

# Research on quantitative trading strategy based on prediction and dynamic programming model

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**Abstract.** Today, the digital currency market represented by bitcoin has become an important part of the capital market. As the COVID-19 pandemic has increased volatility in capital markets in the past two years, effective trend forecasting and risk-averse investment strategies can bring substantial profits to companies and individuals and reduce the possibility of financial risks. To achieve the above objectives, we established the following models: (1) price prediction models of gold and bitcoin; (2) trading market risk judgment model; (3) revenue valuation model based on dynamic programming. This paper uses ARIMA and LSTM neural network to establish the prediction model. After checking the historical data, the best parameter fitting values of ARIMA model were obtained by using the exhaustive method according to BIC criterion, which were ARIMA (4,1,3) (gold) and ARIMA (2,1,2) (bitcoin) respectively. Then LSTM recurrent neural network is used to modify the forecast results, and the price forecast graph with high fitting degree with the real data is obtained. Then, this paper combines the technical indicators commonly used in the financial market to form a market risk judgment model. On the basis of the eight laws of buying and selling, the weight index is introduced to put forward the bull and bear market judgment rules of gold and bitcoin trading, and the tendency distribution map of the market environment in the past five years is obtained. At the same time, the buying risk coefficient is quantified by combining the maximum retraction rate. On the basis of the first two sub-models, this paper establishes a revenue valuation model based on the idea of dynamic programming. By setting the policy trigger threshold to control the risk, the problem that local optimal solution may appear in the model is improved.

**Keywords:** Quantitative strategy; ARIMA; LSTM; Risk judgment; Digital currency.

## 1. Introduction

In order to make the national economy sustainable and healthy, we need to establish a standardized risk identification mechanism and computer-based quantitative investment strategies to reduce the likelihood of financial risks. Financial activity is an important area of national economic activity, meanwhile, the frequency of financial transactions is an important measure of the country's economic prosperity. With the development of the national economy, the financial industry has had an increasingly significant influence on all walks of life. Due to the impact of the Covid-19, all kinds of risks in the national economic operation are gradually obviously reflected in the financial market. In order to make the national economy sustainable and healthy, we need to establish a standardized risk identification mechanism and computer-based quantitative investment strategies to reduce the likelihood of financial risks.

Cash, gold, and Bitcoin are the typical asset forms of today. Gold investment has the characteristics of simple operation and strict regulatory system; Bitcoin has fast capital settlement and low transaction costs, so it is welcomed by various investors and develops rapidly. The allocation of funds in the market should be reasonably planned and calculated to avoid large losses caused by the financial market shocks. At present, for the investment problem, the main research is how to invest based on the target of high return rate and how to avoid risks in the overall market environment and market.

At the request of traders, we need to develop a model for gold and bitcoin investment strategy decisions based only on historical price trends. Thus, the best investment plan from 09-11-2016 to 09-10-2021 was formulated and the final investment value was calculated. We will perform the following tasks based on the given data:

Based on the price data before the current trading day, we will predict the price changes of bitcoin and gold, and make the best daily investment plan according to the change trend. Solve the present value of the strategy at the end of the investment period with the initial \$1,000 investment.

## 2. Methodology

### 2.1 Model assumptions

We make several assumptions in our model. Later we may relax some of these assumptions to optimize our model making it more applicable in the complex reality environment.

(1) Suppose that know the gold / bitcoin price until day N when trading on day N, and when bought at this price, earnings were calculated from day N+1.

(2) Suppose that the commissions resulting from the gold and bitcoin transactions are settled on the same day.

(3) Suppose that for gold, the price on the non-trading day is the same as on the previous most recent trading day.

(4) Suppose that no other expenses are considered expect commission, such as gold storage costs, transaction taxes.

(5) Suppose that the assets are infinitely separable.

### 2.2 Symbol description

Table 1 shows the symbol description of the model.

**Table 1.** Symbol Description of the model

Symbol	Significance of Symbol
$Bulls_{bitcoin}$	Bitcoin bull market indicators
$Bulls_{gold}$	Gold bull market indicators
$AVG_{bitcoin-60}$	Bitcoin consecutive rise period of 60-day moving average
$AVG_{bitcoin-60-Bias(G-15)}$	The previous 60-day average of bitcoin's 5-day divergence rate
$AVG_{bitcoin-120}$	Gold consecutive rise period of 120-day moving average
$AVG_{gold-120-Bias(G-15)}$	The previous 120-day average of gold's 15-day divergence rate
$\beta(G)\&\beta(B)$	Purchase risk coefficient
$Val_{Gold}, Val_{Bitcoin}$	Buying and selling valuation
$PV_{NF}$	Increase forecast value
$Max\ Drawdown_{Gold-30}$	Gold's Maximum retraction rate within 30 days
$Max\ Drawdown_{Bitcoin-15}$	Bitcoin's Maximum retraction rate within 15 days

## 3. Model construction and solution

### 3.1 Prediction Model

#### 3.1.1 Data pre-processing:

In this paper, we are required to use only the data files given by the two data sets LBMA-GOLD.csv and BCHAIN-MKPRU.csv for analysis. In addition, the 10 missing values in the LBMA-GOLD.csv file are interpolated with the prices of two adjacent days for the mean value, and the partial results are as follows (Table 2):

**Table 2.** Partial data

	<b>Date</b>	<b>USD(PM)</b>
<b>1260</b>	9/6/21	1821.60
<b>1262</b>	9/7/21	1802.15
<b>1262</b>	9/8/21	1786.00
<b>1263</b>	9/9/21	1788.25
<b>1264</b>	9/10/21	1794.60
1265 rows × 2 columns		

In the subsequent calculation, we conducted discrete normalization processing for indicators as required, and the formula is as follows:

$$X = \frac{x - \min}{\max - \min} \quad (1)$$

### 3.1.2 Market environment analysis:

According to historical data, from 2016 to 2017, the price of Bitcoin showed a preliminary exponential upward trend, which was in the stage of value discovery and investors flocked to it. Data range is large, variance is large, extremely unstable. The overall price of Bitcoin is in a non-normal distribution state [1]. During 18-20 years, Bitcoin has maintained a "relative steady state" of high price, and the overall price is at a lower level of the average. Since 20-21, the price of Bitcoin has risen sharply again since 2016, accompanied by strong uncertainties.

And change the price of gold is more market risk aversion and the federal reserve's monetary policy change and other factors, the release of liquidity in the market due to COVID-19 outbreak, makes the dollar index high, resulting in the price of gold in the middle of the 19 years break from 16 to 19 years in a relatively stable state, in August 20 years and was once above \$2000 an ounce. As the Fed began to signal to the market in June that it was considering accelerating tapering, the dollar and U.S. bond yields rose, adding to the downward pressure on international gold prices [2].

As trading assets, bitcoin and gold have the following characteristics (Table 3):

**Table 3.** The Characteristics of Bitcoin and Gold

<b>MONETARY PROPERTY</b>	<b>GOLD</b>	<b>BANKNOTES</b>	<b>BITCOIN</b>
<b>Intrinsic Value</b> (Individual recourse if this monetary trade network collapses)	Very high	high	high
<b>Portability</b> (Transaction variable costs)	medium	high	Very high
<b>Divisibility</b> (Ease of contracting fractional units, transaction fixed costs)	high	Very high	Very high
<b>Scarcity</b> (Ability to resist expansion of the money supply, inflation tax)	Very high	low	Very high
<b>Recognizability</b> (Assay costs)	medium	high	Very high
<b>Fungibility</b> (Ease of value calculations, maintenance of recognizability)	Very high	high	Very high
<b>Durability</b> (Total storage, mining and maintenance costs, security)	high	high	high

The average value of bitcoin/gold over different time periods:

When we study the rise trend of gold and bitcoin, we first calculate the average rise of bitcoin and gold in the previous N days. Considering the transaction characteristics of the two products, we set the step size to 5 and traversed the time cycle length from 5-25 days. After comparing the results, N was finally determined to be 5 (bitcoin) and 15 (gold) respectively. The price trend obtained is shown as follows (Figure 1 and Figure 2):

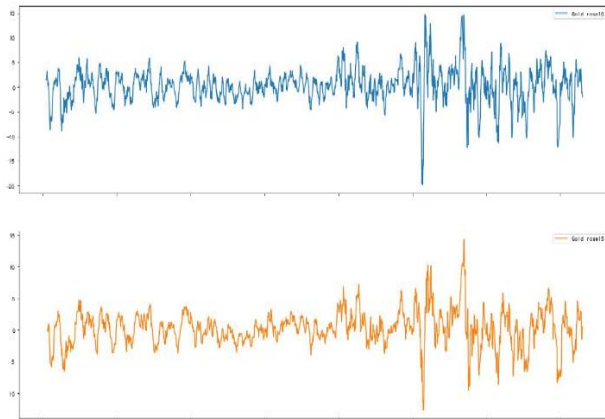


Figure 1. Price trend of Gold table

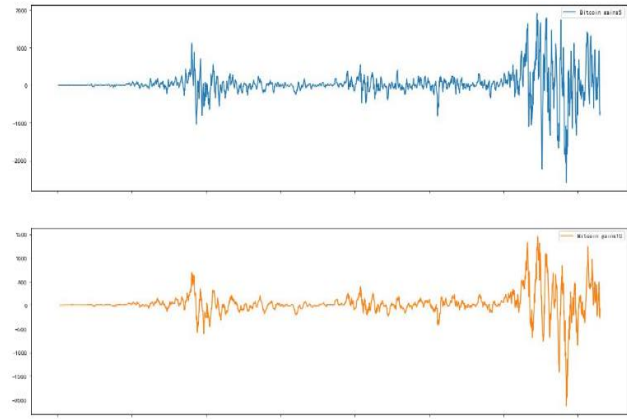


Figure 2. Price trend of Bitcoin table

### 3.1.3 Establishment of prediction model:

The question asks us to construct a daily trading strategy using only the days and previous price data, which in turn depends on the price movements of gold and bitcoin the next day. So, we use the first 15 days of data as a baseline to make future price forecasts. We make a preliminary prediction using the more widely used ARIMA model.

ARIMA (p, d, q) model structure [3] is:

$$\begin{cases} \Phi(B) | \nabla^d X_t = \theta(B)\varepsilon_t \\ E(\varepsilon_t) = 0, \text{var}(\varepsilon_t) = \sigma_\varepsilon^2, E(\varepsilon_t \varepsilon_s) = 0, s \neq t \\ E(X_s \varepsilon_t) = 0, \forall_s < t \end{cases} \quad (2)$$

Among these: p: Autoregressive item /q: Moving average term / $\varepsilon_t$ ,  $\varepsilon_s$ :White noise sequence  $\Phi(B)$  and  $\theta(B)$ : Polynomial of Delay operator B/ $X_t$ : Autoregressive moving average sequence of order p, q.

Since most financial time series are non-stationary, it is necessary to carry out difference calculation on the price data of the two commodities, which can make the non-stationary time series stable. Operation for:

$$\nabla^d X_t = (1 - B)^d X_t = \sum_{i=0}^d (-1)^i C_d^i(B) X_{t-i} \quad (3)$$

After a difference operation, we conducted ADF test on the sequence data, and obtained their P values were respectively as: -2.86(gold), -2.56(bitcoin). All were less than 0.05, indicating that the sequence data passed the stationarity test.

After the price time series of the two commodities become stationary, we write a cycle function in Python according to BIC minimum criterion to determine its optimal parameters, and finally get: p=4, q=3(gold); p=2, q=2(bitcoin).

After price prediction, Durbin-Watson values were calculated as DW(G)=2.005 and DW(B)=1.993 respectively, indicating that the fitting residual of this model presented randomness [4]. However, it was found from the results that although ARIMA could well fit the trend of price change, However, the prediction of the range of change is still insufficient, and we use neural network to make corrections later.

### 3.1.4 Revision of prediction model

Long short-term memory (LSTM) as a special recurrent neural network (RNN), can preserve part of the information by introducing a new internal state, solve the problem of gradient disappearance in long time sequence training, and achieve the effect of further improving the accuracy.

In the hidden layer, each cell has memory cells, and output gates, forgetting gates and output gates jointly determine the generation of output values.  $x_t$  is the input at time  $t$ ;  $c_t$  is Memory cells at time  $t$ ;  $f_t$  is Forgotten door at time  $t$ ;  $i_t$  is in-gate at time  $t$ ;  $\tilde{c}_t$  is candidate Memory cells at time  $t$ ;  $o_t$  is in-gate at time  $t$ ;  $\tanh$  is the activation function [5].

Due to the low-frequency component of VMD, it is easier to express the general trend of economic fluctuations. We decomposed the original data, and then, the training set length of the model was set to 960 days, and the test set length was set to 300 days. The learning rate was reduced by 0.3 times every 50 rounds, and the number of training rounds was set to 200 rounds. A small batch containing 20 observations was used for training and prediction in each iteration [6]. It is verified that the prediction accuracy of our model is high after training, and the results are as follows (Figure 3):

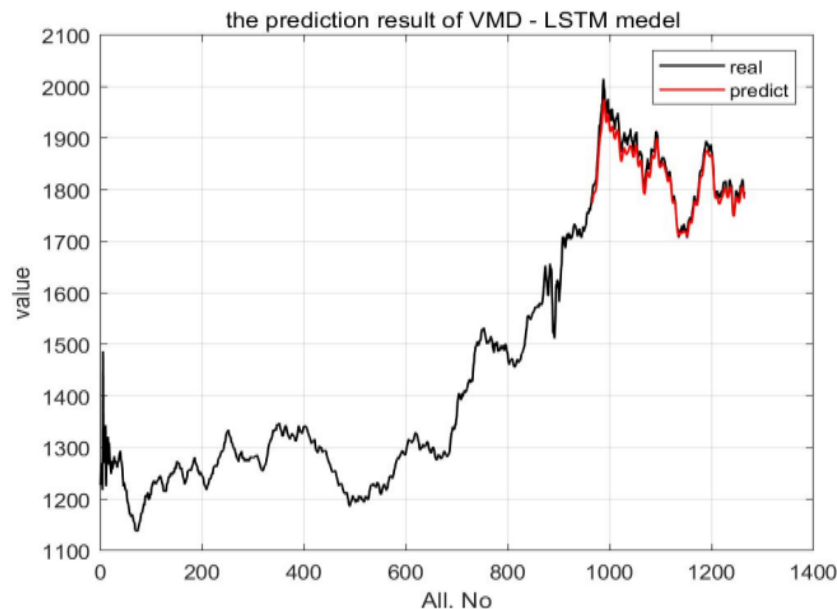


Figure 3. The prediction result of VMD-LSTM model

## 3.2 Strategy Model

### 3.2.1 Analysing Bull and Bear Markets

After obtaining the price trend of Bitcoin and gold, in order to judge the overall market environment, based on the given price data. Calculation of both Obedience rate. Formula is as follows:

$$\text{BIAS} = \frac{\text{Close}-N}{N} \times 100\% \quad (4)$$

Among these: Close: The closing price or index of the day; N: N days average or closing price After data calculation and normalization, some sorted results are as follows (Table 4):

**Table 4.** Daily prediction result table

	Date	USD (PM)	Value	Deal day	Gold rose	Bitcoin gains	AVG-PRICE (G15)	BIAS(G15)	AVG-PRICE(B5)	BIAS(B5)
35	2016-10-16	1251.75	641.42	0	0.566144708	0.510278034	0.63618257	0.48723	0.010228	0.55039
36	2016-10-17	1254.8	638.97	1	0.582613391	0.50994861	0.633916347	0.52893	0.010241	0.55039
37	2016-10-18	1258.2	636.29	1	0.58450324	0.50994861	0.632071903	0.56820	0.010242	0.55039

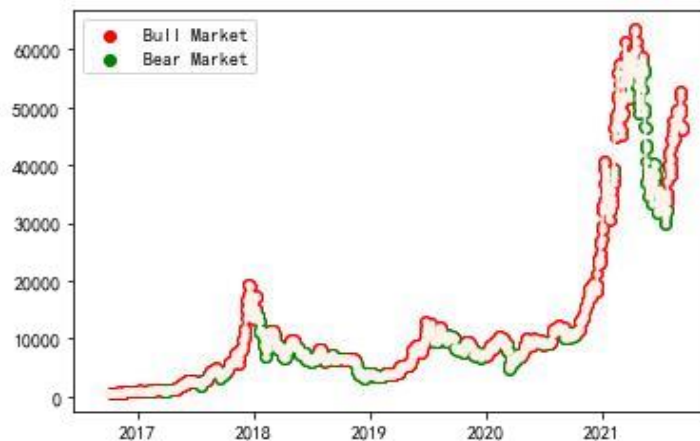
Eight big business law of long points out that if the mobile average is under the stock price and is the time to buy, while the average is above the stock price, it is the time to sell.

Combined with the well-off rate of the 5-day moving average and the cycle moving average, we first constructed the judgment rule of the bull and bear market. Referring to the research results of the bull and bear market cycle [7] in the Chinese and US stock markets, we will set the evaluation indicators as follows:

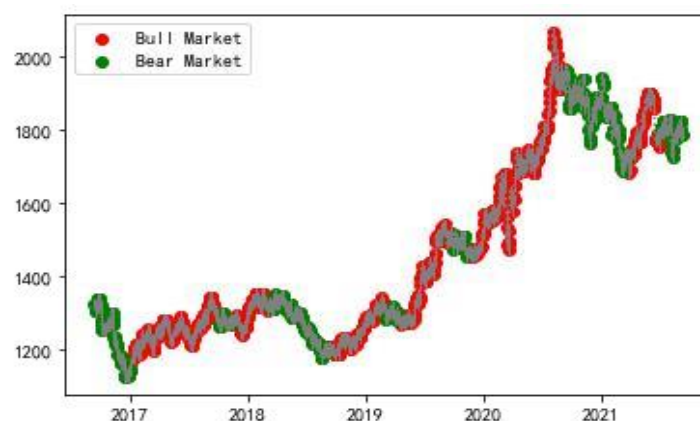
$$Bulls_{bitcoin} = AVG_{bitcion-60} * w1 + AVG_{bitcion-60-Bias(G-15)} * w2 \tag{5}$$

$$Bulls_{gold} = AVG_{bitcion-120} * w3 + AVG_{bitcion-120-Bias(G-15)} * w4 \tag{6}$$

The calculated weight value of each index is:  $w1=0.361$ ,  $w2=0.639$ ,  $w3=0.708$ ,  $w4=0.292$ . Based on this index rule, we obtain the time distribution diagram of the bull bear market as follows (Figure 4 and Figure 5):



**Figure 4.** The bitcoin distribution market



**Figure 5.** The gold distribution of market

At the same time, we introduced the market environment of bull-based on bear market, as a decision auxiliary index, the definition of the purchase risk coefficient is as follows:

$$\beta(G) = \text{Max Drawdown}_{\text{Gold-30}} * \omega_5 + \text{Bulls}_{\text{gold}} * \omega_6 \tag{7}$$

$$\beta(B) = \text{Max Drawdown}_{\text{Bitcoin-15}} * \omega_7 + \text{Bulls}_{\text{Bitcoin}} * \omega_8 \tag{8}$$

The calculated weight value of each index is:  $w_5=0.485$ ,  $w_6=0.515$ ,  $w_7=0.317$ ,  $w_8=0.683$ .

Among them, the maximum withdrawal rate of N Day refers to the return rate of the net product value falling from the highest point to the lowest point in the statistical period of N Day from the same day. The formula is as follows:

$$\text{Max Dawndown} = \frac{(D_i - D_j)}{D_i (D_i = \max(D_x))} \quad D_j = \min(D_x), x = 1 \dots N, \tag{9}$$

Thus, the purchase risk factor scores for gold and bitcoin are as follows (Figure 6):

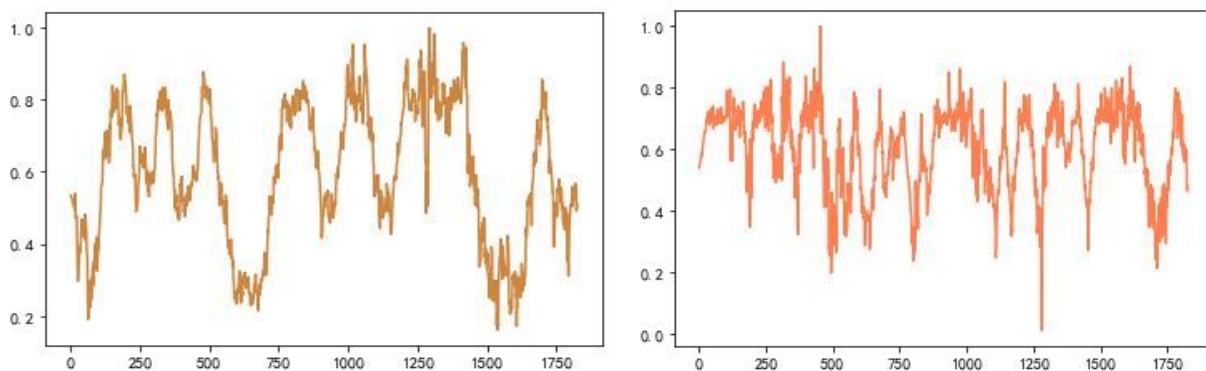


Figure 6. The risk coefficient of gold bitcoin

### 3.2.2 Strategy design

#### I. design discipline:

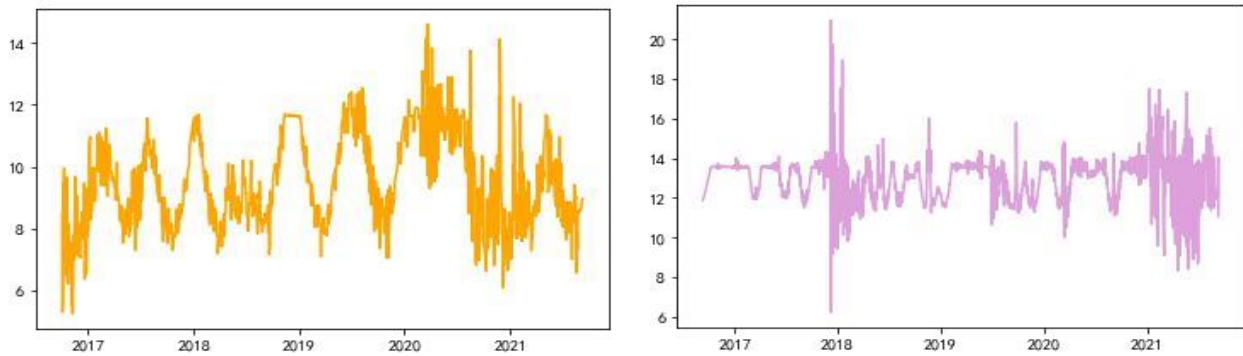
The design of trading strategies needs to follow three principles: simplification, stability, and low risk. Therefore, strategies should not be highly leveraged and engaged in high-risk behavior to cope with the rapidly changing trading market [8].

#### II. design proposal:

Through the determination of the indicators of gold and bitcoin, and combined with the ARIMA model of gold and bitcoin increase forecast, to achieve the valuation of gold and bitcoin trading, and set a reasonable threshold. When the gold valuation is greater than a, buy; when the valuation is less than b, sell; when the Bitcoin valuation is greater than c, purchase; sell at less than d. Special attention should be paid that only the trading of bitcoin is considered on the non-gold trading day, and both gold and Bitcoin on the gold trading day. When both valuations are suitable to buy, if  $(\text{gold valuation} - a) * \lambda > (\text{bitcoin valuation} - c)$  means that gold has more room to gain, buy gold or buy bitcoin. The parameters  $a=0.6$ ,  $b=0.35$ ,  $c=0.7$ ,  $d=0.55$ ,  $\lambda=0.66$  were determined by referring to the world gold and bitcoin trading data and the degree of optimism in the gold and bitcoin markets [9]. Based on the above results, combined with the combination of separation rate, bull market and risk management indicators, the valuation formula of gold and bitcoin is determined as follows (Figure 7):

$$\text{Val}_{\text{Gold}} = (PV_{NF} + \text{Bull maket}_{\text{Gold}}) * 7 + \frac{1}{\beta_{\text{Gold}}} - \text{RESID}_{\text{Gold}} \tag{10}$$

$$\text{Val}_{\text{Bitcoin}} = (PV_{NF} + \text{Bull maket}_{\text{Bitcoin}}) * 7 + \frac{1}{\beta_{\text{Bitcoin}}} - \text{RESID}_{\text{Bitcoin}} \tag{11}$$



**Figure 7.** The risk distribution of gold and bitcoin

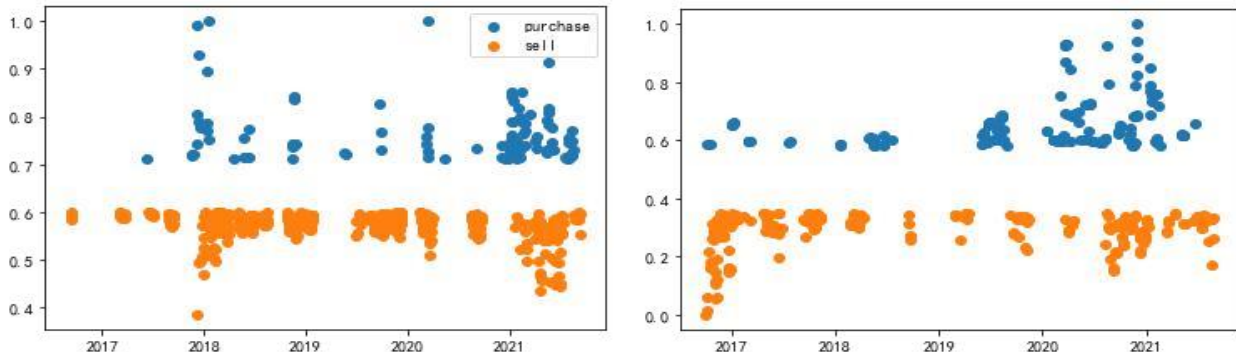
Through the research and analysis of the transaction data of gold and bitcoin in recent years, the relevant policies of the country, the market environment of gold and bitcoin, and combined with the relevant content of futures trading, the purchase quantity formula is determined as follows:

$$\begin{cases} B = (1 - Bkge) * \text{cash} * \text{valuation} \frac{(1-Bkge)*\text{cash}*\text{valuation}}{\text{present price}} \\ S = \text{available quantity}(1.5 - \text{valuation}) \end{cases} \quad (12)$$

Among these: B indicates the buy quantity, and S indicates the sold quantity.

### 3.2.3 Analysis and Evaluation of results

Based the calculation, we get the distribution of gold and Bitcoin as follows(Figure 8):



**Figure 8.** The distribution of bitcoin sale and gold sale

Thus, we draw the total assets changes in the past five years, and the change of Bitcoin, gold and cash holding ratio. The chart can show that if you can predict the price change trend and change range of Bitcoin and gold more accurately, it can effectively avoid some risks, and make huge profits with the help of the instability of Bitcoin price[10]. According to the change curve, Bitcoin is more suitable for short-term investment on the premise of reliable prediction, and gold tends to hold quotas unchanged for a certain period of time(Figure 9 and Figure 10).

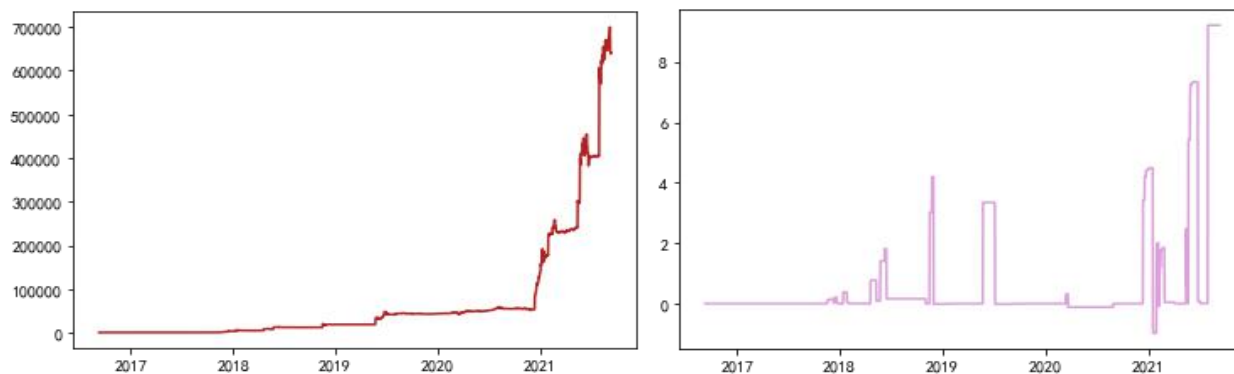


Figure 9. Changes in total assets and bitcoin

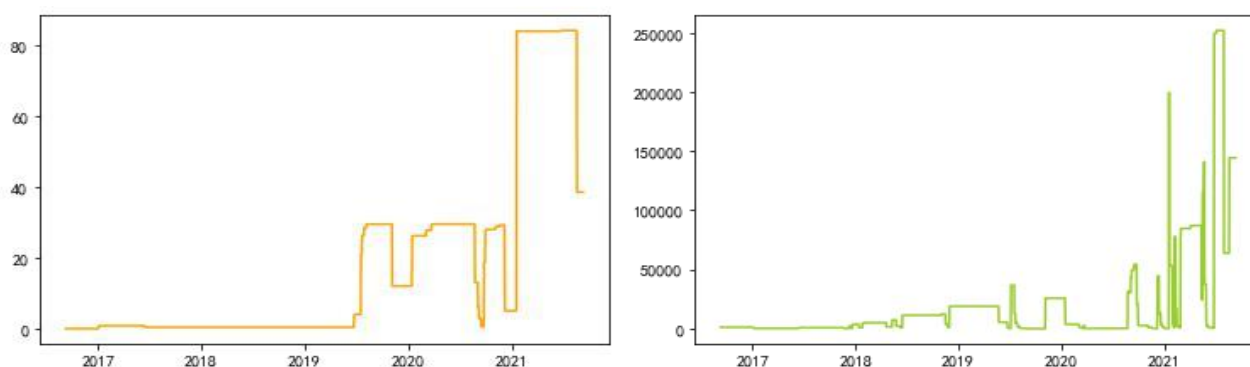


Figure 10. Changes in gold and cash

#### 4. Conclusions

By establishing a trading decision-making model and using the price data of bitcoin and gold futures within five years, this paper obtains the relatively best daily trading strategy within a trading day. Firstly, this paper uses ARIMA model to predict the closing prices of gold and bitcoin respectively. Through model identification, establishment and test, the optimal parameter values corresponding to the two commodities are determined. Through the prediction of the model, it is found that ARIMA model has a wide range of applicability in practice, and can be combined with different application backgrounds and problems to be solved to obtain better prediction results. Then, based on the Granville rule and the bull bear market judgment rule, this paper introduces the weight index, and through the processing of the original price data, quantifies the transaction risk coefficient of gold and bitcoin at a specific time, so as to provide a basis for the design of investment trading schemes.

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