DOES AN ALLOCATION TO BITCOIN IMPROVE THE FUNDS' PERFORMANCE?

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Springboard Capstone II Report

Introduction

In the realm of modern finance, the emergence of Bitcoin as a decentralized digital currency has sparked considerable interest among investment firms and individuals alike. Its unique characteristics offer an alternative investment avenue beyond traditional financial instruments. In this report, I delved into the question of whether allocating funds to Bitcoin could enhance portfolio performance. Through a comprehensive analysis spanning seven years, I explored various facets including risk, returns, correlation with other assets, and the potential impact on portfolio optimization.

What is the problem?

The primary inquiry revolves around whether investment firms should consider including Bitcoin in their portfolios to potentially enhance performance. This inquiry stems from Bitcoin's distinct characteristics, offering opportunities for portfolio diversification and the potential for uncorrelated returns. Throughout this analysis, I address key questions such as comparative performance against traditional assets like the S&P 500 and gold, portfolio characteristics, Bitcoin's role as a hedge against inflation, and the construction of optimized portfolios.

Data:

The dataset included 7 years of data from January 2017 to December 2022. The dataset had the daily open price, high price, low price, close price, adjusted close price, and volume for Bitcoin (BTC), S&P500, and gold. The monthly inflation data was also utilized in the analysis.

Data Wrangling

Data preparation:

The data preparation involved ensuring accurate assignment of data types and merging the data for the three assets. Two datasets were created: one included the daily data for BTC, S&P500, and gold, while the other comprised the monthly data for the three assets along with the inflation data, using the data for the last day of the month.

Exploratory Data Analysis

To gain the first insight into the behavior of these three asset classes, I first compare their performance since 2017 by looking at the following factors:

- Standardized return
- Distribution of monthly return
- Skewness, Kurtosis, and Normality test
- Annualized total return
- Risk and volatility

Standardized returns

Is the price change related to the initial price. Looking the plots, BTC showed the strongest performance during the study period. Also, I found that S&P500 performed better than gold, overall. High volatility of BTC is also evident from the plots.


Fig 1: Assets' Performance
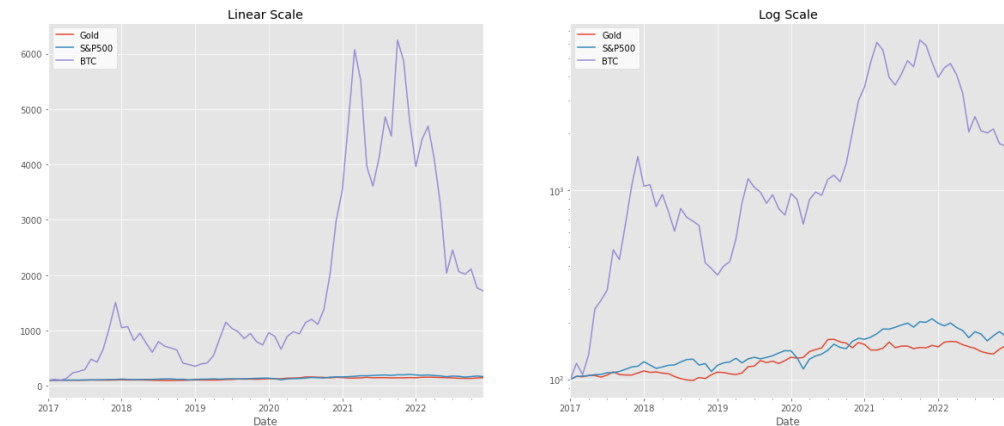
Monthly returns

I plotted pair plots to identify any evident relationships between the assets and to observe the distribution of monthly returns.

From the plots, I realized that the range of monthly return was much larger for BTC than for gold and S&P500. There was also no apparent linear relationship between the three assets. Finally, looking at the figure, the distributions were all looked to be normal.

Fig 2: Pairplot of Assets' Monthly Returns
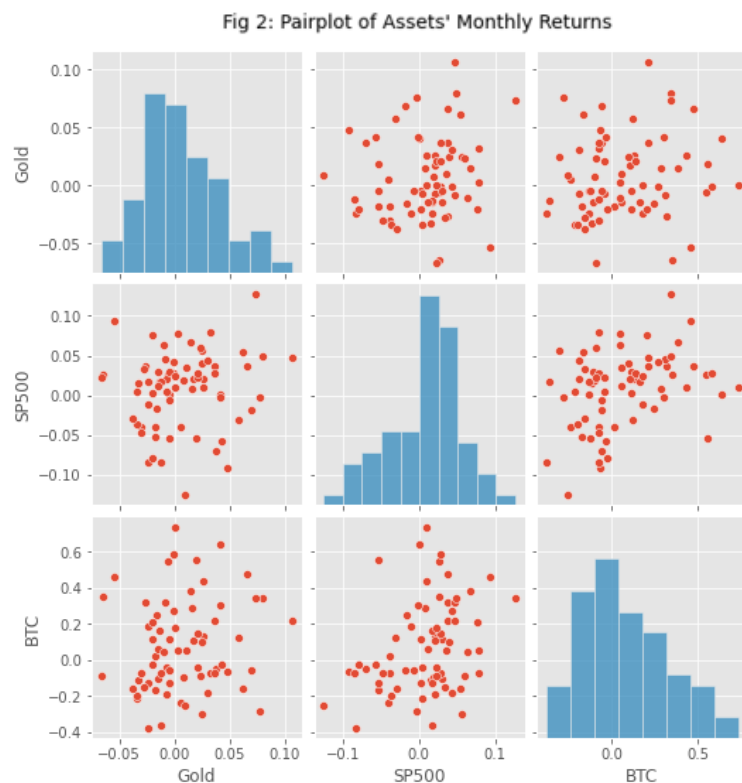
Skewness, Kurtosis, and Normality test

It was interesting to know if the models of risk and return computed by the fund can be relied on. One of the most important assumptions underlying risk and return models is that the returns data are normally distributed. Since the model outputs are relied on for investment decisions, it was crucial to ensure that this model assumption is valid. Therefore, alongside computing risk and return profiles for the three assets under consideration, the normality assumption was also tested.

```
Skewness:
Gold      0.515145
SP500    -0.475061
BTC       0.592264
dtype: float64

Kurtosis:
Gold      0.170110
SP500     0.368550
BTC      -0.260972
dtype: float64

The normality test result for gold is ShapiroResult(statistic=0.9736471772193909, pvalue=0.1405
627727508545)
The normality test result for s&p500 is ShapiroResult(statistic=0.9706397652626038, pvalue=0.09
459386765956879)
The normality test result for btc is ShapiroResult(statistic=0.9605997204780579, pvalue=0.02540
2264669537544)
```

The skewness values showed that gold and BTC were moderately positive skewed. While S&P500 were slightly negative skewed. In addition, the Kurtosis values indicated that all distributions were platykurtic. Lastly, The p-values showed that among the three assets only the distribution of Bitcoin's monthly return was non-normal

Annualized total return

Annualized total return is used to calculate the average annual return of an investment over a specified period by accounting for the effect of compounding on the investment's performance.

$$total\ return = (ending\ value - beginning\ value)/beginning\ value$$

$$annualized\ total\ return = (1 + total\ return)^{12/Total\ number\ of\ months} - 1$$
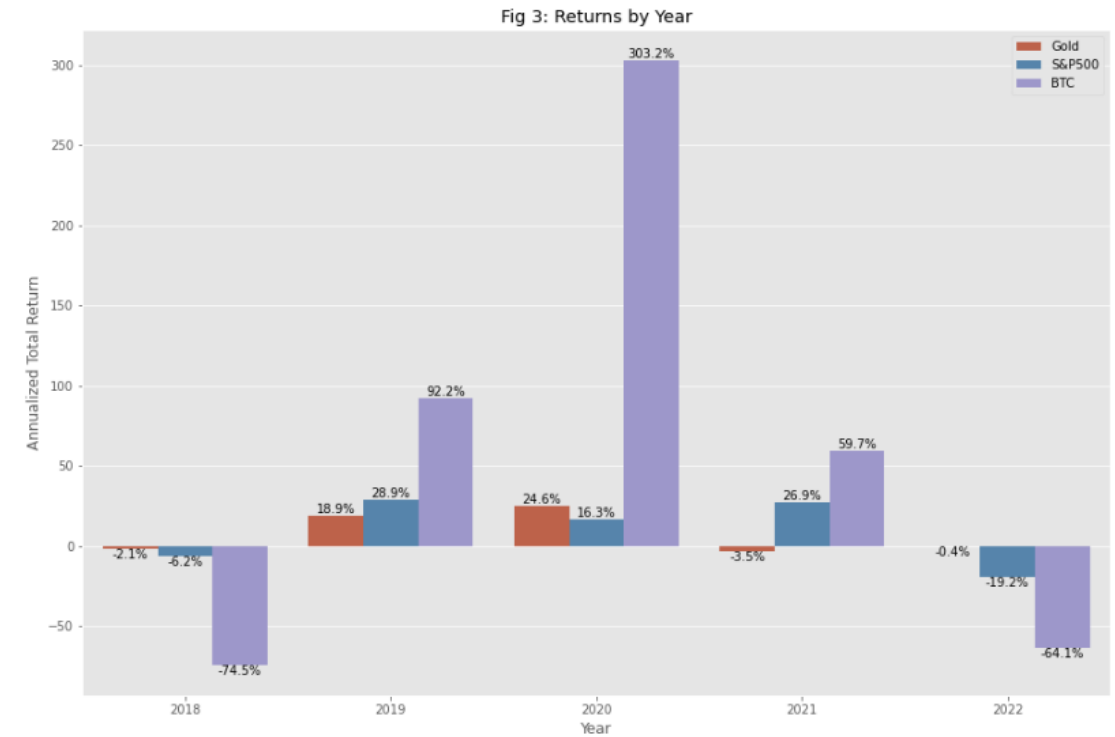
After calculating the annualized total return for the three assets I realized that BTC had the highest annual total return.

```
Total Returns:
Gold       0.505461
SP500      0.689118
BTC       16.149928
dtype: float64

Annualized Returns:
Gold       0.071590
SP500      0.092642
BTC        0.616619
dtype: float64
```


Fig 3: Returns by Year

As part of the analysis, I plotted the annualized total returns for the three assets side by side for comparison. As can be seen in Figure 3, BTC outperformed in 2019, 2020, and 2021, with 2020 being the best year for it. On the other hand, BTC lost a lot of its value in 2018 and 2022.

Risk and Volatility

For investors, understanding the risk and volatility of the assets they are investing in is crucial. Common parameters are used to quantify risk and volatility. I utilized some of these parameters to compare the risk of investing in the three assets.

1. Shaprio Ratio

The Sharpe Ratio is a measure of risk-adjusted performance that assesses the return earned in excess of a risk-free rate per unit of volatility. A higher Sharpe Ratio indicates better risk-adjusted performance, as it suggests that the investment is providing higher returns for the level of risk taken. Normally, the risk-free rate is assumed to be 0.

$$Sharpe\ ratio = {R_p - R_f}/{\sigma_f}$$

R_p: return of the investment or portfolio return

R_f: risk-free rate of return

σ_f: standard deviation of the investment's returns


```
Annualized Standar Deviation:
Gold      0.121653
SP500     0.164035
BTC       0.878700
dtype: float64


Sharpe Ratios
Gold      0.588477
SP500     0.564768
BTC       0.701740
dtype: float64
```

Sharpe ratio values suggest that investing in BTC was a worthwhile risk.

2. Maximum drawdown

Maximum draw-down is an incredibly insightful risk measure and is the largest percentage loss from a market peak to through. Maximum drawdown is calculated by finding the maximum percentage decline from a peak to a trough during a specific investment period.

A smaller maximum drawdown is generally considered more favorable, as it indicates that the investment has been relatively stable and has experienced smaller losses during the specified period.

Looking at the Maximum drawdown values, it can be seen that BTC had the most significant drawdown with about 73% and gold had the lowest with approximately 14%. This showed that investing on BTC is riskier based on the historical data.

3. Historical value at risk (VaR)

VaR is a threshold with a given confidence level that losses will not exceed a certain level based on the historical data. It involves determining the loss level, expressed as a percentage, that would have been exceeded with a given probability based on past market behavior.

I used 95% as the confidence level.

Acknowledging the shortcomings of volatility as a risk measure (e.g. it captures upside volatility as well, which might actually be desirable), BTC's VaR of about 27% was more than 3-times that of S&P500, and about 9-times that of gold.

For BTC, there is a 5% chance that the monthly losses will exceed 27%.

Fig4: Monthly Drawdown
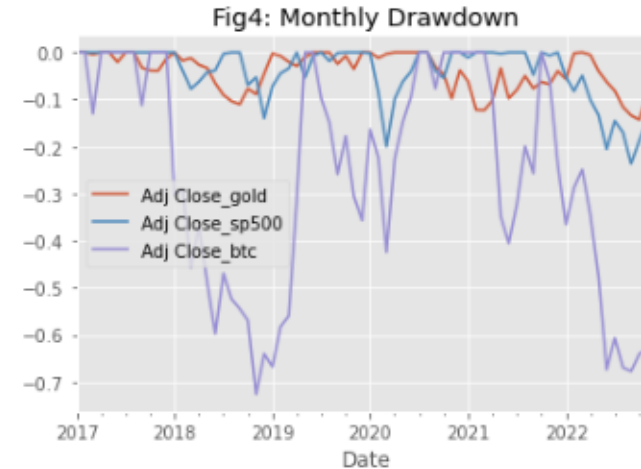
```
Max monthly drawdown
Adj Close_gold      -0.142827
Adj Close_sp500     -0.236187
Adj Close_btc       -0.725900
dtype: float64
```



```
['Gold' 'SP500' 'BTC']
[ -3.60880643  -8.1723587  -26.99333113]
```

Fig 5: Historical Distribution of Returns
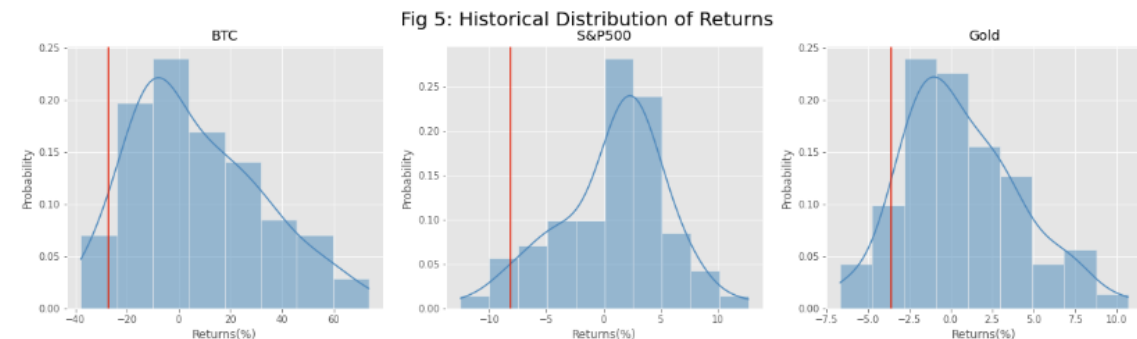
The effect of inflation

Inflation data will also be taken into account during the portfolio construction process. The portfolio construction process utilized in this study is premised on two important factors, namely the selection of assets to include in the portfolio and the quantity of each asset to include. Based on the results from previous sections, BTC was the best performing asset during the period of study. Although it was also the riskiest asset in absolute terms, it offers the best risk-adjusted returns. On the other extreme, gold was the worst performing asset, but it was also the least risky asset in absolute terms. On a risk-adjusted basis, however, gold offered the worst risk-adjusted returns. When constructing a portfolio for the investment fund, it is crucial to remember the fund manager's objective: to minimize volatility in the fund by constructing a portfolio involving the lowest risk.

Taking inflation into account is important for two reasons. First, it is important to ensure that the assets chosen for investment have the potential to deliver returns above the inflation rate. Second, when inflation increases, the assets should also appreciate in value, but ideally by a larger magnitude.

The trajectory of inflation in America is shown in Figure 7. In the 7-year period under study, inflation in America increased by 21.84% as measured by the Consumer Price Index (CPI). The mean monthly CPI change over the period was 0.28%. Keping in mind that the Federal Reserve targets a 'healthy' inflation rate of 2%, deemed necessary for economic growth, this study will adopt the 2% level as the hurdle rate which an investment must achieve in order to beat inflation. The results from the previous section show that all the assets being considered for this portfolio have the potential to surpass this hurdle rate.

Fig 7: Historical Inflation

In order to curtail inflationary effects, the returns from the assets that make up the portfolio must be positively correlated with inflation, meaning that as inflation rises, the assets also generate positive returns. To assess that I created a correlation heatmap.
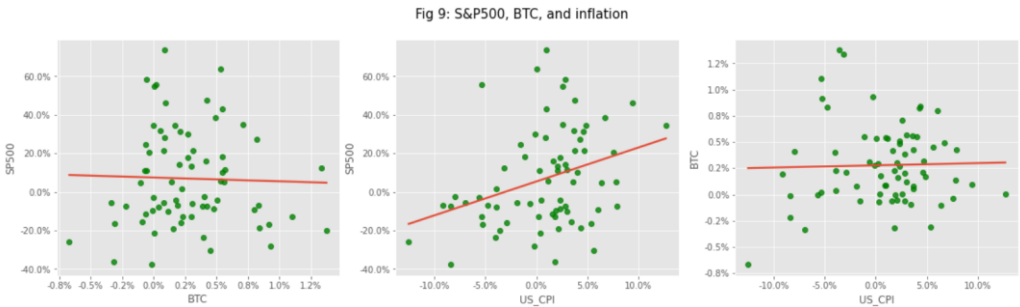
As can be observed from the heatmap, the S&P 500 is most positively correlated with the CPI, although the degree of correlation is a weak positive one. In general, as inflation increases, the S&P 500 index also rises. That makes the S&P 500 index the best hedge for inflation among the three assets. BTC and gold have no correlation to inflation, making them less suitable as inflation hedges.

The heatmap also showed that Bitcoin, gold and S&P 500 returns are all weakly correlated at best, making them all ideal for inclusion into a portfolio. The rationale for including them all in the portfolio is that adding a risky asset whose returns are uncorrelated, or inversely correlated, with those of assets in the portfolio reduces the overall portfolio's risk by reducing volatility.

	Gold	US_CPI	SP500	BTC
Gold	1.00	0.14	0.14	0.03
US_CPI	0.14	1.00	0.33	0.03
SP500	0.14	0.33	1.00	-0.03
BTC	0.03	0.03	-0.03	1.00

Fig 8: Monthly Changes Correlation Matrix

To further asses that, I created scatter plots to see whether it was a significant correlation between the assets. I found that there had been no consistent relationship between changes in the price of BTC and inflation since 2017. BTC does not offer good hedging properties against inflation, as it has been largely uncorrelated to changes in the general price level. It seems neither positively nor negatively affected by inflation.

It's also worth noting the positive correlation between the S&P 500 and BTC. A correlation coefficient of 0.3 suggests that BTC tends to move in the same direction as equities, thus offering only limited diversification benefits in a portfolio with equities.

Fig 9: S&P500, BTC, and inflation

Portfolio optimization

The Efficient Frontier is a key concept in portfolio theory and investment management. It represents a set of optimal portfolios that offer the maximum expected return for a given level of risk or the minimum risk for a given level of expected return. The Efficient Frontier illustrates the trade-off between risk and return in a portfolio. Generally, as an investor seeks higher expected returns, they must be willing to accept a higher level of risk. Portfolios lying on the Efficient Frontier are considered "efficient" because they provide the maximum expected return for a given level of risk or the minimum risk for a given level of expected return.

Diversification plays a crucial role in constructing portfolios on the Efficient Frontier. By combining assets with different risk and return profiles, investors can create diversified portfolios that offer higher returns for a given level of risk.

The Efficient Frontier is often depicted along with a risk-free rate. The point of tangency between the capital market line (representing the risk-free rate) and the Efficient Frontier is known as the "tangency portfolio" or the "market portfolio."

Investors can select a portfolio from the Efficient Frontier based on their risk tolerance and return objectives. The specific portfolio chosen depends on individual preferences and constraints.

The optimization problem: finding optimal weights

$$\underset{\omega}{\text{minimise}} \ \omega^T \Sigma \omega$$

$$\text{subject to} \quad \omega^T \mu \geq \mu^*$$
$$\omega^T \mathbf{1} = 1$$
$$\omega_i \geq 0$$

In words:

- Minimize the portfolio variance, subject to:
- The expected mean return is at least some target return
- The weights sum up to 100%
- At least some weights are positive
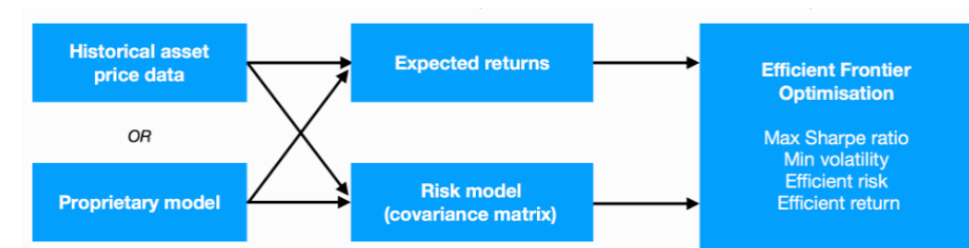
The best portfolio can be picked based on different criteria but normally one the following are considered as the best portfolio:
- Maximum Sharpe ratio portfolio
- Minimum volatility portfolio

As can be seen in the table, the minimum volatility portfolio doesn't include any investment in BTC. Conversely, in the maximum Sharpe ratio portfolio, 14.12% of the portfolio is allocated to BTC, 28.8% to S&P500, and the remaining 57.08% to gold. Apart from these two portfolios, I also created another portfolio with a percentage investment in BTC.
As mentioned earlier, it is up to the investor's willingness to take risks to decide between these portfolios. However, overall, it is worth considering investing at least 10% in BTC.

	Max_Sharpe_Portfolio	Min_Volatility_Portfolio	Min_Volatility_Portfolio (min 10% BTC allocation)
Gold_Weight (%)	57.08	66.68	68.91
S&P500_Weight (%)	28.80	33.32	21.09
BTC_Weight (%)	14.12	0.00	10.00
Annualized_Portfolio_Return (%)	15.46	7.86	13.05
Annualized_Portfoluo_Volatility (%)	78.85	47.55	66.09
Portfolio_Sharpe_ratio	17.07	12.32	16.72

Efficient Frontier
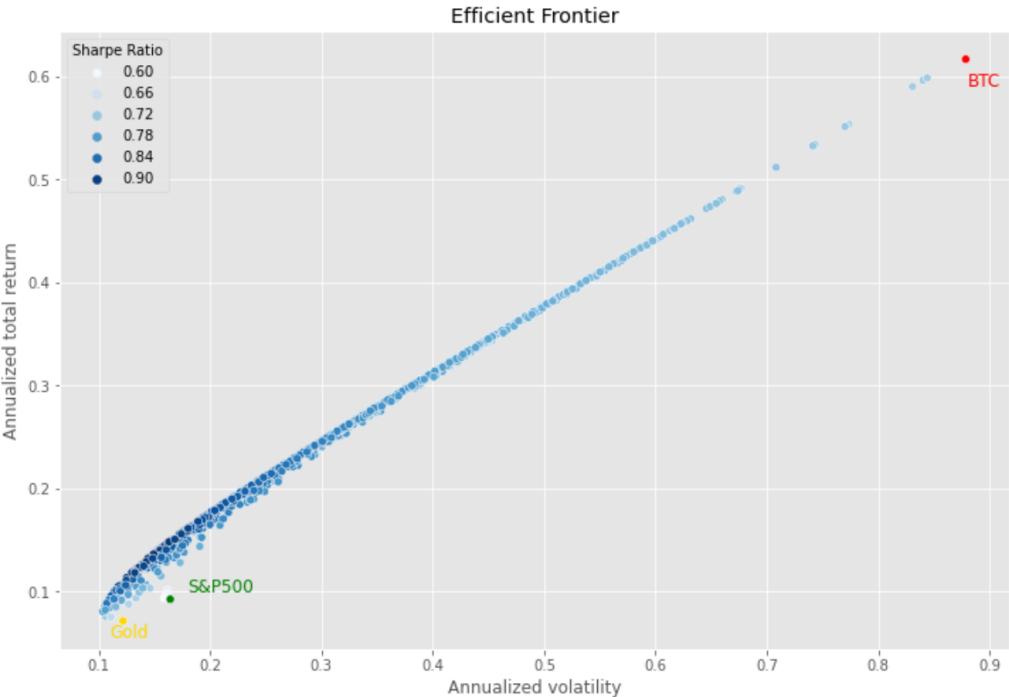
Efficient frontier optimization requires knowledge of the expected risk Sigma and expected returns mu. The truth is, the mean historic returns, or the historic portfolio variance are not perfect inputs and do not reflect future expected risk and return perfectly. The resulting weights of our optimization problem, would have worked well in the past, but we have no guarantee that it will work well in the future. A possible improvement is to use exponentially weighted risk and return. It assigns more importance to the most recent data, and thus aims to improve the estimates. This is especially important when we have a volatile asset like BTC.

Another way of finding the best portfolio for future investment is to use machine learning models. The most important part of the prediction was to find the input data to our machine learning models. For that I took the following steps to create the dependent and independent variables of our models:

1. Calculated monthly returns based on the last business day of the month.
2. Found the daily covariance of assets for each month
3. Generated 1,000 portfolios based on random weights following a uniform distribution and calculate the portfolios' return and volatility
4. Found the "ideal" portfolios for each date and use them as targets for machine learning
5. Creating some features to be able to predict our ideal portfolios. Price movement were used as a feature. To do this a daily exponentially-weighted moving average (EWMA) were created and resampled to the monthly timeframe. Finally, the monthly moving average of price were moved one month in the future to be used as a feature for predicting future portfolios.
6. Targets: Targets will be the best set of weights for the portfolio based on the Sharpe ratio.
7. Features: The exponentially weighted moving averages of prices

I used two regression models for prediction: linear regression and random forest. After developing the models, the following results were obtained for each model:

Linear regression

- The MAE of the training set is: 0.159

- The MAE of the test set is: 0.368

Random forest

- The MAE of the training set is: 0.059

- The MAE of the test set is: 0.380

Based on the model results, linear regression found to have a slightly better performance compared to random forest.

Conclusion

- Using the proposed models, investment companies can decide whether they want to invest on BTC.

- Overall, it was found that investing on BTC is risky, but it is worth the return. Therefore, it is recommended to allocate at least 10% of the portfolio to BTC.