Agent-based Simulation Research on Bitcoin Price Fluctuation

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ABSTRACT

In recent years, with the development of the Internet, network currency has gradually emerged. Bitcoin which is produced on the basis of complex algorithms has developed rapidly and attracted wide attention in academia. This paper explores the influence factors of bitcoin market transaction by analyzing the interaction between agents in bitcoin market transaction. Applying complex adaptive system modeling method based on multi-agent, this paper establishes an agent-based bitcoin market transaction model, and designs behavioral rules as well as transaction mechanism in detail for each agent in the process of market transaction. Then, we carry out a simulation on the Starlogo simulation platform and analyze the impact of the change in trader’s number on market transaction.

KEYWORDS

Bitcoin market, block chain, complex adaptive system, agent-based simulation.

INTRODUCTION

According to relevant information, at present, the scale of China’s network currency market has reached billions of RMB each year, and it grows at the speed of 15%–20% per year. The famous American economist Linton Ralush predicted that by 2050, virtual network currency will be officially recognized to some extent and become a currency that can circulate. So far there have been lots of hot "currencies" on the Internet, such as Q coin issued by Tencent, U coin issued by Sina, Baidu coin, Fox issued by Sohu, Gold ingot, POPO coins issued by NetEase, these network currencies which can be used to pay are issued by network agencies on their own [1]. In recent years, among these network currencies, the exchange rate of algorithm-based bitcoin has become more and more intense, which has risen wide attention. Bitcoin is a new type of network currency proposed by Satoshi Nakamoto in November 2008, it is produced by an open source P2P electronic cash system and characterized by complete decentralization on the basis of cryptographic coding together with complex algorithms. The production of bitcoin is based on the algorithm whose initial setting makes bitcoin’s issuance less and less over time, it produces 10.5 million bitcoins in the first four years, and 5.25 million bitcoins in the next four years, the circulation reduces by half every four years, it is expected that by 2140 the total number of bitcoin will reach the limit value 21 million.

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Bitcoin is not subject to national boundaries, users in different regions can use Internet platform to interact with each other across the border in order to transfer bitcoin. From the beginning of the trading in 2010 when 1 bitcoin could only exchange 0.005 dollars to November 24, 2013, the transaction record has broken 1127 dollars which hit a record. Then the price slumped to 114dollars in January 2015. At the beginning of 2017, the domestic price of bitcoin exceeded 1,000dollars once again, thus it can be seen that bitcoin price fluctuates violently.

It is bitcoin’s characteristic and the influence of many complex factors that determine the fluctuation of bitcoin price. Bitcoin price fluctuates so violently that bitcoin can develop from little-known to attention-attracting within a short period of time. In the period when bitcoin gradually came into people’s vision and the government had not yet taken control measures, many areas accepted bitcoin as a way to buy real estate and artwork, donate and so on. The use of bitcoin in foreign markets is more extensive, there are a series of related industries about bitcoin, such as bitcoin exchange, companies listed in bitcoin, bitcoin information website, and third-party payment sites and so on.

At the same time, the innovative technology of block chain used in bitcoin has attracted the attention of the world’s top 100 companies. IBM wants to regard block chain technology as a global project to improve the efficiency of financial markets through innovation. In addition, the US Commodity Futures Trading Commission (CFTC) firstly defined bitcoin and other virtual currencies as commodity in September 2015 and announced that it would regulate bitcoin’s related transactions. Xu Xing who is the founder of China’s largest bitcoin trading platform OKCoin also said: "The emergence of Bitcoin has changed traditional money market and financial market. Relying on the block chain technology and the extending function of distributed payment clearing mechanism, bitcoin can promote the development of distributed financial transactions."

Therefore, in China, a special seminar on digital currency led by the People’s Bank of China was held in January 2016, which discussed the feasibility of issuing digital currency in China in depth.

**INFLUENCE FACTORS OF PRICE FLUCTUATION**

According to the China News Service, the Wall Street investment bank started to study bitcoin for the first time in December 2013, David Woo (the Head of Global Interest Rates, Foreign Exchange Research at Bank of America Merrill Lynch) believed that bitcoin can develop into one of the main payment channels of e-commerce which may be a strong competitor to traditional currency. At the end of February 2014, Joe Manchin (US Democratic Senator) said that bitcoin would soon threaten the Federal Reserve Bank. In the same period, the America Banking Association made a public outreach that they have begun to study Bitcoin.

Through analyzing domestic and foreign research literature, we think there are many factors affecting the fluctuation of bitcoin exchange rate, such as the balance between supply and demand, the exchange rate of dollar, the oil price, the government’s relevant policies and so on, but in this paper we analyze the fluctuation of bitcoin price only from the economic point of view and just consider the supply-demand balance as the main factor. The main influence factors can be divided into the following two aspects:
Supply Factor

The difficulty of mining

The supplier in the market is called "miner", as more and more people join the ranks of mining, the difficulty to get bitcoin increases gradually. Bitcoin’s production rate is halved, while the mining tools are constantly updated, initial tools are CPU, then they change into graphics card, now they are special computers designed for "mining". At the beginning of bitcoin’s birth, the global mining speed was only 1 Ghash/s, now the global total computing power has reached 90Thash/s which has increased by 90,000 times. Therefore, the difficulty of mining increases by 18 million times. Increased difficulty in mining directly leads to an increase in the cost of each bitcoin, so the greater the difficulty of mining, the higher the exchange rate of bitcoin.

Supply quantity

The production of bitcoin is based on the algorithm whose initial setting makes bitcoin’s issuance less and less over time, it produces 10.5 million bitcoins in the first four years, and 5.25 million bitcoins in the next four years, the circulation reduces by half every four years, it is expected that by 2140 the total number of bitcoin will reach the limit value 21 million. Bitcoin has lots of difference from other network currency, that its total circulation is a fixed value. The scarcity of bitcoin is one of the main factors that affect its price fluctuation.

Demand factors

Acceptance

The speed of Internet’s development has a direct impact on the application of network currency, and it has become so integrated into people’s lives, in the meanwhile, network currency is affected deeply by governmental agency’s control. According to the statistics of Bitoinity.org which is a website in the industry, on China’s largest trading platform BTC China, the daily trading volume in October 2013 is close to 90,000, and BTC China’s global downloads are still rising. Some scholars believe that with more and more people accepting bitcoin, the fluctuation of bitcoin price will become more stable, and the smoothness of exchange rate means reduced risk, and there will be more people to accept bitcoin, thus promoting a virtuous circle of bitcoin investment.

Speculative demand

The fluctuation of bitcoin price is huge and the corresponding risk is great, thus bitcoin is suitable for short-term speculation. Based on international situation, speculators create a counterfeit demand for bitcoin artificially by making the use of the characteristic of bitcoin exchange rate, leading to the huge fluctuation of bitcoin exchange rate in a short time.
The exchange rate of dollar

Dollar is the major international reserve currency, that it has direct impact on the global economy. Many commodities, such as oil and gold, are denominated in dollars, so dollar exchange rate is also one of the important factors affecting bitcoin price fluctuation.

Inflation

In a certain period of time, the continually rising price and currency devaluation will cause people to panic. There are two major fluctuations of bitcoin price in history, one is the outbreak of the Portuguese financial crisis in 2011 which made bitcoin rise from $2 to $30; The other is the outbreak of the EQ3 and Cyprus crisis in the United States at the end of 2012, which helped Bitcoin jump from $20 to $250. Inflation has a positive relationship with Bitcoin.

Alternatives

Bitcoin also follows economic laws, high yield makes its alternatives inevitable, and the emergence of alternatives is bound to lead to sharp fluctuations in the price of bitcoin. As bitcoin sweeps the world, new alternatives are constantly emerging. These emerging currencies have lower mining cost and greater appreciation space, for they are easier to mine as well. The price of alternatives such as Litecoin, Ripple, is also rising sharply.

AGENT-BASED BITCOIN TRANSACTION BEHAVIOR MODEL

Relevant literatures at home and abroad [1-13] analyze related characteristics of Bitcoin from multiple perspectives, while most of them lack the quantitative analysis of bitcoin transaction mechanism. In this paper, we use the method of complex adaptive system theory to establish the transaction model of bitcoin market by describing the interaction and behavior rules among multiple agents, as well as agent’s adaptability. Through the simulation, we make a quantitative analysis of bitcoin price fluctuation’s influence factors.

Top transaction model

According to the trading mechanism of bitcoin, we build an abstract model for bitcoin in the light of the analysis of bitcoin price fluctuation’s influence factors, and the model is shown in Figure. 1. From an economic point of view, the entire bitcoin market can be divided into supply-side and demand-side. The supplier is composed of miners guild organized by numerous miners and a few individuals. The demand-side obtains bitcoin mainly through the direct purchase from the miners, commodity transactions in the realistic society and market speculation. In the market, two types of traders make decision according to the information of exchange rate in the bitcoin market, while sends order information to the market. After trading platform matches orders according to the matching mechanism, the order is deal in accordance with system rules.
**Trader model**

After receiving bitcoin’s price information in the trading market, traders take current price as the basis and take into account their asset status (cash and bitcoin holdings), and then calculate psychological expected price according to system rules. After that, traders make trading decisions and calculate the quotation as well as order’s trading volume, then the order is formed. Order information consisting of trading decisions, speculator’s quoted price and the number of transaction will be packaged and sent to the trading market. The trading model of speculator is shown in Figure 2.

**Miner model**

The main difference between the miner and the trader is that the miner will put produced coins into the market. Bitcoin is based on the algorithm whose operating mechanism confirms a block about every 10 minutes, in the first 210,000 blocks, each block produced 50 bitcoins, now it produces 25 bitcoins, the amount is gradually halved. So 10.5 million bitcoins is produced in the first four years, 525 million bitcoins in the second four years, the circulation reduces by half every four years, by 2140 the total will reach the limit value 21 million.

**Trading market**

The effect of trading market is to provide an interactive platform for each agent and describe the information interaction in the market. Among many price fluctuation’s influencing factors, the impact of the change in trader’s number is especially prominent, and therefore, trader’s number is the focus of this paper. After receiving the order information sent by trading agent, trading market matches orders on the basis of market mechanism and calculates trading volume together with turnover, finally it sends the information to each agent.

Throughout the whole transaction process, the behavior of trading platform mainly includes store quotations, matching orders, matching tradeoff, calculating market trading price and issuing a flat signal (shown in Figure 3). The process of matching tradeoff includes matching deal and adjusting quoted price.

![Figure 1. Top model of bitcoin market.](image)
RULE DESIGN FOR AGENT

Basic assumptions

1) Traders whose amount is changing only carry out speculative transaction in the bitcoin market, but they only use the bitcoin in the market to trade, and don’t produce new bitcoin.

2) The total amount of bitcoin is about 11 million in the current market, and about 0.36 million new bitcoins are produced per day. Given that, we assume that the total amount of bitcoin in the market is 1,100, miners generate 0.36 new bitcoins in each iteration and can only sell bitcoin. The number of miner is fixed at 100 units, and each miner generates 0.0036 bitcoins supplied to the trading market in each iteration.

3) Bitcoin trading market is very safe, there will be no hacker attacks, bit currency theft or other security issues.

4) Bitcoin price is updated in each iteration.

5) The market price of bitcoin is formed according to the matching mechanism.
Agent Behavior Rule

Trader behavior rule mainly includes decision-making, as shown in Figure 5, the decision-making behavior includes the behavioral process of expecting price, determining quoted price, determining trading volume and issuing an order.

Except price:

Trader calculates the expected price for bitcoin and determines whether to buy or sell bitcoin by comparing the expected price to historical deal price. Due to the fluctuation of bitcoin price, speculator accounts for a big proportion in the market, in this paper, traders in the market are assumed to be random traders by referring to the classification of consumers in the stock market together with the situation of the bitcoin market.

Random traders: traders whose decision behavior is random expect price on the basis of noise signal in the market. Given that, this model sets expected price for such traders as follows:

$$EP_t = P_{t-1} \cdot \varepsilon$$  \hspace{1cm} (1)

$EP_t$ is trader’s expected price for bitcoin, $P_{t-1}$ is the trading price in bitcoin market during the $t-1$ period, $\varepsilon$ is trader’s variation coefficient of expected price, $\varepsilon \in (0.9 - 1.1)$.

After calculating expected price, traders decide whether to buy or sell based on the expected price.
- When $EP_t > P_{t-1}$, buy bitcoin
- When $EP_t = P_{t-1}$, no trade
- When $EP_t < P_{t-1}$, sell bitcoin

Determine quoted price:

Quoted price is abbreviated as $QP$, in order to simplify the model, it is determined by the trading price in the current market, its own psychological expected price and the amount of the capital held by agent. The formula is shown as following:

$$QP = r_1 \cdot P_{r-1} + (1 - r_1) \cdot EP_t$$  \hspace{1cm} (2)

While $r_1$ is the weight coefficient based on the deal price in the current market, $r_1 \in (0,1)$. The value of $r_1$ is decided by the amount of the capital held by traders, the specific method to determine $r_1$ is shown in Table 1. As can be seen from Table 1, the higher the amount of capital held by trader, the smaller the weight coefficient. That is, when the amount of capital held by traders is more than 7,500 dollars, traders tend to participate in transaction based on their current expected price, in other words, quoted price is equal to expected price. When traders hold very little capital, they tend to decide quoted price with reference to historical trading price in the market to trade with others. To the traders with more capital holdings, psychological expectation of price has a higher proportion when they decide quoted price, otherwise the proportion of historical deal price is higher.
Determine trading volume:

After making the trading decision, trader determines the amount ($\eta$) of capital invested in transaction according to the magnitude ($R_e$) of the difference between deal price and quoted price, and then calculates the amount of the bitcoin used to trade on the basis of quoted price and the amount of owned capital. The formula to calculate the magnitude of the difference between trading price and quoted price is as following:

$$R_e = \left| \left( \frac{P_t - Q_P}{Q_P} \right) \right|$$  \hspace{1cm} (3)

The rule of deciding the proportion of trader’s investment capital is shown in Table 2. From table 2, trader is in conservative state when there is a large deviation between deal price and quoted price, and the trading volume is less. When the difference accounts for more than 10% of quoted price, the proportion of trader’s invested capital is only 0.3. While when the difference is less than 2% of quoted price, trader will increase trading volume, the proportion is 0.9.

The formula based on the proportion of investment capital to calculate order volume submitted by trader is as following:

$$Q_b = \frac{C_t}{Q_P} \cdot \eta$$  \hspace{1cm} (4)

$C_t$ is the amount of the capital held by the trader, $Q_P$ is quoted price.

Issue an order
After trading behavior, market quoted price and the number of bitcoin transaction have been determined, trader can issue an order and send order information to the market. Order information mainly includes trader’s type, trading decision, quoted price and trading volume.

Trader decides excepted price according to last historical deal price and makes trading decision on the basis of expected price, then the quoted price is determined based on historical deal price together with psychological expectations of the price. In the meantime, order’s trading volume is determined according to capital holdings as well as quoted price. After quoted price and trading volume are determined, order information will be sent to trading market, then traders can carry out a transaction according to market matching mechanism.

Similarly, we can design "miner’s behavior rule" (due to length limitation) and "rules of matching trading platform"(omitted) in detail.

SIMULATION RESULTS ANALYSIS

Based on the model established above, simulation is implemented on the Starlogo platform developed by the Massachusetts Institute of Technology. Starlogo provides a visual window for researchers to set turtle body’s color, the color of agent is white in the absence of trading, and turns green when agent decides to sell or red when agent decides to buy. We draw a curve graph of bitcoin price fluctuation in the plot window, the Starlogo simulation interface is shown in Figure 5. This simulation mainly observes the change in agent’s number and its influence on price.

Initial parameter setting

According to the assumptions of above simulation conditions and the analysis of whole trading system, we set initial parameters for this simulation system model. Agent’s main attributes include transaction status, expected price (psychological price), sale status, bitcoin holdings, capital holdings, quoted price, order’s trading volume, deal price. Market’s attributes mainly include trading price in the market, total amount of bitcoin transaction and so on. Details are as follows:
Initial value settings of agent’s attributes:

In transaction status, 0 means no participation in transaction, 1 means making a deal. The initial state is at the beginning of a new round trading when agents are in a non-traded state, so this model sets initial transaction status to zero.

Expected price, the calculation of expected price in transaction process involves the value of market deal price. In this model, the initial deal price in the market is set to $100, therefore, based on expected price’s formula, the initial value of expected price is set to a random number \( EP_t = 100 \times e, e \in (0.8, 1.2) \)

In sale status, 0 means no participation in transaction, 1 represents buying, 2 represents selling. Since agents are initially in a non-traded state at the beginning of a new round, this model sets sale status to zero.

Bitcoin holdings, based on assumed condition, the initial total amount of bitcoin is set to 1100 units.

Capital holdings, as miners in the market can only supply bitcoin while traders can both buy and sell bitcoin, the initial capital of the miner and the trader is set to $0 and $8,000, respectively.

Deal price, since each agent is in the initial state of a new round transaction, the initial value of agent’s deal price is set as 0.

Initial value settings of market attributes:

The initial deal price in the market is set to $100.

On the basis of the completion of these initial value settings, agent can trade in the environment of bitcoin market.

Simulation Results Analysis

As actual bitcoin market is a huge and complex system involving a large number of traders, trading mechanism is complicated. This simulation is an abstraction and simplification of this real trading mechanism, it just observes the impact of the change in trader’s number on bitcoin trading market, regardless of security, government’s regulation and other factors. In the simulation process, the number of miner is set to
100 and remains unchanged, while trader’s number is set to 100, 175, 450, 1000 and other different magnitudes respectively, then we make an simulation contrast analysis. The following figures show the cases of 100 traders and 1000 traders.

Figure 6. Market deal price chart (1000 traders).

Figure 7. Market deal rate chart (1000 traders).

Figure 8. Market deal price chart (100 traders).
It can be observed from simulation results that the change in trader’s number in the market affects deal rate and deal price in the market directly. When the number of trader in the market is large, the fluctuation range of bitcoin price’s fluctuation curve is obviously smaller than that in the situation where there are few traders in the market, and the latter has a higher deal rate.

**CONCLUSION**

At present, the study on bitcoin is still a new research field, and the elaboration of bitcoin trading mechanism is mostly in the form of news reports at this stage. Bitcoin trading system is a complex system, the factors affecting the fluctuation of bitcoin price are so complex and uncertain that it is difficult to quantify all factors. Therefore, it is quite difficult to accurately predict the trend of price fluctuation. Based on multi-agent simulation method, this paper analyzes the relationship between speculator’s behavior and the fluctuation of bitcoin price in the bitcoin trading market, and lays foundation for future research. In addition to analyzing the factors that affect price fluctuation from multiple perspectives, the further work can modify and improve this model, and try to explore the self-evolution mechanism of digital currency on the basis of block chain technology.

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