Problem Chosen	2022 MCM/ICM Summary Sheet	Team Control Number
C		2226121

The world is in a post-covid depression right now, with record-high inflation rates unemployment rates creating a sense of financial instability for the public due to which investing in the right assets is a great way to fight inflation and create a profitable investment that will provide returns and dividends in the long term. Along with this, the meteoric rise of Dogecoin and Gamestop in 2021 has attracted everyone to the stock market. Though there are examples of many people who successfully made huge profits during the wild run of these stocks, many people also suffered a massive blow to their financial circumstances due to a lack of proper knowledge of trading. This paper puts forward various trading strategies that one can implement to avoid such losses and ensure profits.

This paper explores multiple methods of algorithmic investing using technical analysis of Bitcoin and Gold with Relative Strength Indicator (RSI), Moving Averages (MA) indicator, and Moving Averages Convergence and Divergence Indicator (MACD). The reliability of these three indicators is determined by measuring an individual stock's returns. Using the RSI index for making trading decisions, gold asset returns increased from 3% to 79.42%, and Bitcoin asset returns increased from 7% to 21.98%. Using the MA index for making trading decisions, gold asset returns increased from 30% to 50% and for Bitcoin from 4640% to 5257%. Using the MACD index for making trading decisions did not yield a significant increase in gold asset returns and gave the optimized value of returns (around 8000 percent) for bitcoin assets.

Based on these indicators' returns, the relative strength of their accuracy for that stock is estimated. Then a new comprehensive model with all three indicators is developed to make the trading strategy more accurate. In this model, the commission rate also impacts the trader's decision-making process. The optimal asset return is determined by changing the maximum number of each stock (N_b and M_b) that can be bought or sold. The optimal asset return reaches up to 6048 percent when the maximum number of gold stock the trader can buy is 0.2 and bitcoin is 0.02. Even though the return of 6048 percent is less than 8000 percent, it comes with relatively high security. Not only this, a trader can themselves decide their relative security over their investment by choosing their N_b and M_b values, and this model can suggest the optimal return they will get based on those values.Since bitcoin is highly volatile, it can give a trader high returns but will not be able to provide a sense of security.Similarly with the gold asset, since it is highly stable, it will not be able to give exponential returns like bitcoin. In this way, this paper presents how a trader can determine a 'sweet spot' for their degree of priority to security and returns.

Trading Strategies

Control Number **2226121**

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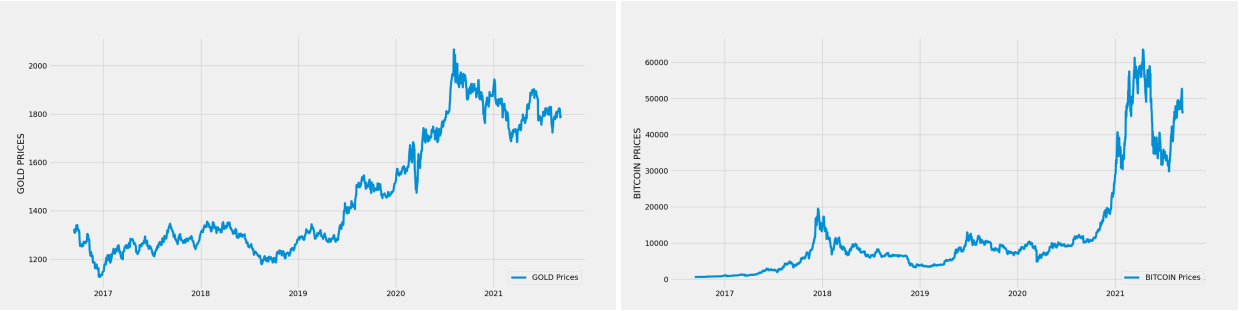
Contents

1 Introduction

The objective of this problem is to make a trading model that gives good returns and provides a stable trading strategy for a trader in a given time interval. The trader has a portfolio containing: money (in dollars), gold (in troy ounces), and bitcoin (in bitcoins): [C, G, B]. The initial state of the trader is [1000,0, 0]. The commission cost for each transaction of gold and bitcoins are α_{gold} = 1% and $\alpha_{bitcoin}$ = 2% respectively whereas there is no cost in holding the assets. Similarly, bitcoin can be traded every day while gold can be traded only on the days the market is open, i.e Monday through Friday except national holidays. With the use of various technical analysis tools like RSI, A/D line, MACD, Fibonacci Retracement, etc. We came up with a realistic algo-trading model that can analyze the state of the market or stock and place trades accordingly.

1.1 Overview of the problem

In this problem, we are asked to maximize the profit by investing $1000 worth of cash, gold, and bitcoins in the stock market over a period of 5 years. For each buys and sell of gold, we pay a commission of 1%, whereas 2% for bitcoins. There is no cost in holding the stocks. Our main challenge in this problem is to find the optimum plan to distribute the $1000 for bitcoins and gold every day in such a way that at the end of five years, the trader ends up with the maximum profit. The first two charts are the visual representation of the data given to us.



(a) Gold (b) Bitcoin

Figure 1: Line chart of Gold and Bitcoin over a period of 5 years from 9/11/2016 to 9/10/2021.

2 The Model

2.1 Motivation

In the last 5 years, stock market trading has reached the fingertips of people through the apps like Robinhood and Coinbase. With just a click of a button, people can buy and sell stocks within seconds. Buying and selling stocks has become simpler and more common among the youth. However, not all traders have enough time or knowledge to learn to trade stocks. Most amateur traders directly dive into trading without doing enough research and technical analysis because of which they face huge losses, which can get frustrating at times. What they fail to realize is that stock trading is not luck but a game of probability, and with enough analytical skills and trading experience, we can predict the price movements of a stock and use it to our advantage. Keeping all this in mind, we came up with a mathematical model which can accurately predict those movements and help the trader generate the optimal returns possible.

2.2 Abbreviations

- **MACD :** Moving Average Convergence Divergence Indicator
- **RSI :** Relative Strength Index
- **MA:** Moving Average Indicator
- **G :** Price of gold stock
- **B :** Price of bitcoin stock
- $\mathbf{b}_b$ **:** Number of bitcoins bought
- $\mathbf{b}_s$**:** Number of bitcoins sold
- $\mathbf{g}_b$**:** Number of gold bought
- $\mathbf{g}_s$**:** Number of gold sold
- $\mathbf{N}_b$**:** maximum number of bitcoins that a trader can buy on a day
- $\mathbf{M}_b$**:** maximum number of golds that a trader can buys on a day

- $\mathbf{N_s}$**:** maximum number of bitcoins that a trader can sell on a day
- $\mathbf{M_s}$**:** maximum number of golds that a trader can sell on a day
- **A(**t_{final}**):** total amount of assets in dollars on 9/10/2021
- **C(t):** total amount of cash in dollars on 't' days
- **G(t):** total amount of gold asset in dollars on 't' days
- **B(t):** total amount of bitcoin asset in dollars on 't' days

2.3 Assumptions

- Since the time interval for data presented for Bitcoin and Gold are on days, we assume that the trader decides whether to buy, sell, or hold stock just before the opening of the trading hour for that stock.
- We assume that the trader makes the trading decision for Bitcoin and gold at the same time at 9 am EST.
- Our entire model assumes that Gold and Bitcoin perform like stocks, whereas Bitcoin is a cryptocurrency and Gold is a commodity.
- Cryptocurrency trading is also based on the assumption that we will be able to trade it actively without any failure in blockchain technology backing bitcoin.
- All trades for a stock placed at the time of decision making are executed at the same price.
- First indicators for selling, buying, or holding bitcoin and gold are measured using the model, and if there is a strong suggestion that the trader should sell the stocks, it is sold first before addressing the indicator that suggests buying. Doing this will help to have funds available for buying stocks.
- If the analysis of one asset suggests buying and the indicator of the other asset does not suggest selling, then the other stock is not sold for any condition, including lack of cash to buy the first stock.
- If the trader calls for buying the stocks of gold or bitcoin, we assume that the trader has successfully purchased the stocks.

- If the trader calls for selling the stocks of gold or bitcoin, we assume that the trader has successfully sold the stocks.

2.4 Parameters Explanation

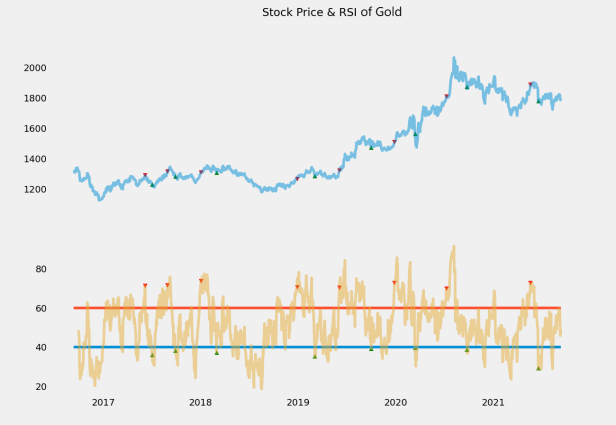
This model is based on the study of three stock market parameters: Moving Average Convergence Divergence(MACD) indicator, Relative Strength Indicator(RSI), and Moving Averages(MA).

RSI Trading is based on the Relative Strength technical indicator, which tends to measure if a stock is overbought or oversold. If a stock is overbought, its market value increases to more than it should be, giving us time to sell the stock at a high price before the stock price comes back to its average price. Similarly, when a stock is oversold in the market, its value falls, creating a window of opportunity to buy more Bitcoin/Gold, before its value increases back to its average value. Relative Strength Index varies between 0 and 100, usually lying between 40 and 60 for any stock. In our model, we use the RSI when it crosses the value of 40 and 60 where we can distinguish moments of stock being overvalued/oversold from just irregular movements of stock. When this indicator crosses the barrier, we watch for opposite movements in price charts. For example, the Relative Strength of a stock is over 60, hence it is overbought, we will look for a small decline in price, indicating a local peak has been reached and the stock price will go back to its average price as reflected in the figure (2). At this point, we sell our stock and vice-versa. Since this model tracks unusual movement patterns, it gives the best results on stocks with low to medium Volatility. It is evident from our results that this model gives the best results by trading Gold (Less Volatile) and insignificant results with Bitcoin (Highly Volatile).

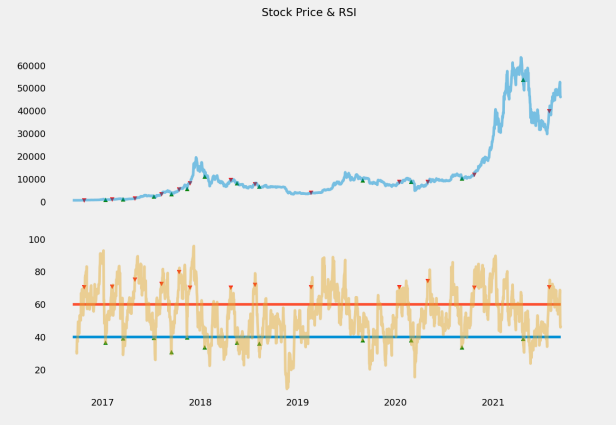
$$\text{Relative Strength (RS)} = \frac{\text{Average increase in Price}}{\text{Average decrease in Price}}$$

$$\text{Relative Strength Index (RSI)} = 100 - \frac{100}{\text{RS}}$$

Moving Averages Trading (MA) is based on the fact that stocks prices will oscillate around long-term moving average. In MA, we track the movements of a long-term average and a short-term average. When the short-term average is above the long-term average, it indicates that the stock price is overvalued and should be sold and vice versa. For this model, we will look at the points of interest where the moving average curves cross each other, which indicates that they will continue to go in the same direction, which is away from the point of interest. After this point, we will look for opposite price movements to find local extreme



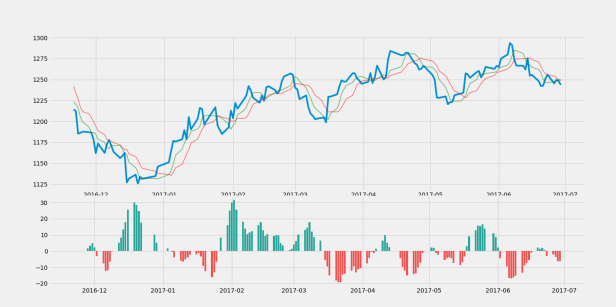
(a) Gold



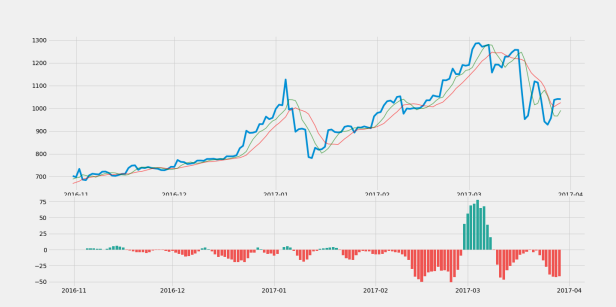
(b) Bitcoin

Figure 2: Comparison between Line chart and RSI of Gold and Bitcoin over a period of 5 years.

points for trading. Since this model profits by finding extreme average price movements, it is reliable and much beneficial for highly volatile stocks. Even though this strategy relies on extreme price movements, it yields good returns from less volatile stocks, mostly due to the high frequency of these low-price oscillations as compared to the low frequency of high price oscillations of highly volatile stocks. This is evident in our model tests, which gave maximum returns of 56% with Gold while 5257% returns on Bitcoin.



(a) Gold



(b) Bitcoin

Figure 3: Comparison between Line chart and MA of Gold and Bitcoin over a period of 5 years.

MACD Trading is an advanced form of stock trading, where we use the Moving Average Convergence and Divergence (MACD) Indicator to track patterns in stock prices. MACD is used to track points of lowest movement in stock prices with extreme price changes before that point, which is the local minimum/maximum. It can be defined as an extension of the Moving Averages (MA) trading strategy, but instead of

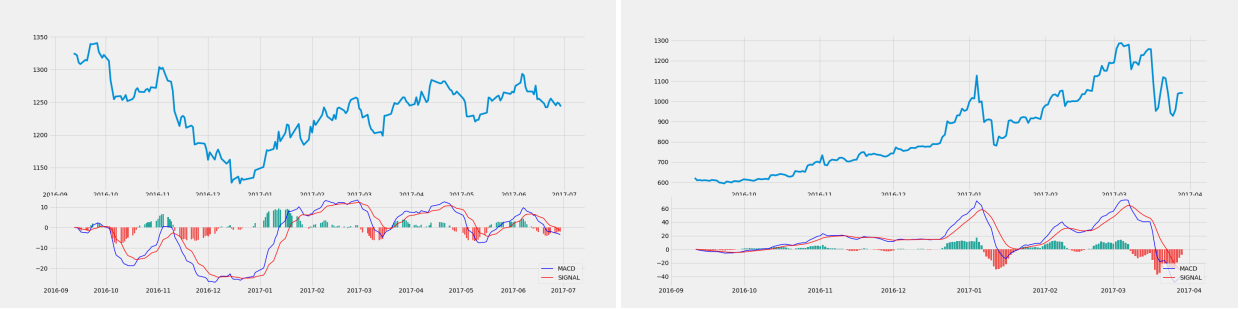
moving averages, we use exponential moving averages. Exponential moving averages (EMA), are moving averages that place greater weight on most recent values. Moving Averages Convergence and Divergence (MACD) can be defined as the difference between these two EMA's. Since the stock price tends to oscillate around long-term EMA, the difference between these two values, i.e., MACD, also oscillates around the axis. For this model, we also track another indicator, called the Signal Line, where the signal line represents an exponential moving average of MACD. Even though MACD tracks stock prices with exponential weights, it takes time to reflect sudden stock price movements. Also, it is hard to track quality local peaks and valleys in the MACD curve. So, to counter that, we track the Signal line, which closely follows the MACD line, and accurately reflects the changes in the MACD curve. To visually track these changes, we can plot a histogram of the difference between these two curves, Signal and MACD respectively.

Like Moving Averages trading, this model tracks extreme price movements, but since it specifically tracks slow movements after extreme changes in stock prices, this model doesn't yield good returns on low volatile stocks, but performs extraordinarily well on highly volatile stocks, like bitcoin. This is evident from our tests on this model, which gave returns of 8502% returns on Bitcoin as compared to 20% on Gold. Just for comparison, if you had bought bitcoin at the start of this trading strategy and did not trade it until the end of this trading period, it would yield just 7400% and 80% returns on Bitcoin and Gold respectively.

$$MACD = EMA_{faster} - EMA_{slower}$$

$$\text{Signal} = EMA_{MACD}$$

EMA(x) = Exponential Moving Average over x days



(a) Gold (b) Bitcoin

Figure 4: Comparison between Line chart and MACD of Gold and Bitcoin over a period of 5 years.

2.5 Model Development

A certain amount of cash is available every day before the trading hours. We have used stock price data till the day before to analyze whether it is advisable to buy, hold, or sell the stock on that day. In this model, indicators like MACD, RSI, news of assets, and resistance and support levels are incorporated to determine whether to buy, hold, or sell stocks. At first, individual stocks' buy and sell signals are determined using MACD, RSI, and MA indicators. In this model, we attempt to optimize the total asset on 9/10/2021. We denote the net asset on this day as $A(T_{final})$. The total asset on that day depends on the trading strategies. The trading strategy means how traders base their decision to buy, hold or sell the stock. The trading strategy also includes how many stocks a trader buys or sells if the trader decides to buy or sell. For this model, the maximum number of stocks that a trader buys or sells on a day is constant. The N_b, N_s, M_b, and M_s are the maximum number that a trader can buy or sell for gold and Bitcoin. Every time investors want to invest in gold or Bitcoin; they have to go through two decision-making processes.

Decision Process 1:

The first step is to look up the MACD, RSI and MA indicators. I_1 is the result of MACD, I_2 is the result of RSI, and I_3 is the result of MA. Using I_1, I_2, and I_3 values, the deciding factor γ is calculated, which we have defined as

$$\gamma = K \times I_1 + L \times I_2 + M \times I_3 \tag{1}$$

Where,

$$K + L + M = 1 \tag{2}$$

and

$$0 \leq K, L, M \leq 1$$

The K, L, and M are the relative strength of the indicator in optimizing the $A(T_{final})$. If MACD gives a more accurate signal for a stock than the other two indicators, then the value of K for that stock is more significant than L and M. For this model, more accurate means more value of $A(T_{final})$. So, if the optimal return by just using each of MACD, RSI, and MA are x,y, and z, respectively, then the values of K, L, and M are calculated as follow:

$$K = \frac{x}{x+y+z} \qquad L = \frac{y}{x+y+z} \qquad M = \frac{z}{x+y+z} \tag{3}$$

And, the values of I_1, I_2, and I_3 are as follows:

$$I_1 = \begin{cases} 1, & \text{if MACD signals to buy} \\ 0, & \text{if MACD is inconclusive} \\ -1, & \text{if MACD signals to sell} \end{cases} \quad I_2 = \begin{cases} 1, & \text{if RSI signals to buy} \\ 0, & \text{if RSI is inconclusive} \\ -1, & \text{if RSI signals to sell} \end{cases} \quad I_3 = \begin{cases} 1, & \text{if MA signals to buy} \\ 0, & \text{if MA is inconclusive} \\ -1, & \text{if MA signals to sell} \end{cases}$$

Since, the RSI indicator shows the strength of the stock based on past price movements, using it for low to medium volatile stock will result in better returns. In High volatile stocks, unexpected price fluctuation might produce false signals in this strategy that can cause big losses. Since there is a lot of movement in High Volatile stocks, movement tracking indicators usually give us better results due to their ability to adapt to extreme changes faster. The MACD indicator is a perfect strategy for these kinds of stocks, where we profit from the high frequency of price fluctuations.

Given all of these conditions, we can conclude that using the RSI trading model, will result in maximum returns for gold trading and using the MACD trading model for Bitcoin trading. This decision is also backed by the outstanding returns achieved with these models.

Using this information, it can be said that γ takes any value from -1 to 1. If the γ value is positive, it signals the investor to buy the stock and if γ value is negative it signals the investor to sell its position and 0 signals the investor to hold. Once the investor gets their γ values, they will go into the second phase of decision making.

Decision Process 2:

Every time an investor buys a stock, they expect to sell it higher than they bought. They have some expectation that stock will go up to some price based on their analysis. In our analysis, we have considered RSI, MACD, and MA. One way to roughly estimate by how much the stock will go up is to use the moving average value of that stock. One cannot simply choose a certain number of days to calculate the moving average of the stock price when they attempt to buy or sell their stock. It has to consider the volatility of the signal. A higher volatility means higher fluctuations in the stock price. A higher fluctuation in stock price means the error in analysis rises more quickly as time increases. One can compare the volatility of two

stocks by calculating the variance of the stock prices of the two stocks. Since bitcoin has a higher variance than gold, it has greater volatility than gold; one likely has to consider fewer days for bitcoin than gold to calculate the moving average of the stock price.

Buying and selling a stock costs the investor some commission. In the case of gold, it is 1%, and for Bitcoin, it is 2%. One must also consider the cost incurred due to the commission of the stock while buying and selling to determine whether it is worth buying or selling after getting buy or sell signals from γ value.After considering the γ value, an investor has to make an educated about where he is going to sell the stock. One way to do that would be by using the average price movement of the stock under a justifiable number of days. As explained in the last paragraph, the number of days for taking an average price movement for bitcoin is fewer than the number of days for taking an average price movement for gold due to its high volatility. Let us denote the average price movement is ΔP.

- Now, if γ is positive, then Expected Profit is given by:

$$EP = \Delta P - \alpha(2P + \Delta P) \tag{4}$$

  Where, α is the commission rate for the stock that the investor is considering, and P is the price at which the investor is making the buying decision.
  If this EP is greater than zero, the investor decides to buy, and If it is not, he does not do anything.

- Now, if γ is negative, then:
  An investor expects that by selling at this price, they can buy the stock at a lower price, which will lower their loss than if they hold it. Moreover, the expected amount of loss saved is given by:

$$\text{Expected loss minimization by selling at price P (LP)} = \Delta P - \alpha(2P - \Delta P) \tag{5}$$

  Where, α is the commission rate for the stock that the investor is considering, and P is the price at which the investor is making the selling decision.
  If this LP is greater than zero, the investor decides to sell, and If it is not, they hold their stock.

- If γ is 0, then the investor holds whatever stock they have for that stock.

As per our assumption, trading happens only at the beginning of the day when we have C(t-1) money. For a given day, if there is a buy command for one asset and a sell command for another asset, then the investor

perform the sell command first and then move on to buying command. Addressing the selling command first and buying command second can help to increase the amount of cash that can be used to address buying command for that day. And, once the selling is done, the amount of cash, gold, and Bitcoin (in dollars) is given by:

$$\begin{aligned} C(t_1) &= C(t-1) + g_s \times \mathbf{G}(1-\alpha_g) + b_s \times \mathbf{B}(1-\alpha_b) \\ G(t) &= G(t-1) + g_s \times \mathbf{G} \\ B(t) &= B(t-1) + b_s \times \mathbf{B} \end{aligned} \tag{6}$$

Where, $C(t_1)$ = Amount of cash assets in dollars after addressing the selling command

While selling, if the amount of bitcoins or gold to be sold is not enough, then the investor sell all the amount they have. Whereas, if there is sufficient amount, then the investor only sell the maximum number of the stock that is assigned for the stock.

After selling, the investor proceed to address buy commands. After buying:

$$\begin{aligned} C(t) &= C(t_1) - g_b \times \mathbf{G}(1+\alpha_g) - b_b \times \mathbf{B}(1+\alpha_b) \\ G(t) &= G(t-1) + g_s \times \mathbf{G} \\ B(t) &= B(t-1) + b_s \times \mathbf{B} \end{aligned} \tag{7}$$

Let M_b and N_b are the optimized value to buy both gold and bitcoin. Then, ratio of b_b to $g_b = \frac{N_b}{M_b}$

If amount of cash asset in dollars is not sufficient:

$$C(t-1) = [b_b \times \mathbf{B} \times (1+\alpha_b) + \frac{g_b \times M_b}{N_b} \times \mathbf{G}(1+\alpha_g)]$$

1. If both decision process give green signal to buy bitcoin only, then we buy either of

$$\left\{ \frac{C(t-1)}{(1+\alpha_b) \times \mathbf{B}}, N_b \right\}.$$

If

$$N_b > \frac{C(t-1)}{(1+\alpha_b) \times \mathbf{B}},$$

then

$$b_b = \frac{C(t-1)}{(1+\alpha_b) \times \mathbf{B}},$$

else

$$b_b = N_b$$

Note: Similar is the case with gold!

2. If both decision process give green signal to buy both the bitcoins and gold and available cash is $C(t^p)$, then:

   If

$$C(t^p) \geq [N_b \times \mathbf{B}(1+\alpha_b) + M_b \times \mathbf{G}(1+\alpha_g)]$$

   else,

$$b_b = \frac{N_b \times C(t-1)}{N_b \times \mathbf{B}(1+\alpha_b) + M_b \times \mathbf{G}(1+\alpha_g)}$$

   and,

$$g_b = \frac{M_b}{N_b} \times b_b$$

3. If both decision process give green signal to sell bitcoin, then If

$$N_s > \text{number of bitcoin stock the investor has,}$$

   then

$$b_s = \text{number of bitcoin stock the investor has,}$$

   else

$$b_s = N_s$$

4. If both decision process give green signal to sell gold, then If

$$M_s > \text{number of gold stock the investor has,}$$

   then

$$g_s = \text{number of gold stock the investor has,}$$

else

$$g_s = M_s$$

Whenever investors want to analyze the stock market for gold and bitcoin, they follow the above steps to decide whether to buy or sell. After analyzing simple models for gold and bitcoins, the optimized value of K,L, and M are determined which are explained in the next section. The optimized value of N_s,N_b, M_s, and M_b are also determined by using simple models which only consider one stock at a time.

The main goal of this model is to optimize the value of total assets on 9/10/2021 and also suggest what strategy will be better to secure better returns and higher securities. The total asset on 9/10/2021($A(t_{final})$ is the function of K, L, M, N_s, N_b, M_s, M_b, α_G, and α_B.

2.5.1 Finding optimized values of the parameters for the model

In order to find the K, L, and M values of gold, we first attempted to analyze the market using the MACD index of gold only. We are attempting to find the maximal value of assets that can be generated on May 1st, 2021, just by using MACD index values of gold which only depends on two variables: the number of days over which the MACD index is taken. So, to simplify the process, if the MACD index signal suggests buying or selling, we have decided to buy or sell a maximum of one stock. Also, we have ignored the commission rate. Using different combinations number of days for the MACD index, the decision to buy, sell or hold gold is made, and $A(t_{final})$ is determined and recorded. From these recorded values, the optimal $A(t_{final})$ is determined. By following a similar approach, the optimal value of $A(t_{final})$ is determined just using the RSI index and then the MA index for gold. Again, these steps are repeated for Bitcoins too.

The values of assets on 9/10/2021 compared to assets on 9/10/2016 are shown in table (belows-instruction give specific numbers for table). From Table I to VI, it can be seen that the optimal return for gold using RSI index only is 79%, using MACD index only is 20%, and MA index only is 56%. Similarly,for bitcoin, the optimal return is 8902% using MACD index only, 5257% for MA index only,and 22% using RSI index only. Using equation(3) the values of K,L, and M are calculated as follows: $K_g = 0.129$, $L_g = 0.510$, $M_g = 0.361$ and $K_b = 0.617$, $L_g = 0.002$, $M_b = 0.381$.

Once these values are determined, we attempted to find the value of N_s, N_b, M_s, and M_b using these values. The analysis of our model, as shown in the Figure 5, suggest the asset is optimized when $N_b = N_s = 0.2$ and $M_b = M_S = 0.02$.

RSI-Over	Returns%
4	0.51243879
6	-1.1521681
8	-1.1257026
10	3.09269322
12	4.53689177
14	4.76284293
16	10.5831774
18	13.1376982
20	16.5172886
22	21.2916686
24	21.9796734
26	21.0467963
28	17.5073879
30	19.6885941

Table I. Returns for Bitcoin for RSI index

RSI-Over	Returns%
30	19.3163878
32	11.9681708
34	12.4321353
36	14.9673302
38	14.5386095
40	16.1410163
42	17.1365501
44	21.3949414
46	76.6089456
48	76.6377385
50	79.4292975

Table II. Returns for Gold for RSI index

Average Days#1	Average Days#2	Profits
24	13	5257
16	7	5242
18	17	5200
8	11	5005
26	13	4976
4	15	4913
4	2	4654
4	2	4654
10	11	4650
28	11	4646
28	13	4539
14	5	4507
12	13	4323
6	8	4303

Table III. Returns for Bitcoin MA index

Average Days#1	Average Days#2	Profits %
6	4	56
8	3	54
6	3	51
6	5	50
10	4	49
10	5	45
12	2	45
12	2	45
4	3	44
8	5	43

Table IV: Returns for gold for MA index

Average1	Average2	Profit %
26	12	20
24	11	19
24	9	19
24	8	19
22	12	19
26	10	18
22	10	18
20	10	17
18	11	17
22	9	16
20	12	16

Table V: Returns for gold for MACD index

Average1	Average2	Profit%
22	8	8502
20	8	8372
24	10	8337
20	9	8181
24	8	8170
18	8	8159
20	9	8072
24	9	8044
24	8	8012
18	8	8003

Table VI. Returns for Bitcoin for MACD index

3 Implementation of the model to address given questions

3.1 Best Daily Trading Strategy

3.1.1 Volatility

Volatility is a good indicator to find the nature of a stock or commodity, it shows how susceptible this asset is to extreme price changes. Even though high volatile assets don't provide good security on their investments, it can be used to achieve extremely high but risky returns through active trading. In stock trading, volatility can be measured with the average standard deviation of a stock over a period. We calculated Standard deviation of Gold and Bitcoin over a period of 5 years to be 14040.04 and 249.19 respectively. Since the

prices of Bitcoin and Gold have incomparable price ranges, comparing their standard deviations to find their volatility won't be insightful. To make more sense of their standard deviation, we calculated volatility as average of deviation percentage from its average value over a period of 5 years, which can also be written as standard deviation divided by its average value.

$$\text{Volatility} = \frac{\text{Standard Deviation}}{\text{Average Value}}$$

Using price data, we get the average price of Bitcoin =12206.07 with standard deviation=14040.04, and the average of Gold = 1464.55 with the standard deviation of 249.19.So, the volatility for bitcoin is 1.1502 while the volatility for gold is just 0.17015.

For Comparison, Volatility of Meta(Facebook), Microsoft and SP500 Stock is 0.48, 0.30, 0.22, where Facebook and Microsoft represent high performing stocks and SP500 representing average volatility of top 504 high valued companies' stock in the US.

1. Volatility (Microsoft) = 0.48
2. Volatility(FB) = 0.30
3. Volatility(SP 500) = 0.22

From our calculations, Bitcoin is 7x times more volatile than Gold. Therefore, Bitcoin is susceptible to higher price changes

3.1.2 Model Optimization

After making the model from our theory, our goal was to optimize the asset on a long run. Since different stocks move at different pace with different volatility, taking averages and moving averages over same number of days make our model less efficient. So, we optimized average number of days by considering it as a variable and tested its accuracy by observing the results that gives optimal result for returns to find best averages. The optimized value can be evaluated by looking at Table IV, V and VI.

Deciding investment strategy needs investment goal. On the hand, we have maximum profits and less security, while on the other we have low profits and highly security. For this model, we will first attempt to demonstrate two strategies with two different goals. Fist strategy is aim for the investor who wants better returns, and the second strategy is aimed for the investor who prefer stability. Investing more in Bitcoin and less in gold will likely address the need of first types of investor, while investing less in Bitcoin and more in

gold will likely address the desires of the second types of investor.

For Gold trading:

- **RSI Model**: Average price increase/decrease was optimized at 50 Days. We got 79.42% returns with this optimization.
- **MACD Model**: long-term EMA, short-term EMA and EMA of MACD were optimized over 26,12, and 9 days respectively. We got 20% returns with this optimization.
- **MA Model**: Long term MA and short term MA were optimized over 6 and 4 days respectively. We got 56% returns with this optimization.

For Bitcoin Trading:

- **RSI Model**: Average price increase/decrease was optimized at 24 Days. We got 21.98% returns with this optimization.
- **MACD Model**: long-term EMA, short-term EMA and EMA of MACD were optimized over 19, 8,and 4 days respectively. We got 8902% returns with this optimization.
- **MA Model**: Long term MA and short term MA were optimized over 24 and 13 days respectively. We got 5257% returns with this optimization.

For both Bitcoin and Gold:

Until now, we are only considering one stock at a time. On the one hand, bitcoin gives high return, but it is unreliable due to its high volatility. On the other hand, gold gives high sense of security to the investor, but it gives comparatively marginal returns. So, a good approach would be secure the bags with some sense of reliability. To address this issue, we ran algorithm with different number of $N_b = N_s$ and $M_b = M_s$. Figure 5 shows the result of our simulation.From figure 5, one can see that the optimal return is 6048 percent which happens when $N_s = N_b = 0.2$ and $M_s = M_b = 0.02$. This is the strategy where an investor can get very high return with relatively high sense of security.

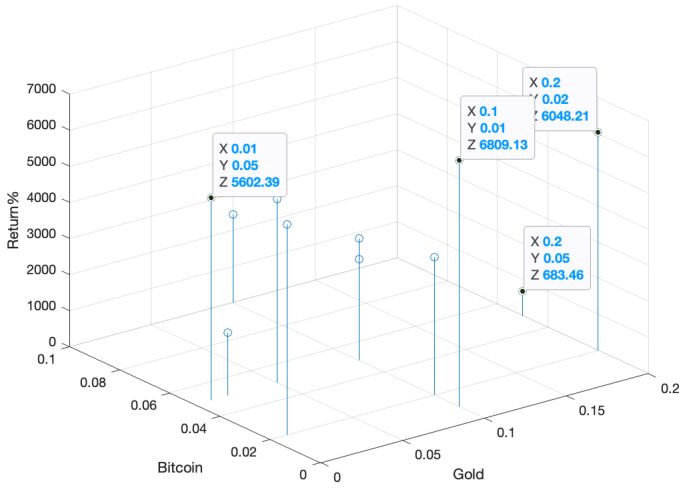


Figure 5: Scatterplot of N_b, M_b, and Return%

4 Model Analysis

4.1 Sensitivity Analysis

We studied the effect of varying values of α_b and α_g in our model. Since α is the commission rate that depends on the stock price for a given day, it is very important factor in determining the decision of the trader. We changed the values of α_b and α_g to various random values and observed the returns we get. The Fig. 6 shows the commission rate of bitcoin and gold along with corresponding returns.

From Fig. 6, we observe that as the commission value decreases, the amount of return increases. For eg: when α_b = 0.05 and α_g are 0.01. the return we get is 5602%. But, when α_b = 0.02 and α_g = 0.01, we get 5831% return. Likewise, the return is 5705%when both α_b and α_g = 0.05 and 2435% when both α_b and α_g = 0.1. This matches with our intuition and understanding of the real world stock market situation.

4.2 Strength

- Since our model consider three index to make decision to buy, sell, or hold, other trading index can also be incorporated without much difficulties.
- Our model incorporates commission rate to decision making process. If one wants to also include tax and brokerage fee in decision making process, then it can be easily done by following similar

Gold_Commision	Bitcoin_Commisi	Returns%
0.01	0.05	5602.3899
0.01	0.02	5831.16386
0.1	0.01	6809.13134
0.1	0.02	3811.04814
0.1	0.05	2799.16398
0.1	0.1	2435.9523
0.02	0.05	1748.97942
0.1	0.05	3373.50022
0.2	0.05	683.46046
0.2	0.02	6048.20558
0.05	0.05	5074.6503

Figure 6: α_G and corresponding returns

approach.

- Our model also shows negative returns for some choice of parameters that asset is depended upon. So, the model can also warn the trader that some of strategy are better not to apply.
- Model is sensitive to commission rate.
- The model described is easy to implement on a daily basis.
- The model also gives the number of stock the investor should buy or sell once they go through two decision making processes
- The model also allows the investor to choose from ranges of trading strategy as per their degree of preference on security and returns.

4.3 Weakness

- This model does not allow to do analysis of Bitcoin and Gold at separate time of a day to make trading decisions.
- The model does not take the volatility and security of the stock in decision making process, but in real world these two factors are important factors in decision making process.
- Short term profits are not given strong consideration while optimizing the total assets on 09/10/2021

- The model does not allow the investor to withdraw partial amount of assets before the end of running period. Intial amount of cash can be change, but while running the simulation, traders have to wait for the entire period of time they are supposed to trade.
- Other than buying and selling the stocks, our model does not consider swing and option trading.

5 Future Works

This model is optimized for Gold and Bitcoin, which are less volatile, low returns; and Highly volatile, high returns assets, which are not the optimal types of assets to make algo-trading models for. Our process of making a model should first answer the goal of the model, profits or security? Then we will calculate volatility for some selected stocks to find out which stocks serve our interest, and train their trading models. Combining models with one goal will give better results due to the similarity of the stocks in the portfolio. An opposite approach to this is to diversify, which is the most common, secure and easiest strategy. Since you divide your portfolio, you essentially divide your risk over multiple stocks, while also increasing your returns with high performing stocks.

In recent years, the news of stock has played an instrumental role in its future price action. So, the inclusion of news in our model will make the model more efficient and practical, which can be the next step for this model. Sentiment Analysis of Market using news, websites and blogs is another great way to analyze the market. Recent developments in artificial intelligence have allowed us to scrape the internet for material related to stocks and analyze them. With sentiment analysis, we can discover trading patterns of the public, which we can use to trade stocks before that public sentiment affects the market. Many hedge funds use this strategy along with other algo-trading strategies, to predict the market and generate higher profits. Since we were only limited to the data given to us which had no information about the news, we were unable to incorporate that into our model. Similarly, other commonly used analytical tools like support and resistance can be incorporated into the model to make it more realistic. As more and more people have swarmed over the stock market in recent years, simple tools like support and resistance have become more powerful to drive the stock market psychology.

6 Conclusion

Based on our theory, we evaluated different types of models by trading with the help of technical indicators used for stock trading. We developed three base models (RSI, MACD, and MA model) and optimized their variables for Gold and Bitcoin trading separately. We then calculated their optimal returns to find the reliability of each model. Then we combined all three models to make a new model, where we weighted signals from each model and decided trades based on that output signal. We then studied the effect of change in commission rate for gold and bitcoin and how it affects the decision-making process. We also discussed how amounts and profits are calculated and how all of these values are optimized.

Our tests found that, even though we receive a higher degree of security over investments with our model, it gives lower results(6000%), than if they were traded with different models separately(8000%). It is because we are trading gold and bitcoin together, and bitcoin's higher performance is dragged down by trading gold, which in turn provides long term stability. But with the decrease in returns, an investor can gain high sense of security over their investment. Again, if the investor prioritizes mainly on security, then the maximal profit is 79 percent. Overall our model can suggest different optimal trading strategies based on the degree of investor's priority on security and returns.

Memorandum

To: Mr. X

From: Our Group

Date: 21 Feb 2022

Subject: Best Strategy for Stock Market Investment

We are writing to inform you that our team has developed a new mathematical model recently, which helps you to optimize your return from the stock market. Keeping in mind the naivety and lack of knowledge of the amateur traders, we came up with this model to help them. However, this model is not just limited to new traders. If implemented properly, any trader can get huge benefits from this model.

Our model optimizes the profit earned from trading of gold and bitcoin (though it is not limited to just two of them.) The model is based on three major widely used analytical tools in stock trading: Moving Average Convergence Divergence (MACD) indicator, Relative Strength Indicator (RSI), and Moving Averages (MA). Moving Averages Trading (MA) is based on the oscillation of stock prices around the long-term moving average. In this method, we track the movements of a long-term average and a short-term average. When the short-term average is above the long-term average, it indicates that the stock price is overvalued and should be sold and vice versa. Likewise, RSI is another indicator that gives information about the status of the stock. It ranges from a value of 0-100 where 40 represents the stock is oversold and 60 represents the stock is overbought. Moving Average Convergence and Divergence, aka, MACD is an extended form of moving average that gives the main focus on recent stock values. In this model, we studied the combined effect of all these parameters on the momentum of the stock, and then we tried to predict its future.

First, we created three models based on each tool and studied their effect of them on gold and bitcoin separately. Then, we combined the model to encompass both the stocks at the same time. The result obtained from the individual study is as follows. For gold, the RSI model predicted a return of 79.42%, the MACD model predicted the return to be 20%, and we got a 56% return with MA optimization. Likewise, for bitcoin, the return was 21.98% from RSI optimization, 8902% from MACD optimization, and 5257% from MA Model. From these individual data for each stock, we found the required coefficients K, L, and M for the equation: $\gamma = K \times I_1 + L \times I_2 + M \times I_3$. From then on, we found the number of stocks to be bought for both bitcoin and gold whenever the transaction happened. After determining the values of all the required variables, we fed them to the equation which gave us either a buy or sells signal. That decision

was passed through another decision table that looked at the profit generated due to the transactions. If the calculated profit was greater than the commissions paid for the transactions, then only the transaction happened.This is how our model functions.Our models also incorporates the idea of volatility. When we fed the information we were given, our tests found that, even though we receive a higher degree of security over investments with our model, it gives lower results(6000%), than if they were traded with different models separately(8000%). It is because we are trading gold and bitcoin together, and bitcoin's higher performance is dragged down by trading gold, which in turn provides long term stability.

Our model, though not 100% accurate, is a fairly good model that helps a trader to do a profitable trading.When tested to the real life data, it gave us a good amount of profit depending on the type of stock which was our goal. I am excited for you to try our model on your own! Please let us know if you have any questions. Thank you for your time.

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