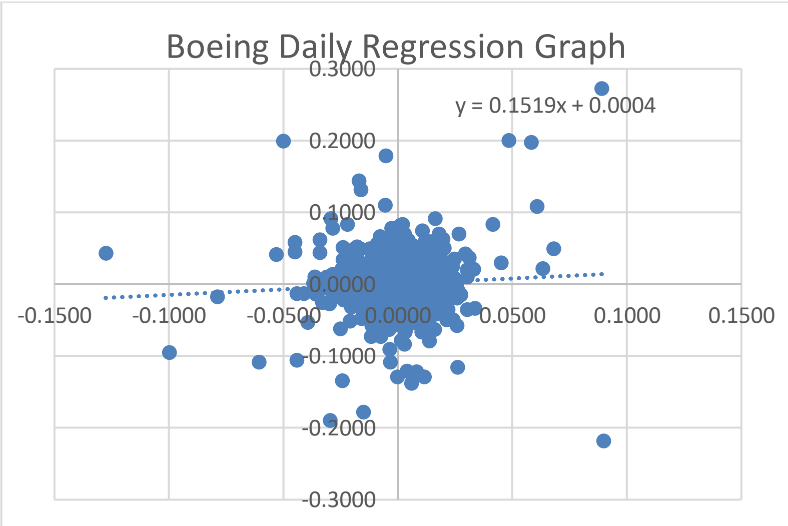

Figure 10 - Boeing Daily Regression Graph

Table 4 - Daily Beta Coefficients

	Boeing	**Caterpillar**
Beta Coefficient (β)	0.152	0.112

The realised/actual returns plots below the SML for both 9th and 24th July. This signifies that the stocks underperformed against the expected return on these two days. This is further proved by the negative Jensen's alpha calculated on both days. A negative alpha signifies that the stock in the market is yielding less than what is expected, which implies that both stocks are overvalued. The realised return on 31st July plots above the SML which indicates that the stocks are undervalued. A positive Jensen's alpha signifies that the asset has outperformed the expected returns, which implies that the stocks are undervalued.

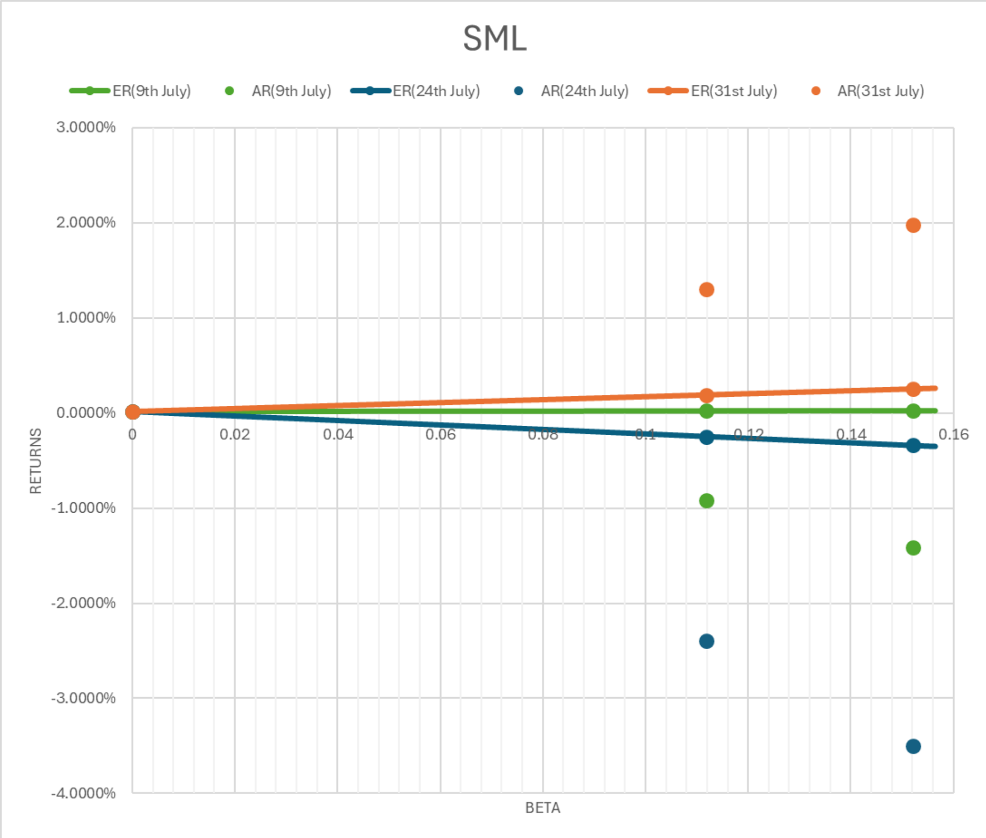

Figure 11 - SML Graph

Comparing the alphas across the two stocks, we can infer that the stock with a larger positive Jensen's alpha has outperformed its expectation more than the other stock, and a stock with a smaller negative alpha has underperformed at a smaller percentage than the other stock. That is, Caterpillar has provided better risk-adjusted returns on 9th and 24th July, given the stock has lower negative Jensen's alpha on both days. On 31st July, Boeing has a higher positive alpha which implies that it has provided better risk-adjusted return. This is in line with the interpretation on q8) beta, that Caterpillar would be an attractive investment for a risk averse investor where the losses on unexpected risks are lower compared to Boeing, but also the gains are also smaller in comparison.

Table 5 - Jensen's Alpha

	Boeing	Caterpillar
9th July 2024	-0.014	-0.009
25th July 2024	-0.032	-0.021
31st July 2024	0.017	0.011

Conclusions

In terms of a two-asset portfolio consisting of a mix of the two stocks, a portfolio weighted heavily towards Caterpillar dominates for both risk-averse and risk-taking investors alike. A portfolio weighted towards Boeing not only provides lower returns but also introduces greater levels of risk. However, when we consider a three-asset portfolio now including the addition of 10-year US Treasury Bonds, we find that the optimal balance between risk-free and risky assets depends heavily on the investor's attitude towards risk. A less risk-averse investor seeking maximum returns will opt to put more of their money towards a portfolio containing more of the risky assets i.e. the two stocks whereas someone with a lower appetite for risk will tend to invest in a portfolio weighted towards the risk-free asset i.e. the US 10-Year Treasury Bill.

Appendices

1.11 Appendix A – Python Script

In [1]:

```
import pandas as pd
import numpy as np
```

In [2]:

```
boeing = pd.read_csv('Boeing Prices.csv')
catp = pd.read_csv('Caterpillar Prices.csv')
```

In [3]:

```
boeing = boeing.set_index('Date')
catp = catp.set_index('Date')
```

In [4]:

```
import matplotlib.pyplot as plt
```

In [5]:

```
boeing['Close'] = boeing['Close'].str.replace("$", "")
boeing['Close'] = boeing['Close'].astype(float)
```

```
C:\Users\danie\AppData\Local\Temp\ipykernel_3088\27984824.py:1: FutureWarning: T
he default value of regex will change from True to False in a future version. In
addition, single character regular expressions will *not* be treated as literal
strings when regex=True.
  boeing['Close'] = boeing['Close'].str.replace("$", "")
```

In [6]:

```
catp['Close'] = catp['Close'].str.replace("$", "")
catp['Close'] = catp['Close'].astype(float)
```

```
C:\Users\danie\AppData\Local\Temp\ipykernel_3088\4095284162.py:1: FutureWarning:
The default value of regex will change from True to False in a future version. I
n addition, single character regular expressions will *not* be treated as litera
l strings when regex=True.
  catp['Close'] = catp['Close'].str.replace("$", "")
```

In [7]:

```
boeing_returns = np.log(boeing['Close'] / boeing['Close'].shift(1))
caterpillar_returns = np.log(catp['Close'] / catp['Close'].shift(1))

# Calculate mean and standard deviation of Boeing returns
boeing_mean = boeing_returns.mean()
boeing_std = boeing_returns.std()

# Calculate mean and standard deviation of Caterpillar returns
caterpillar_mean = caterpillar_returns.mean()
caterpillar_std = caterpillar_returns.std()

# Calculate correlation of Boeing and Caterpillar returns
correlation = boeing_returns.corr(caterpillar_returns)

print("Boeing Returns:")
print(f"Mean: {boeing_mean:.4f}")
print(f"Standard Deviation: {boeing_std:.4f}")

print("\nCaterpillar Returns:")
print(f"Mean: {caterpillar_mean:.4f}")
print(f"Standard Deviation: {caterpillar_std:.4f}")

print(f"\nCorrelation of Boeing and Caterpillar Returns: {correlation:.4f}")
```

```
Boeing Returns:
```

```
Mean: 0.0005
Standard Deviation: 0.0320

Caterpillar Returns:
Mean: -0.0007
Standard Deviation: 0.0204

Correlation of Boeing and Caterpillar Returns: 0.4799
```

```
r1 = 0.0005  # mean return of Stock 1

sigma1 = 0.032  # standard deviation of Stock 1

r2 = -0.0007  # mean return of Stock 2

sigma2 = 0.0204  # standard deviation of Stock 2

rho = 0.5  # correlation coefficient between Stock 1 and Stock 2


# Define the weights for each portfolio

weights = [

    (1.6, -0.6),  # i

    (1.4, -0.4),  # ii

    (1.2, -0.2),  # iii

    (1.0, 0.0),  # iv

    (0.8, 0.2),  # v

    (0.6, 0.4),  # vi

    (0.4, 0.6),  # vii

    (0.2, 0.8),  # viii

    (0.0, 1.0),  # ix

    (-0.2, 1.2),  # x

    (-0.4, 1.4),  # xi

    (-0.6, 1.6)  # xii

]

# Calculate the mean returns and standard deviations for each portfolio

mean_returns = []

std_devs = []

for w1, w2 in weights:

    mean_return = w1 * r1 + w2 * r2

    std_dev = np.sqrt(w1**2 * sigma1**2 + w2**2 * sigma2**2 + 2 * w1 * w2 *
sigma1 * sigma2 * rho)

    mean_returns.append(mean_return)

    std_devs.append(std_dev)


# Print the results
```

```
print("Portfolio | Mean Return | Standard Deviation")
print("---------|------------|-------------------")
for i, (w1, w2) in enumerate(weights):
    print(f"{i+1}. ({w1*100:.0f}%, {w2*100:.0f}%) | {mean_returns[i]:.4f} | {std_devs[i]:.4f}")
Portfolio | Mean Return | Standard Deviation
---------|------------|-------------------
1. (160%, -60%) | 0.0012 | 0.0463
2. (140%, -40%) | 0.0010 | 0.0413
3. (120%, -20%) | 0.0007 | 0.0365
4. (100%, 0%) | 0.0005 | 0.0320
5. (80%, 20%) | 0.0003 | 0.0279
6. (60%, 40%) | 0.0000 | 0.0243
7. (40%, 60%) | -0.0002 | 0.0217
8. (20%, 80%) | -0.0005 | 0.0203
9. (0%, 100%) | -0.0007 | 0.0204
10. (-20%, 120%) | -0.0009 | 0.0220
11. (-40%, 140%) | -0.0012 | 0.0248
12. (-60%, 160%) | -0.0014 | 0.0284
In [9]:
type(boeing_returns)
Out[9]:
pandas.core.series.Series
In [10]:
boeing_returns.to_csv('boeingreturns.csv', index=True, header=False)
In [11]:
caterpillar_returns.to_csv('catreturns.csv', index=True, header=False)
In [19]:
from openpyxl import Workbook
from openpyxl.drawing.image import Image
In [23]:
import yfinance as yf
import matplotlib.pyplot as plt

# Download the stock price data
boeing_data = yf.download('BA', start='2019-07-01', end='2024-06-30')

# Create a figure and axis
fig, ax = plt.subplots(figsize=(12, 6))
```

```
# Plot the stock price
ax.plot(boeing_data['Close'])

# Set the title and labels
ax.set_title('Boeing Stock Price')
ax.set_xlabel('Date')
ax.set_ylabel('Price (USD)')

# Show the grid
ax.grid(True)

# Show the plot
plt.show()
```

1.12 Appendix B – Expected Returns and Standard Deviations of Varying weighted portfolios

w (Boeing)	w (Caterpillar)	Exp Return (μ	Std Dev (σ)
100%	0%	0.050%	3.200%
80%	20%	0.026%	2.779%
60%	40%	0.002%	2.420%
40%	60%	-0.022%	2.154%
20%	80%	-0.046%	2.019%
0%	100%	-0.070%	2.040%

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