

Our problem at hand is to develop a model that determines, over a particular past five-year span, whether to hold, buy or sell particular assets in a particular trader's portfolio. We focused on two particular volatile assets: gold and bitcoin. Despite being given the full price data for both assets over our five-year span, our model could only use the price data up to the particular trading day in question. Keeping in mind the different commission fees, our model utilized moving averages strategy: simple moving average and exponential moving average. We first determined what type of moving average strategy works better for a particular asset. Then we used the selective two strategies to develop a combined strategy. We also determined how each of models responded to transaction costs. Finally, with our data and sensitivity tests, we make recommendations to investors in regards to the strategies we found that proved to be most profitable after the five years.

Contents

1	Statement of Problem	3
2	Moving Average Strategy	3
2.1	Dow Theory [1]	3
2.2	Moving Average Strategy(Variant of Dow Theory)	3
3	Selection of Best Moving Average Strategy for Gold and Bitcoin separately	5
3.1	Implementation Rules of SMA and EMA	5
3.2	Running Results for Gold and Bitcoin	5
4	Combined Gold-Bitcoin Strategy	8
4.1	Combined Strategy Description	8
4.2	Total Return	9
5	Analysis	9
5.1	Sensitivity Analysis	9
6	Conclusions	11
6.1	Memorandum	11

1 Statement of Problem

In our paper, we are given the daily prices of gold and bitcoin over a five-year span from 9/11/2016 to 9/10/2021. We start with \$1000 dollars in cash on the first day, with the goal of increasing total value by the end of the five-year period. To maximize the return on investment, we developed a model that focuses on daily activity, particularly one that gives the best daily trading strategy. A difficult part of our problem was that despite being given the full list of prices for both gold and bitcoin over the five-year span, our model could only be based upon the price data up to the day in question. Additionally, our model needed to factor in the differences between trading gold and bitcoin. In particular, commission prices, for both purchasing and selling, were significantly different for gold and bitcoin. Another key difference is that while bitcoin could be traded on any given day in the five-year span, gold could only be traded on particular days when the market was open.

2 Moving Average Strategy

2.1 Dow Theory [1]

In stock trading, investors believe in "trend". This is based on Dow Theory. Specifically, price of the asset will follow the upward or downward trend [1]. For example, if gold price has been rising in the past week, the strategy is to buy to follow the trend and thus have gains.

2.2 Moving Average Strategy(Variant of Dow Theory)

We introduce two types of moving strategies: SMA and EMA.

Simple Moving Average (SMA)

Firstly, we choose a time span. Since the data is presented in a daily basis, the time span will be in unit of days. We consider the time spans ranging from one to 200 days. We denote the time span as T and the prices of a single asset from day 1 to day n as p_1, p_2, \dots, p_n . SMA is a common average of the previous T data points. Every point of a SMA curve is derived by taking the average of the previous T days. We define simple moving average (SMA) on the k th day as:

$$SMA_k = \frac{1}{T} \sum_{i=k-(T-1)}^k p_i[2]$$

To calculate the simple moving average for the $k+1$ th day, we instead substitute $k+1$ for k and $(k-1)-T$ for $k-T+2$, yielding the follow result:

$$SMA_{k+1} = \frac{1}{T} \sum_{i=k-T+2}^{k+1} p_i[2]$$

Exponential Moving Average (EMA)

While SMA considers the prices equally for the given time span, exponential moving average method considers more weight on the most recent days since these days are more relevant of current price. Exponential moving average on the k th day can be calculated recursively through the following formula:

$$EMA_1 = Y_1$$

for

$$EMA_k = \alpha \times Price_k + (1 - \alpha) \times EMA_{k-1}[2]$$

α represents a smoothing factor between 0 and 1. This smoothing factor is commonly calculated as

$$\alpha = \frac{2}{T + 1}$$

with T representing the T data points that we wish to factor into our calculations. [2]

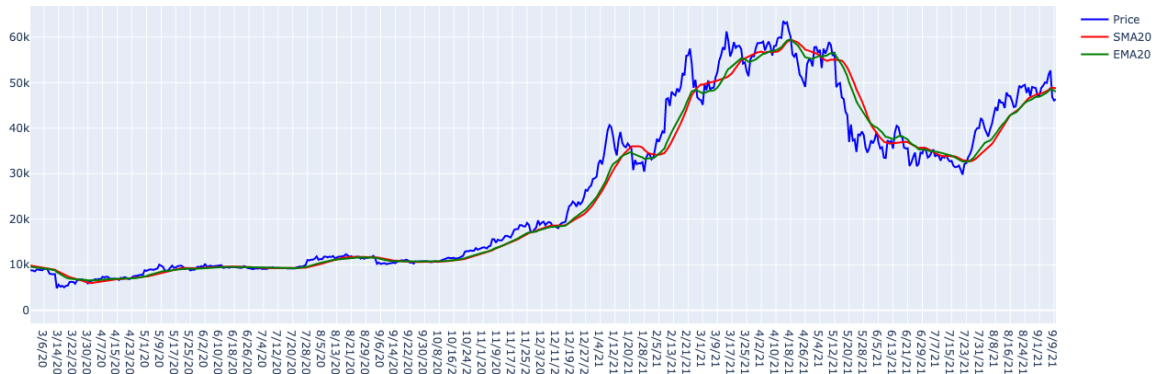


Figure 1: Bitcoin Prices, together with SMA, EMA (20 day periods). Selected dates from March, 2020 to September, 2021.

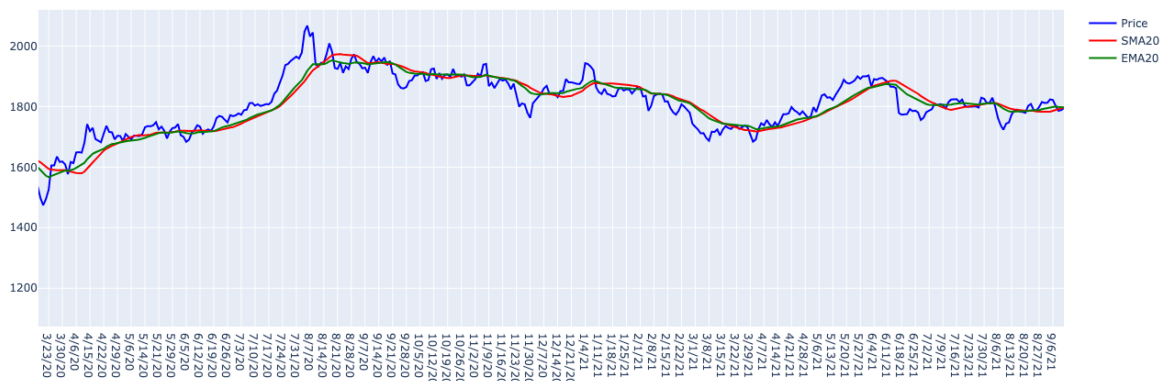


Figure 2: Gold Prices, together with SMA, EMA (20 day periods). Selected dates from March, 2020 to September, 2021.

From the above graphs we note that in spans of increased prices for both gold and Bitcoin, EMA20 followed the change more closely and increased faster than SMA20. This reflects the general nature of exponential moving average, which puts more weight on more recent days in the 20 day periods.

3 Selection of Best Moving Average Strategy for Gold and Bitcoin separately

3.1 Implementation Rules of SMA and EMA

We implement both EMA and SMA using Python with given data (gold and bitcoin respectively). In both cases, we regard EMA and SMA as indicators of trend. We find intersections of EMA or SMA and the real price line. When the real price line approaches and cross the trend from below, we buy the asset. We hold the asset until the real price line approaches and cross the trend from above, at which point we sell.

3.2 Running Results for Gold and Bitcoin

We consider gold and bitcoin separately, assuming that we have \$1000 at the beginning for both scenarios. In both cases, we plot both SMA and EMA according to the above formulas. We test time spans ranging from one day to 200 hundred days of both SMA and EMA for both Gold and Bitcoin separately, closely observing the intersection points between average curves

and price curves. With the intersection points, we make sell or buy decision according to the rules and calculate the return from the first day to 9/10/2021.

Gold Return on Different SMA Time Spans

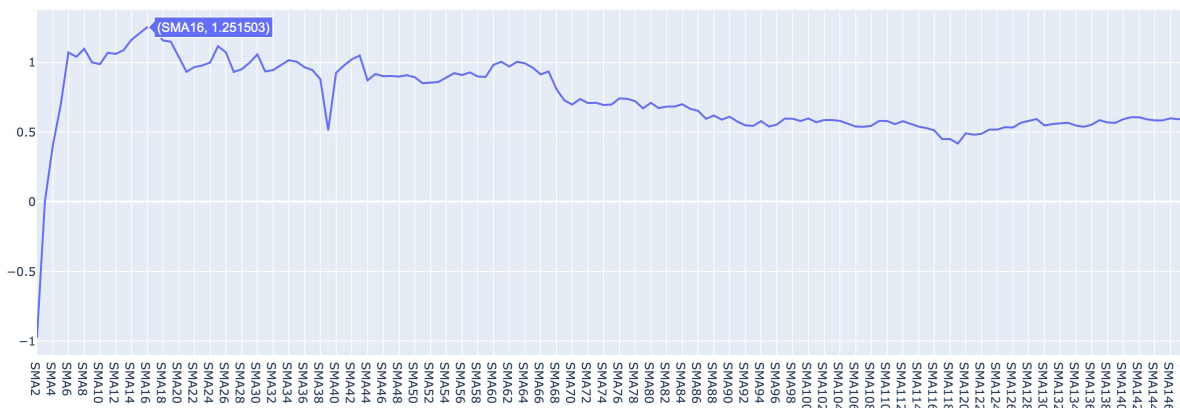


Figure 3: Limiting the SMA to 16-day periods of Gold prices yields the best returns of 125%. Note the vertical axis denotes the factor of increase, so an increase by a factor of 1.25 suggests a return of 125%.

Gold Return on Different EMA Time Spans

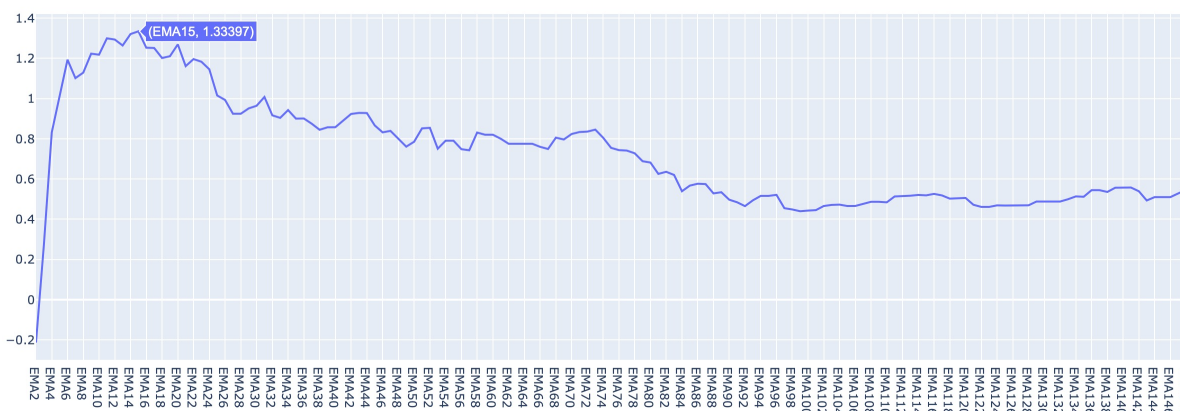


Figure 4: Limiting the EMA to 15-day periods of Gold prices yields the best returns of 133%. Note the vertical axis denotes the factor of increase, so an increase by a factor of 1.33 suggests a return of 133%.

Bitcoin Return on Different SMA Time Spans

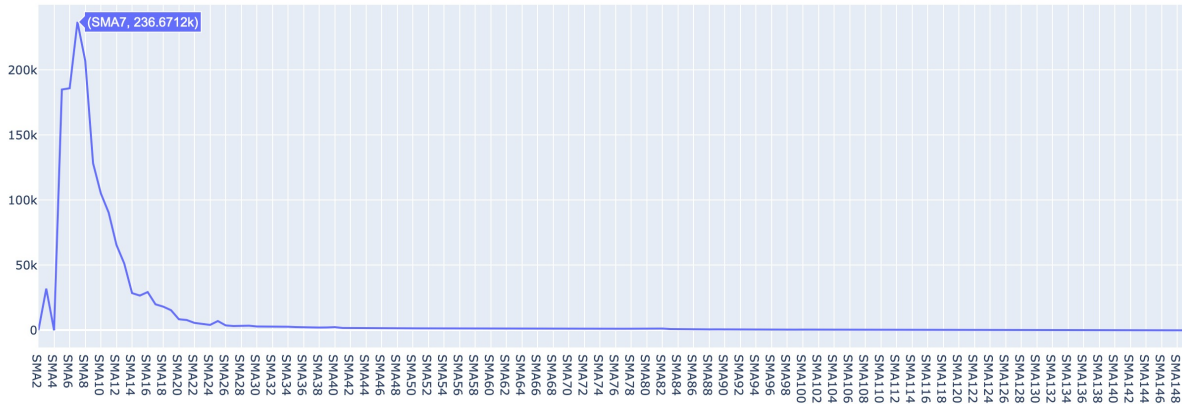


Figure 5: Limiting the SMA to 7-day periods of Bitcoin prices yields the best returns of 23667100%. Note the vertical axis denotes the factor of increase, so an increase by a factor of 236.671k suggests a return of 23667100%.

Bitcoin Return on Different EMA Time Spans

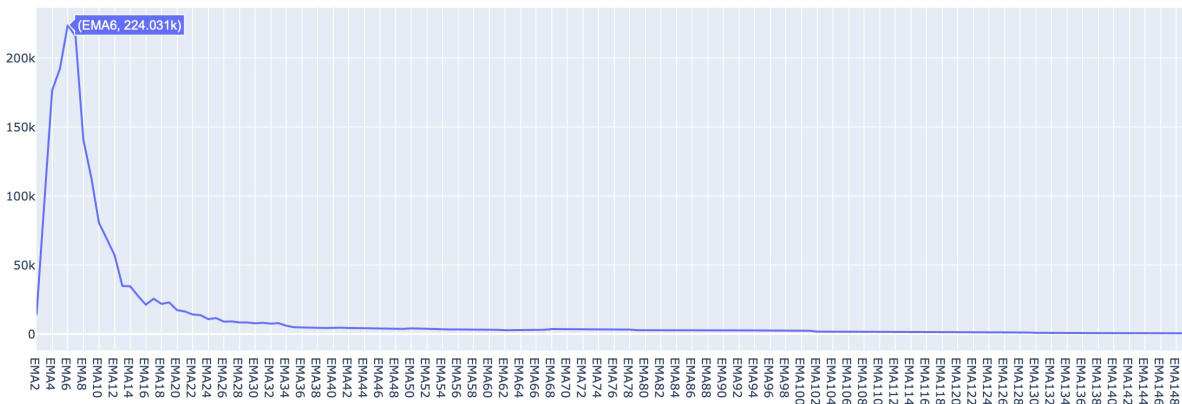


Figure 6: Limiting the EMA to 6-day periods of Bitcoin prices yields the best returns of 22403100%. Note the vertical axis denotes the factor of increase, so an increase by a factor of 224.031k suggests a return of 22403100%.

From the above implementations and comparisons, we present the best selection of moving average strategies as below:

Asset	Best Strategy	Return in Percentage
Gold	EMA15	133%
Bitcoin	SMA7	23,667,100%

4 Combined Gold-Bitcoin Strategy

4.1 Combined Strategy Description

Now we have the best strategy for gold(EMA15) and bitcoin(SMA7) separately. We will then develop the best combined strategy:

- 1.Our first option is to buy or hold bitcoin. That is, whenever our bitcoin SMA7 tells us to buy or hold bitcoin, we do so.
- 2.If not, we check if our gold EMA15 strategy tells us to buy or hold. If so we put all of our cash into gold. Otherwise, we hold cash.
- 3.In the case where both strategies signals cash or sell, we hold cash.

Total Combined Return

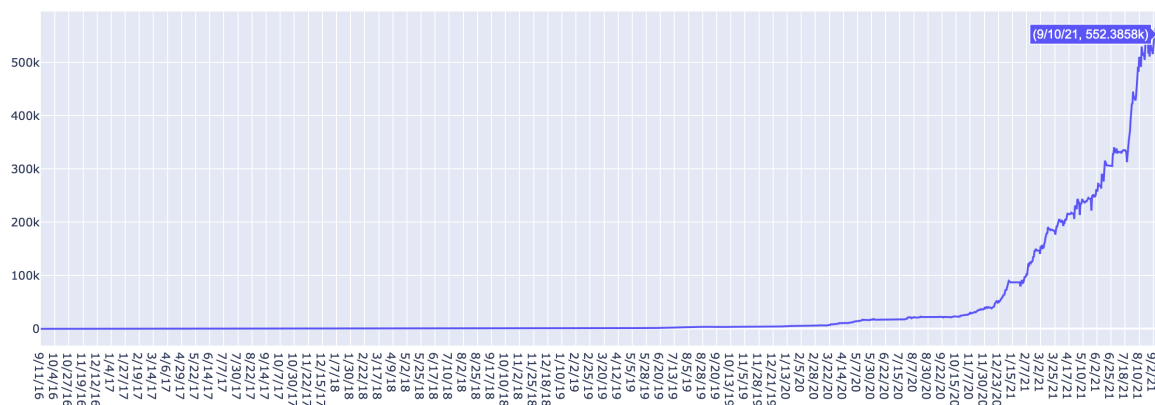


Figure 7: It shows that we will have a return in the factor of 552.385k, suggesting return of 552,385%.

As the table shown below, the combined strategy has more return than pure gold or bitcoin strategy.

Asset	Best Strategy	Return in Percentage	Ending Value
Gold	EMA15	133%	\$2330
Bitcoin	SMA7	23,667,100%	\$236,672,000
Combined	EMA15 and SMA7	55,238,500%	\$552,386,000

4.2 Total Return

We developed the following formula to calculate total return:

$$R = r(1 - \alpha_g)^g \times (1 - \alpha_b)^b$$

with

α = commission rate, $0 < r < 1$

r = nominal asset return

b = number of times bitcoin was traded

g = number times gold was traded

5 Analysis

5.1 Sensitivity Analysis

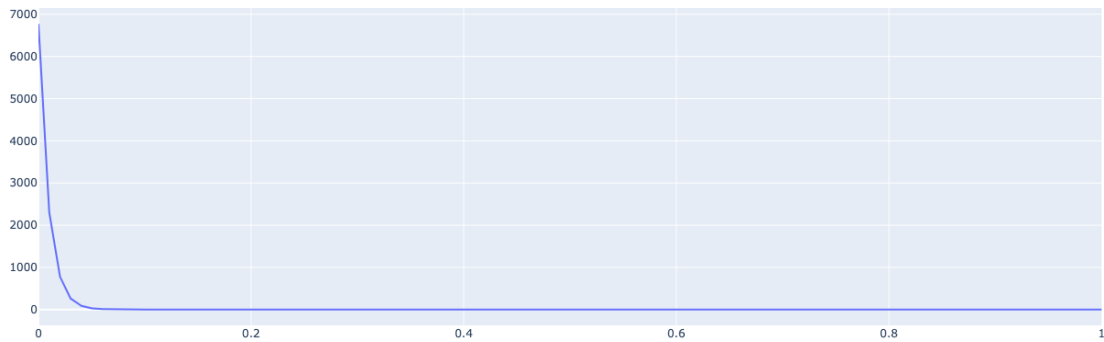


Figure 8: Percent return from only trading gold, as a function of varying commission rates.

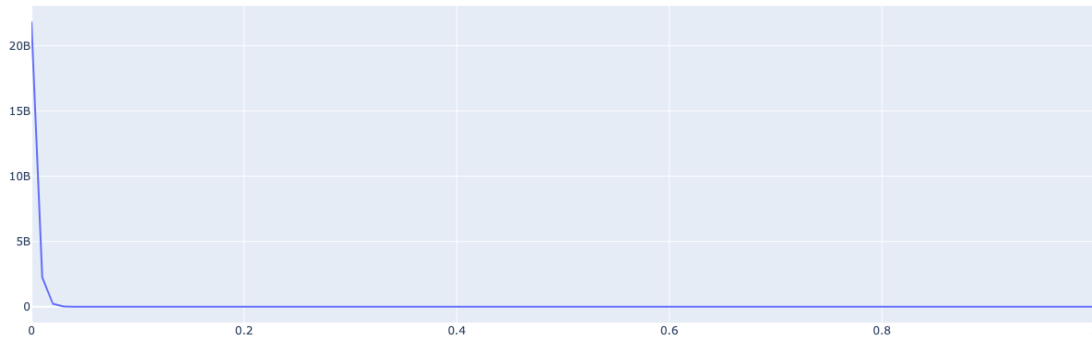


Figure 9: Percent return from only trading Bitcoin, as a function of varying commission rates.

Finally, the combined strategy's sensitivity to increasing commission prices could be best expressed through the total rate formula.

$$R = r(1 - \alpha_g)^g \times (1 - \alpha_b)^b$$

with

α = commission rate, $0 < r < 1$

r = nominal asset return

b = number of times bitcoin was traded

g = number times gold was traded

In general, gold's return is much less than its commission rate, meaning that the strategy of just trading gold is most sensitive to transaction costs.

6 Conclusions

6.1 Memorandum

Starting with a thousand dollar in cash, our trading strategy gave us a lucrative return of \$552386000. Based on our analysis, we utilize moving average strategies to obtain an optimized daily strategy. Our testing showed that in regards to pure strategies (as in focusing only on one asset throughout the five years) that the most return will result if we limit the SMA to 7-day periods for pure Bitcoin strategy. It also showed that if we were to follow a pure gold strategy, we should only buy when the 15-day period EMA curve crosses the price curve from below. However, it was the combined strategy that worked best. In this strategy, our priority is to always buy or hold bitcoin, but only if our 7-day SMA curve tells us to. If not, then we check the to see if it is worth buying or holding gold according to the 15-day EMA curve. We either put all our cash into gold or hold the cash. The combined strategy eventually gave us the value about \$569,353,000 total return. However, it is noticeable that our strategy is very sensitive to commission fees. A slight change in the percentage of commission fee would come to a different strategy.

References

- [1] Zvi Bodie, Alex Kane, and Alan J. Marcus. *Investments*. McGraw-Hill/Irwin, 2011.
- [2] Seng Hansun. “A New Approach of Moving Average Method in Time Series Analysis”. In: *2013 Conference on New Media Studies* (2013), pp. 1–4.