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# Investor Sentiment and IPOs Anomalies: An Agent-Based Computational Finance

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**ABSTRACT**

It is worthwhile to investigate abnormal performance of IPOs by incorporating investor sentiment. Using the method of Agent-based Computational Finance (ACF), we analyze the effect from different kinds of investor sentiment on IPOs first-day underpricing and long-term performance. The results show that individual investor's sentiment is positively correlated with the IPO's first-day underpricing and its long-run performance. In the long run, along with the rising of individual investor sentiment, IPOs' long-term performance will change from underperforming to outperforming. This conclusion provides a more reasonable explanation for the different IPOs long-term performance.

**Keywords:** institutional investor sentiment, individual investor sentiment, agent-based computational finance, IPOs long-term performance

## INTRODUCTION

IPOs first-day underpricing and the long-run underperformance are ubiquitous anomalies observed in initial public offerings (Ritter and Welch, 2002). Many scholars attribute the reason for the high IPOs underpricing rate in China to the low efficiency of IPOs pricing because of the control imposed by government (Song and Liang, 2001). Even since 2009, when a series of IPO market-oriented reforms were adopted by China Securities Regulatory Commission. Despite the reforms, China's IPOs underpricing level is still much higher than that of developed security markets. So, in addition to the pricing efficiency of IPOs, the IPOs underpricing may be driven by other factors. The Chinese stock market is an emerging market and most of the investors are individual investors without any experience who enthusiastically seek to buy the new shares under the short sell constrain. It is reasonable to investigate whether there exists a measurable relationship between the excess returns and the low IPO pricing, and more importantly whether and how much IPO underpricing is also affected by the secondary market investors' sentiment and market environment (Zou et al., 2013).

The Chinese stock market has not yet reached semi-strong efficiency (Han and Wang, 2004), so it is not appropriate to explain IPO first-day underpricing based on the theory of rational investors (Pu and Han, 2002). Moreover, this theory can hardly explain IPOs long-run underperformance. As an important branch of behavioral finance, the investor sentiment theory abandoned the hypothesis that all of the investors are rational investors. So compared with the classical theory of information asymmetry, investor sentiment theory seems to be a better way to explain IPOs first day underpricing (Oehler et al., 2004).

DeLong et al. (1990) posited the existence of two types of traders in the stock market, rational traders and noise traders. In contrast with the rational traders who hold Bayesian beliefs, the noise traders hold random beliefs about future dividends. Sentiment investor is a kind of noise trader, so the investor sentiment can be defined as the overall optimism of the stock market (Brown and Cliff, 2004) or the tendency to speculate (Baker and Stein, 2004). Miller (1977) found that the stock price only reflects the expectations of optimistic investors, so the stock price is always


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**Contribution of this paper to the literature**

- The government should pay more attention on investor education so as to reduce the proportion of noise traders, alleviate the IPOs first-day underpricing and keep the IPOs market running smoothly. The pre-IPO companies should issue their stocks when investors' sentiment is relatively high.
- Based on the method of agent-based computational finance from the view of behavior finance, which is an innovative work and effectively compensate for the method of econometric and stochastic dynamic equilibrium when study behavior finance.

higher than the fundamental value when there is a short sell constraint and heterogeneous expectations in the market.

It is difficult to measure sentiment accurately due to the unique characteristic of investor sentiment (Dorn, 2009). Different scholars use different sentiment proxies, such as the words used in media (Delong et al., 1990), willingness to overpay for IPOs in the when-issued market (Dorn, 2009), the market condition before IPOs (Derrien, 2005), the discount rate of Closed-end funds (Lee et al., 1991), etc. Different from the proxies above, Baker et al. (2012) uses four proxies to estimate investor sentiment for six international markets; the four proxies are volatility premium, total volume of IPOs, underpricing rate and market turnover rate. They found that the investor sentiment was negatively related to the IPOs return rate and the sentiment can be spread around different market through private capital flows.

The investor sentiments not only affect the initial market but also the inter-temporal market (Han and Wu, 2007). Studies found that with short-sell constraints, individual investor's high sentiment is positively related to the first-day return and negatively related to the long-term performance of IPOs. These relationships suggest that high investor sentiment can push up the initial return, but as the sentiment gradually fades, it leads to a reversal of the long-term performance (Dorn, 2009; Cornelli, 2006; Tetlock, 2007). So, issuers tend to make use of the investors' optimism to make a high IPO price, but in order to make up for the loss of underwriters and institutional investors foreseeing by the early end of investor sentiment, they will reduce the issue price. So the high IPO pricing and severe IPOs underpricing can both occur, but with the end of the hot-issue market, the stock will return to its real value and will lead to the IPOs long-term underperformance (Ljungqvist, 2006).

Starting later, Chinese scholars struggled to elucidate the relationship between IPOs anomalies and investor sentiment. Han and Wu (2007) found that the investor sentiment could explain the IPOs anomalies in China. Wang and Xia (Wang et al., 2009) investigated the effect of investor sentiment on IPO underpricing by constructing proxy variables of investors' emotion, and the results showed that media attention and the analysts' prediction of the degree of price dispersion was a good way to measure investor sentiment, and had a significant influence on IPO underpricing. The study by Shao et al. (2001) also found that the individual optimism and the selling behavior of institutions were the main reasons for high turnover rate, which precede the low long-term return.

From the review above we can see that most of the existing researches are based on the method of econometric or dynamic stochastic general equilibrium. The econometric method can forecast a few quarters ahead as long as things stay more or less the same, but fail in the face of great change (Chai and Fan, 2016). The dynamic stochastic general equilibrium models assume a perfect world, which is very far from reality (Farmer and Foley, 2009). In contrast, the research in this paper involves different kinds of factors such as investors, issuing market, trading market and information environment, etc. The complexity level will increase so significantly that if we consider all of the factors and use the econometric or dynamic stochastic method, it will be hard to get an analytic solution or reliable empirical research result. But agent-based computational finance (ACF) provides us a new method to solve these problems. ACF do not rely on the assumption that the economy will move towards a predetermined equilibrium state, instead, at any given time each agent acts according to its current situation, which can involve different kinds of factors in the model (Farmer and Foley, 2009; Chang and Wang, 2016). It is a good way to fully and effectively mine the relationship between investor behaviors and the stock price, to remedy the deficiencies of econometric and dynamic stochastic general equilibrium method in studying behavioral finance.

The innovation of this paper is mainly manifested in the following three aspects: First, this paper finds a new way to investigate the influence of investor sentiment on IPOs anomalies by the method of ACF, which can describe the investor sentiment more precisely. Second, considering the institutional investors and individual investors have a lot of difference in access to and reactions to certain information, we separate the investors into individual investors and institutional investors and research their behavior separately. Most of the sentiment literature is specified in ways that do not provide any validation exercise of such aspects. Third, the method of ACF provides us a technique to find some initial evidence on different kinds of investor sentiment. So we investigate the effect of investor sentiment at the agent level, where we find some significant predictability relationships between investor sentiment and IPO anomalies.

# BOOK-BUILDING MECHANISM IN CHINA AND AGENT-BASED COMPUTATIONAL MODELING

## IPO Book Building Mechanism in China

The book building was adopted by the China Securities Regulatory Committee (CSRC) on January 1, 2005. The IPOs book building process in China is quite similar to that in developed stock market. However, the underwriter has no right to decide the issue amount and offering price by itself, which are regulated by CSRC. The underwriters file the application paper works and submit them to the CSRC. Once the application for issuing new shares gets approved by CSRC, the prospectus will be delivered to the institutional investors who will bid in offline preliminary book building and individual investors who will participate in online new share subscription. After that, the underwriter organizes road show campaigns, allocates new share amount in offline (around 20%)and online system (around 80%), and stimulate all qualified institution offline to bid at their favorite prices and amounts for new issue. There should be no less than 20 institutions which give effective bid on the price and amount. Based on the biding "book", the underwriter settles the final offering price and allocates the shares by using a lottery system. The remaining of the new stocks are subject to individual or institutional investors' bids using a lottery system at the offer price.

## Agent-Based Computational Modeling

Over the last twenty years, a number of researchers pay more attention to agent-based modeling of financial markets. Financial markets are particularly well suited for agent-based computational explorations. Following the original work done at Santa Fe Institute, a number of artificial financial markets have been built, such as SFI-ASM and Surprising Unrealistic Market (SUM) [lebaron]. These artificial financial markets populated with heterogeneous agents, can be used to simulating the actions and interactions of multiple autonomous investors (individuals, institutions or other entities). The rules how agents will behave during various inputs are specified in the agent-based computational model. Each agent calculates its gain and makes decisions according to the decision rules. When the initial conditions and agent rules are specified, the artificial financial market will be driven by agent interactions. After each time step, the new condition and values for the variables resulting from the interaction of the agents is fed into the simulated world for the next-step iteration. The model can be run repeatedly and generate a distribution of results. In general, the behaviors in these artificial financial markets always show some characters similar to those in real world financial markets. Our objective is to set up an artificial financial market, which we will refer to as the Chinese IPOs market, exhibits realistic investors' features and takes into account the IPO book-building regulation in CSRC. The goal was to build a robust simulated multi-agent market model on which it would be possible to perform computational experiments using various types of artificial agents.

# AGENT-BASED COMPUTATIONAL FIANCE PLATFORM FOR IPO MARKET

We build an Agent-based Computational Finance Platform for IPO Market (ACFP-IPO). This platform is designed to fit the Chinese IPO market, including primary market and secondary market. The designing of issue price in primary market and opening price in secondary market connects the two markets successfully. As we are concerned more about the effect of investor sentiment on IPOs underpricing and long-term performances, we will give a brief introduction to the structure of this platform.

Assuming that one inter-agent transaction is a cycle, in order to reduce the randomness of the experiment result, we carry out 30 experiments in each cycle. In the first 30 cycles, no dividend is distributed, and we use the average market-clearing price as the closing price. In the last 100 cycles, we distribute dividend in each cycle, and the stock market turns into the long-term market.

## Asset Allocation

There are two kinds of assets in the market, a risk asset and a generic risk-free asset. Risk asset refers to the common stock and risk-free asset refers to a generic bond. In this paper, we classify the assets into an index and IPO stock, and we take market index as the benchmark of long-term performances of IPO stock.

Previous empirical research shows that risk-aversion coefficient is a constant, so our model assumes that the utility function of all investors is:

$$U(W) = \frac{W^{1-\alpha}}{1-\alpha} \tag{1}$$

This utility function is a constant relative risk aversion function (CRRA). $\alpha$ refers to risk-aversion coefficient, and $W$ refers to the investor's wealth.

## Investors

Referencing the designing thoughts of LLS model (Levy and Levy, 2000), we classify investors into three groups: besides Rational Informed Identical Investors (RII) and Efficient Market Believers (EMB), considering the requirement of our research, we add a group of sentiment investors, which is called Sentiment Efficient Market Believers (EMBS).

RII are rational informed investors[1]. They get the fundamental value of the stock by discounting future cash dividends. They believe that the stock price will converge to their fundamental value. Given that the institutional investors tend to be rational informed investors, all the RII investors in this paper refer to institutional investors.

EMB investors believe that the market is efficient, and the stock market price accurately reflects the fundamental value of stock. Therefore, investors don't have to concern themselves with timing or with searching for the cheapest stock. The main decision the investor makes is the wealth allocation between the stock and the market index. Some institutional investors and individual investors are EMB investors.

Details about the utility function and the wealth allocation of RII investors and EMB investors can be seen in the reference paper (Friend and Blume, 1975), and we won't reiterate them here.

Referring to the thought in (Lovric, 2011), the EMB sentiment investors add a sentiment parameter to reflect the investor sentiment based on LLS model. Specifically, for investor $i$, he uses the past $m^i$ return data of a certain stock to forecast the return of next issue:

$$\tilde{R}_{t+1} = \left( \frac{1}{m^i} \sum_{j=1}^{m^i} \left(R_{t-j}\right)^s \right)^{1/s} \tag{2}$$

where $j$ refers to the forecast period, $R_{t-j}$ is the return of the $t-j$ period, $s$ is used to forecast the investor sentiment and the higher the $s$, the higher the investor sentiment and the higher the return of the stock in next period. So we can research the effects of the investors' pessimistic and optimistic sentiment on stock return. In this article, both the institutional investors and individual investor cohorts have sentiment investors.

During each period, in order to maximize their utility, EMB sentiment investors will allocate their wealth between the indexes and stocks. Suppose, for any price $P_h$, the wealth possessed by EMB sentiment investor $i$ is $W_h^i$, portion of $x$ is invested in stocks and the rest $1-x$ is invested in indexes, so the expected wealth $W_{t+1}^i$ of the investor $i$ during $t+1$ period is as follows:

$$\widetilde{W}_{t+1}^i = W_h^i\left[(1-x)\left(1+r_f\right) + x\tilde{R}_{t+1}\right] \tag{3}$$

Here, the parameter $r_f$ refers to the return of index, $\tilde{R}_{t+1}$ is the expected stock return in period $t+1$.

From (2) and (3), we can get the expected utility of sentiment investor in $t+1$ period:

$$\begin{aligned} EU\left(W_{t+1}^i\right) &= \frac{\left(W_t^i\right)^{1-\alpha}}{(1-\alpha)}\left[(1-x)\left(1+r_f\right) + x\tilde{R}_{t+1}\right]^{1-\alpha} \\ &= \frac{\left(W_t^i\right)^{1-\alpha}}{(1-\alpha)}\left[(1-x)\left(1+r_f\right) + x\left(\frac{1}{m^i}\sum_{j=1}^{m^i}\left(R_{t-j}\right)^s\right)^{1/s}\right]^{1-\alpha} \end{aligned} \tag{4}$$

## Market Clearing Mechanism

As with LLS model, this article adopts the temporary Market Clearing Mechanism. For different price $P_h$, investors need to determine the optimal proportion $x$ and the stocks number $N$. Here, we use $P_t$ to represent $P_h$.So the clearing price is the price when total demand equals to total supply:

$$\sum_i N_h^i(P_t) = \sum_i \frac{x_h^i(P_t)W_h^i(P_t)}{P_t} = N \tag{5}$$

$N_h^i$ and $x_h^i$ are the number of stocks owned by investors $i$ and the proportion of wealth invested in stocks respectively when the stock price is $P_t$, and $N$ is the total number of stocks.

[1] RII investor, which is calculated according to the principle of utility maximization model, usually keeps the ratio of wealth for their stock to be 0 or 1 in the next investment. In fact, institutional investor will add or reduce their positions step by step. Therefore, on the basis of LLS model, we stipulate that institutional investor will reduce the position in uniform distribution of [0,0.1] when current-period price of stock is higher than the price in next period. Otherwise, institutional investor will add the position in uniform distribution of [0,0.1].

## Design of Primary Market

In the primary market, inquiries are made mainly to institutional investors, and individual investors subscribe to IPOs online. To simplify the platform and retain the characteristics of inquiries at the same time, we create the preliminary inquiry stage and the process of accumulated bidding inquiry, and then combine them.

### *Off-line subscription of institutional investors*

Assuming the number of institutional investors is $Q^o$, the money of institutional investor $i$ is $C_o^i$, the total number of stocks issued off-line is $N^d$. In specific subscription, some institutional investors may not be engaged, so the parameter $\gamma_o^i$ is the participation probability of the institutional investor $i$, and it conforms to uniform distribution of [0,1].

Suppose $\frac{N^d \cdot M^d}{Q^o}$ is the subscription base, $M^d$is the multiple of over-subscription and it's exogenous, $S_o^i$ is the quantity subscribed by institutional investors, and the expression is:

$$S_o^i = \frac{N^d \cdot M^d}{Q^o}(1 + |f_o^i|) \tag{6}$$

For the subscription price of IPOs, assuming the benchmark price given by analyst is $P_b$, lead underwriter and issuer give price interval, the quote of institutional investors conforms to a normal distribution in this interval, and institutional investors give their own subscription price $P_o^i$ based on information they have:

$$P_o^i = P_b(1 + \frac{|f_o^i| - \mu_o}{\sigma_o}) \tag{7}$$

The random variable $f_o^i$ conforms to normal distribution $N(\mu, \sigma_o^2)$.

The lead underwriter and issuer determine the off-line subscription multiple $M^d$ and issue price $P^{iss}$ based on the subscription quantity and price institutional investors give.

### *Online subscription of individual investors*

The way individual investors determine subscription quantity is similar to that of the institutional investors. As the issue price $P^{iss}$ has already been set during the inquiry stage, individual investors will subscribe to the IPO online at that price. The subscription quantity that the individual investor obtains is determined by drawing lots.

## Design of Trading Mechanisms of the Secondary Market

After subscription in primary market, investors will enter into the secondary market. So how to construct the smooth connection between primary and secondary market is the key to the construction of this platform. A key feature of our research is that we design the first day issue market and the long-term market separately.

### *The first-day issue market*

There is a short-sell constraint in the first day, and there is no price limit. As the lock-up period was canceled in China, the institutional investors who get stocks through off-line allotment can sell them on the first day. The distinction between institutional investors and individual investors in our model is mainly determined by the amount of money given in the initial purchase. Institutional investors are given more money than individual investors. Every investor has to determine the capital allocation between the index and stocks by maximizing their utility of wealth. So, they trade stocks and the index to obtain each transaction price.

**a. The opening price**

The method for determining the opening price is the same as the centralized competitive bidding of real market.

RII Investors give the opening price accordance to formula (8):

$$P^{open} = P_{t+1}^f = \frac{E_{t+1}[\widetilde{D}_{t+2}]}{k-g} = \frac{D_{t+1}(1+g)}{k-g} = \frac{D_{t+1}(1+\tilde{z})(1+g)}{k-g} \tag{8}$$

$P_{t+1}^f$ refers to the basic value of stock in period$t+1$, $D_{t+1}$refers to the dividend in period $t+1$, $E_{t+1}[\widetilde{D}_{t+2}]$ is the expected dividend of period $t+2$in$t+1$,$k$ is the expected return rate of stocks, and$g$is the expected growth rate of dividends, $g = E(\tilde{z}) = \int_{z_1}^{z_2} f(z)zdz = \frac{z_1+z_2}{2}$. The quote formula of EMB investors is as follows:

$$P^{open} = P^{iss}(1 + R^{emb}), R^{emb} \sim N(\mu, \sigma^2) \tag{9}$$

$R^{emb}$ is the expected opening return rate of EMB investors, and it obeys the normal distribution. $\mu$ is the average opening return rate of the first 5 IPO stocks during listing day[2] and $\sigma^2$ is the variance of opening return rate of the 5 IPO stocks.

The quote formula of EMBS investors is as follows:

$$P^{open} = P^{iss}(1 + R^{semb}), R^{semb} \sim N(\mu, \sigma^2) \tag{10}$$

$$\mu = (\frac{1}{5}\sum_{1}^{5}(R_j)^s) \tag{11}$$

$R^{semb}$ refers to the expected opening return rate of EMBS investors. If the institutional investors and individual investors do not subscribe the stocks at the time of subscription they will have higher probability of participating in trading.

**b. Market price after opening**

After the opening, investors will determine their allocation between the market index and stock. And the market clearing process in each period determines the stock price. Different parameter values are set up to study the formation mechanism of IPO underpricing.

### *The long-term market*

The stock enters to the long-term market after the first day. Each period, investors determine their investment proportion between the market index and stocks according to their own utility functions. Each time the market is cleared, the stock price of this period is obtained and one time of stock dividends and index interests are paid, and the next period of trading begins. In the long-term market, in order to generate different price series, we set different values for the emotion parameter. The model simulates 100 periods and 30 experiments are done in each period to reduce the random dispersion of the experiment.

## EXPERIMENTS AND DATA ANALYSIS

### Setting Parameters

The parameters are set mainly based on the literature and on characteristics of the Chinese stock market. The number of institutional investors is 100, including 80 RII investors and 20 EMB sentiment investors. The institutional investors purchase 10 million new shares, and their cash holdings obey the uniform distribution between (50000, 150000). The number of individual investors is 10,000, including 8000 EMB investors and 2000 EMB sentiment investors. They purchase 100 new shares, and their cash holdings obey the uniform distribution between (1500, 2500). The total stock in circulation is 100 million shares, where the number purchased on-line and off-line is 80 million and 20 million respectively. The required return $k$ for stock is 4%. Both the dividend growth rate and market index return are set as 5 % so as to better compare the long-term performance between stock and index only under the influence of investor sentiment, not the other.

At the same time, considering the unique characteristics of the Chinese stock market, we set the earning forecast periods $m^{\mu}$ as uniform distributed between (1,10), which is in line with the actual Chinese stock market[3]. Meanwhile, we assume that investors have enough money to purchase shares and the wealth will be re-set at the end of each subscription. The wealth of the investors who have successfully purchase the new shares in the stock market is the value of the common stock plus a certain amount of cash, while for those who failed to purchase, their wealth only is the initial cash.

### Investor Sentiment and IPOs Anomalies

There are two kinds of emotional parameters. One is for institutional investors and the other is for individual investors. The multiple simulations show the impact of institutional and individual investors' sentiment on IPOs on the first day return and the long-term performance. It should be noted that the emotional parameters are only provided for EMB sentiment investors in this paper.

[2]The opening return rates of 5 IPO stocks is randomly set up, and based on the return rate of listed companies on the mainboard and small and medium-sized plate from 2010 to 2012 in the first day of listing.

[3] In the LLS model, the value of $m^{\mu}$is fixed.

**Table 1.** Emotional values for institutional investors in primary market

| | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| Emotional value | (-4, -6) | (-2, -4) | (0, 2) | (2, 4) | (4, 6) |

**Table 2.** Emotional values for institutional investors in secondary market

| | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| High emotional investor number | 0 | 5 | 10 | 15 | 20 |
| Low emotional investor number | 20 | 15 | 10 | 5 | 0 |

**Table 3.** Emotional values for individual investors in secondary market

| | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| High emotional investor number | 0 | 500 | 1000 | 1500 | 2000 |
| Low emotional investor number | 2000 | 1500 | 1000 | 500 | 0 |

### *Institutional investor sentiment*

We set different values for the emotional parameter S to analyze how institutional investors' sentiment influences the stock issue price. The range for the emotional parameters that we used in our simulations of the first-day price of the stock are given below. As can be seen, the value of the emotional parameter from emotional parameter from Experiment 1 through Experiment 5 go from low to high.

We separate the institutional investors into 2 groups, high sentiment group and low sentiment group, to analyze institutional investors' sentiment[4]. Specifically, the parameter of high sentiment group is uniformly distributed between (3, 5) and the law sentiment group is uniformly distributed between (-5, -3). We analyze the impact of institutional investor sentiment on IPO first day returns and the long-term performance by setting different numbers of emotional investors in each of the two groups. As specified in **Table 2**, from Experiment 1 to 5, the institutional investor's sentiment gradually becomes higher.

### *Individual investors sentiment*

The parameter settings for individual investors are similar to the settings for the institutional investors. With our method of setting emotion parameters for the individual investors, it is possible to see the influence that individual investors have on IPO anomalies. In the study of the individual investor sentiment, the emotional value of all institutional investor sentiment sets to 1 to control their emotional value. The settings that we used are shown in **Table 3**.

## EXPERIMENTAL RESULTS AND ANALYSIS

We use Matlab software to realize the simulation process stated above. In order to minimize the pact of extreme cases and also to create a statistical result of sufficient reliability, we repeat every simulation experiment 30 times and choose the average value as trading price.

### Impact of Institutional Investor Sentiment on IPOs Anomalies

### *Institutional Investor sentiment on issue price*

Due to the limitations of the methods used in previous studies, the literature until now has only focused on the effect of institutional investor sentiment on IPOs returns (Wang et al., 2009) and there is little research analyzing the effect of investor sentiment on IPOs pricing. However, through our two-stage synthetic process, we can efficiently integrate institutional investor sentiment into the inquiry phase when simulating the issuance in primary market. Thus, we can study the impact of institutional investor sentiment on IPOs issue price.

From **Table 4**, we can see that with the growth of institutional investors' sentiment, the stock issue prices gradually increase, which indicate that institutional investors' sentiment has a positive effect on issue price of IPOs.

[4] In the study of the institutional investor sentiment, the emotional value of all individual investor sentiment sets to 1, so that the individual investor sentiment is neither high nor low mood.

**Table 4.** Different issue prices under different subscription emotion

| | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| Issue price | 13.85 | 13.95 | 14.06 | 14.20 | 14.37 |

**Table 5.** IPOs underpricing

| | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| Issue Price | 14.40 | 14.40 | 14.40 | 14.40 | 14.40 |
| Opening price | 17.77 | 17.77 | 17.77 | 17.77 | 17.77 |
| Closing price | 29.97 | 30.16 | 30.18 | 30.56 | 31.07 |
| IPOs underpricing rates | 1.08 | 1.09 | 1.10 | 1.12 | 1.16 |

### *Impact of institutional investor sentiment on IPOs underpricing*

We define IPOs underpricing rete$Return$as follows:

$$Return = \frac{P_{close} - P_{issue}}{P_{isue}} \tag{12}$$

where $P_{close}$ and $P_{issue}$ are denoted as the issue price and the closing price on the first day separately.

The results of the experiments are displayed in **Table 5**. In order to study the impact of institutional investor sentiment on first day underpricing, for each experiment we set the same issue price and opening price[5].By setting the same issue price and opening price for each experiment, we make it easy to see the effect that institutional investor sentiment has on first-day IPO underpricing. The results are that with the proportion of high sentiment investor increasing, IPOs underpricing rate gradually increases from 1.08 to 1.16, indicating a significant impact of institutional investor sentiment on IPOs first day underpricing. That is to say, the higher the institutional investor sentiment, the higher the rate of IPOs underpricing, thus showing a positive correlation of institutional investor sentiment with IPOs first day underpricing.

### *The impact of institutional investor sentiment on IPOs long-run performance*

We use two indicators to analyze the IPOs long-run performance, and the two indicators are IPOs long-term yields and price-value ratio. Comparing IPO's long-term yields with index yields can analysis whether the IPO's long-run performance is strong or weak. Price ratio is used to measure the impact of investor sentiment on IPOs long-term performance.

IPO long-term return is defined as follows:

$$R_{long} = \sum_{i=1}^{30} (P_{end}^{i} / P_{start}^{i})^{0.01} \tag{13}$$

where $P_{end}^{i}$ denotes the stock price when the $i$(th) simulation experiment ends, $P_{start}^{i}$ denotes the first day's closing price in the $i$(th) simulation experiment, $(P_{end}^{i}/P_{start}^{i})^{0.01}$ refers to the complex yields from beginning to end of the simulation.$R_{long}$ refers to the average value of 30 experiments. We can research the IPOs long-term performance by comparing this mean yield with the index yield 5%.

Statistics of IPOs long-run composite yields are shown in **Table 6**. From the five experiments, we can see that all of the long-term yields are less than 1.05, that is, all the stocks are underperforming the market index. Besides, the composite yields did not show a clear regular pattern. It indicates that the IPO shave the characteristics of long-run underperformance. However, there is no significant impact of institutional investor sentiment on IPO long-term performance. That is probably because most institutional investors are rational investors and they only make purchases when the stock prices are lower than fundamental value. In the specification used here, as time passes, institutional investors' sentiment tend to be more rational, and the emotion parameters will be slowly weakened, thus leading to IPO long-run underperformance. This finding is similar to the study of Ljungqvis (2006) and some other Chinese scholars (Shao et al., 2001) when there is no strict distinction between institutional investors and individual investors. Ljungqvist et al found that investors' sentiment would improve the short-term return of IPOs, but over a long time frame, investors' sentiment would gradually weaken, and thus cause a reversal of the long-term benefits. The Ljungqvis result can also confirm the reliability of the computational experiments platform we built.

[5]The issue price and the opening price provided here are calculated and produced by the program of the artificial stock market for the issue price and opening price based on the determining method.

**Table 6.** Stock returns

| | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| Mean | 1.047206 | 1.047777 | 1.047355 | 1.047610 | 1.047247 |
| Median | 1.047059 | 1.047447 | 1.047689 | 1.047693 | 1.047367 |
| Maximum | 1.050720 | 1.051337 | 1.050527 | 1.050893 | 1.049972 |
| Minimum | 1.043794 | 1.045312 | 1.043134 | 1.042366 | 1.043524 |
| Std. Dev. | 0.001946 | 0.001799 | 0.002056 | 0.002071 | 0.001556 |

**Table 7.** Trading price statistics of long-term market

| | Fundamental value | Experiment1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|---|
| Mean | 469.6449 | 510.1152 | 511.1565 | 517.0120 | 519.3553 | 524.0961 |
| Median | 207.7498 | 218.1109 | 211.0366 | 223.9713 | 219.1765 | 211.4865 |
| Maximum | 3051.577 | 3106.590 | 3286.975 | 3166.414 | 3301.478 | 3218.237 |
| Minimum | 17.50000 | 19.71707 | 17.84851 | 18.14457 | 17.13758 | 18.63405 |
| Std. Dev. | 647.3994 | 707.3492 | 705.7595 | 712.0171 | 725.1073 | 734.7016 |

**Table 8.** The statistics of stock price-value ratio

| | Experiment1 | Experiment2 | Experimen3 | Experiment4 | Experiment5 |
|---|---|---|---|---|---|
| Mean | 1.097621 | 1.100672 | 1.110213 | 1.108946 | 1.116841 |
| Median | 1.079917 | 1.093786 | 1.103432 | 1.096070 | 1.100429 |
| Maximum | 1.712308 | 1.723279 | 1.724460 | 1.746049 | 1.775299 |
| Minimum | 0.966003 | 0.904313 | 0.901375 | 0.897446 | 0.914461 |
| Std. Dev. | 0.096383 | 0.111739 | 0.098623 | 0.121303 | 0.125095 |

Price-value ratio formula is as follows:

$$ratio = P_T / Fvalue_T \tag{14}$$

where $P_T$ represents the stock price of period $T$. $Fvalue_T$ represents the fundamental value of period $T$, which is calculated based on the dividend discount model. With this formula, the stock price is higher than its fundamental value if the ratio is greater than 1; and if the ratio is less than 1, the stock price is lower than its fundamental value.

The stock price in the five experiments of the last simulation is shown in **Table 7**. From **Table 7**, we observe that the average stock price gradually increases and the standard deviations also increase as institutional investor number, which indicates that institutional investors can push up the trading price and raise the volatility of the stock.

The descriptive statistics and the growing trend of the stock price-value ratio are shown in **Table 8** and **Figure 1** respectively. Form **Table 8**, we can see that the price-value ratio in all the five experiments is greater than 1, and the more the emotional investors number, the higher the price-value ratio and the greater the volatility. It indicates that the investor sentiment will make the stock price higher than its fundamental value, and the higher the investor sentiment, the greater the gap or divergence between the price and fundamental value. **Figure 1** to **Figure 5** show the trend of price-value ratio in the five experiments respectively. From **Figure 1**, we can see that the PV ratio oscillates around 1.05. Institutional investors will buy stocks when PV ratio is greater than 1.05 that is when the stock return is higher than the market index, which will lead a rise of the price-value ratio. Meanwhile, since the institutional investors are rational investors, they promptly sell the stocks when the PV ratio increases above a threshold level, which will lead to a decrease of the price-value ratio. Also, when the price-value ratio falls below 1, institutional investors will buy the stocks again, and lead a rise of the price-value ratio again.

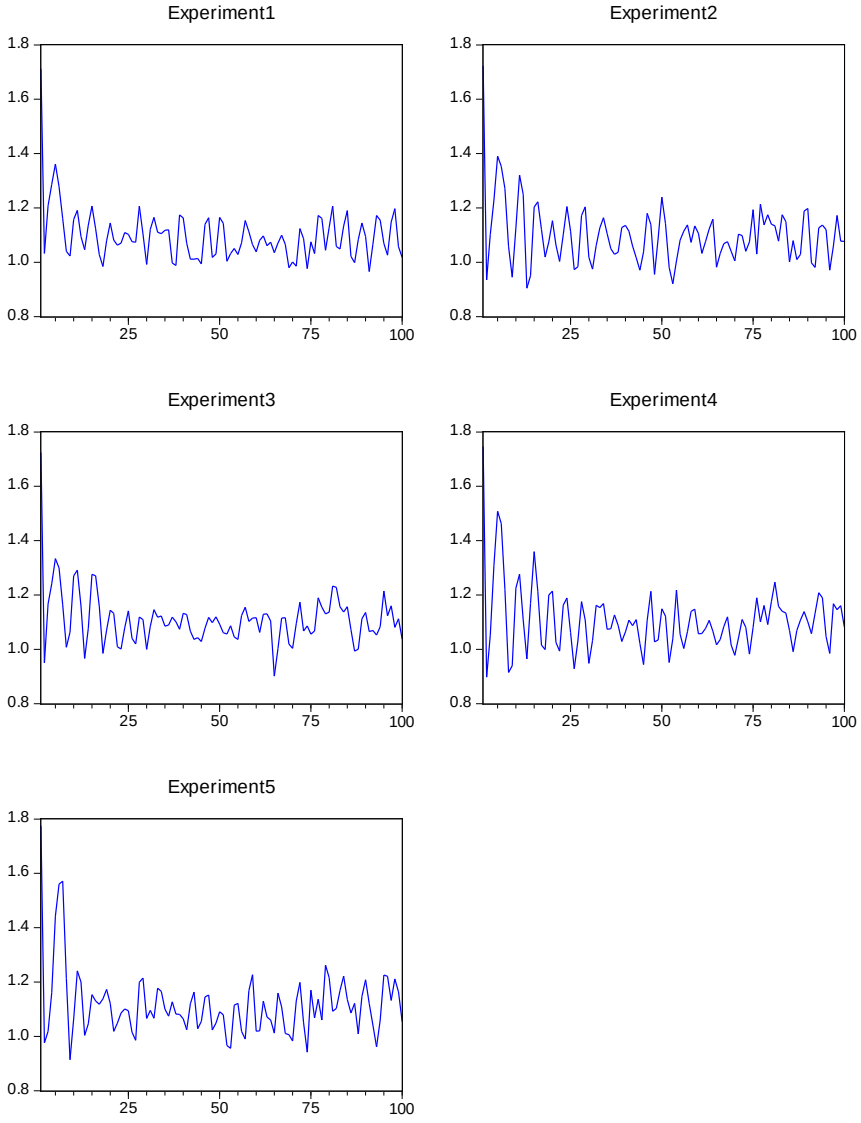


**Figure 1.** The chart of stock price and fundamental value ratio trend

**Table 9.** The statistics of IPO underpricing

| | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| Issue price | 14.40 | 14.40 | 14.40 | 14.40 | 14.40 |
| Opening price | 17.77 | 17.77 | 17.77 | 17.77 | 17.77 |
| Closing price | 27.20418 | 27.87154 | 27.45078 | 28.4502 | 29.41465 |
| IPO underpricing | 0.889179 | 0.935524 | 0.906304 | 0.975708 | 1.042684 |

## The Impact of Individual Investor Sentiment on IPOs Anomalies

### *The impact of individual investor sentiment on IPO first day underpricing*

The impact of individual investor sentiment on IPO first day underpricing is shown in **Table 9**. From **Table 9**, we can see that with the increase of individual sentiment investor proportion, the IPO first day underpricing rate increases from 0.88 to 1.04, which is the same as most of the research results done by scholars all over the world. In other words, the higher the individual investor sentiment, the greater the IPO first day underpricing.

**Table 10.** The statistics of composite yield

| | Experiment1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| Mean | 1.043744 | 1.049694 | 1.054063 | 1.054151 | 1.054757 |
| Median | 1.044258 | 1.050167 | 1.052968 | 1.054989 | 1.055834 |
| Maximum | 1.053162 | 1.057972 | 1.067697 | 1.065713 | 1.065581 |
| Minimum | 1.030987 | 1.040115 | 1.040622 | 1.042938 | 1.037319 |
| Std. Dev. | 0.005903 | 0.004212 | 0.006592 | 0.006495 | 0.007055 |

**Table 11.** The long-term market trading price statistics

| | Experiment1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| Mean | 547.4516 | 712.0814 | 1004.084 | 1053.705 | 1103.111 |
| Median | 249.9275 | 226.9590 | 252.7023 | 250.5170 | 273.0272 |
| Maximum | 2429.639 | 3844.574 | 6356.339 | 6674.341 | 7253.798 |
| Minimum | 19.43311 | 17.69083 | 15.56054 | 18.71904 | 20.44393 |
| Std. Dev. | 656.6737 | 967.4589 | 1534.198 | 1618.437 | 1674.832 |

## *Impact of individual investor sentiment on stock long-term performance*

In contrast with the research conclusions found by Ljungqvist and other scholars (Dorn, 2009; Cornelli et al., 2006; Tetlok, 2007; Ljungqvist, 2006) that investor sentiment will cause IPO underpricing and long-run underperformance, we find that there is no significant linear relationship between IPO underpricing and long-term performance; and the relationship varies according to the investor sentiment. This finding might be because of we can make a detailed classification of investors and investor sentiment by the agent-based computational platform. It provides us a chance to find how the subdivisions of investor sentiment influence the IPOs long-run performance. This result is difficult to achieve by the traditional empirical research or mathematical modeling method.

As shown in the **Table 10**, the IPO long-term returns increase gradually from 1.0437 to 1.0547 with the rises of individual investor sentiment. The performance changes from underperform the market (1.05) to outperform the market. When the investor sentiment is low, the IPO stocks will underperform the market index in the long run, this may be because when the proportion of individual sentiment investors is low, the sentiment investors affectless than the rational investors the stock prices, and the rational investors will make the stock price return to the fundamental value in the long run, which in turn leads to the long-run underperformance. When individual investor sentiment is high, IPO stock long-term performance is stronger than the market index; this is because with the increase of the proportion of sentiment investors, sentiment investors will have a stronger effect on stock price than rational investors. Those sentiment individual investors make the long-term stock returns consistently remaining at a high level all through the time frames in this experiment.

The influence of individual investor sentiment on stock prices is shown in **Table 11**. As the parameter of individual sentiment investor increases, the average stock price increases, and the standard deviation also shows a trend of increase. This result illustrates that individual investors' sentiment will push up the stock price and increase the stock volatility.

The descriptive statistics and trends of IPO stock price-value ratio are shown in **Table 12** and **Figure 2** respectively. As we can see, the IPO stock price-value ratio and the variance basically assume a growth tendency with the increase of the number of emotional investors. These statistics show that the more the individual sentiment investors, the higher the stock average price, and the bigger the fluctuation. **Figure a** to **Figure e** denote the stock price-value ratio trend of the five experiments respectively. From **Figure 2** we can see that with the increase of the number of individual sentiment investors, the price-value ratio increased significantly. Individual investors with high sentiment will increase the stock price and their high sentiment continues to influence the stock price, and it gives higher and higher above fair value. This shows that the long-term effects of individual investor sentiment on stock price are much higher than that of institutional investors. This may be because the component of non-rational individual investors is higher relative to institutional investors, and the individual investors cannot obtain information as institutional investors can from a securities analysis, and they can be affected easily by some common factors such as "new unbeaten" myth. Therefore, with the short sell constraint, optimistic individual investors will greatly increase the stock price.

**Table 12.** The statistics of price-value ratio

| | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 | Experiment 5 |
|---|---|---|---|---|---|
| Mean | 1.146159 | 1.278404 | 1.523779 | 1.557609 | 1.665210 |
| Median | 1.139087 | 1.190110 | 1.276587 | 1.244398 | 1.395372 |
| Maximum | 1.554525 | 1.923302 | 3.132159 | 3.288859 | 3.574393 |
| Minimum | 0.993934 | 0.963673 | 0.847629 | 1.010042 | 0.912438 |
| Std. Dev. | 0.082490 | 0.243487 | 0.559763 | 0.618863 | 0.617478 |

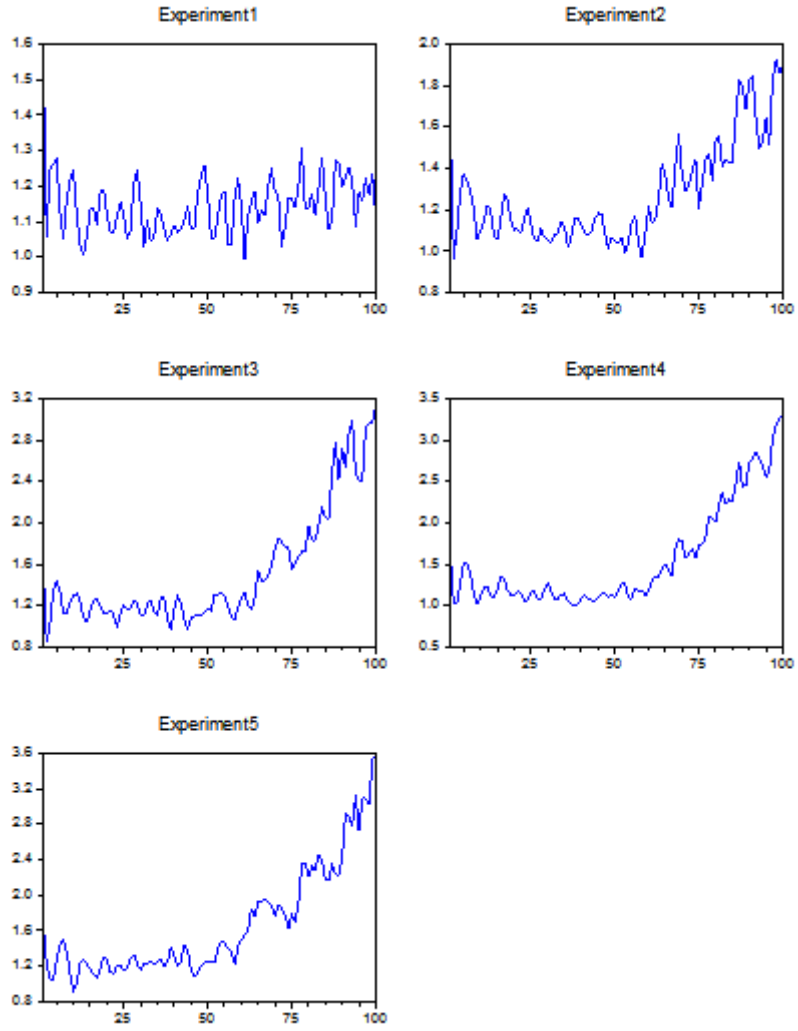


**Figure 2.** The price-value ratio chart

## Comparison of the Individual Investors' Wealth and Institutional Investors' Wealth

Friedman (Friedman, 1953) once said that in the stock market, economic interest selection mechanism will eventually drive the noise traders out of the market. Through the research above we can see that in comparison with different from individual investors, institutional investors are more rational, even when there are some sentiment-driven institutional investors, the sentiment will weaken gradually with the passage of time. Then the important question is whether the rational investors or the emotional investors attain more wealth in the market eventually? We compared the wealth changes of institutional investors and individual investors6 and they are shown in **Figure 3**.

[6] For this experiment, we set the emotional parameters of institutional investors at 1, meaning that all institutional investors are rational investors, individual investors are emotional investors

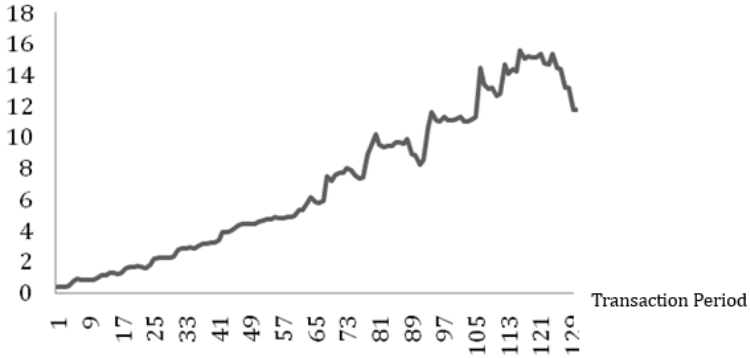


**Figure 3.** The ratio between the wealth of institutional investors and wealth of individual investors

The ratio between the wealth of institutional investors and individual investors at the first simulation is 0.38, and then the ratio goes up, reaches 15.61 at the 116th simulation and goes down gradually. According to the wealth ratio between the two kinds of investors, rational investors get richer while individual sentiment investors get poorer, which means that rational investor will encroach on the wealth of sentiment investor and make some sentiment investors exit the market. As a category kind of investor, although the sentiment investors' wealth decreases, they would not be totally "eliminated", due to the fact that different sentiment investors are ceaselessly in and out of the market, as Zhang et al. argued, individual investors include some who are motivated by the thrill of stocks that fluctuate---i.e., they consume excitement and deceive enjoyment from it (Zhang et al., 2010).

## CONCLUSION

This article builds a multi-stage synthetic financial market based on heterogeneous agent behavior, within the framework of new financial theory, which takes adaptive markets hypothesis, bounded rationality and nonlinear evolution as research paradigms. We studied the relationship between different kinds of investor behavior and IPOs underpricing as well as long-run performance. The conclusions are as follows:

(1) The institutional investor sentiment has a positive influence on the IPO price in the primary market, i.e., the higher the investors' buying sentiment, the higher the IPO price and vice versa.
(2) No matter whether they are institutional investors or individual investors; the higher sentiment in first trading day lead to the higher IPO underpricing and vice versa.
(3) There is no relationship between the institutional investors sentiment in long-term market and IPO long-run performance. But the sentiment of institutional investors in long-term market may leads to IPOs long-run underperformance. The sentiment of individual investors has a significant impact on stocks' long-term performance, which means that the higher the sentiment of individual investors, the better the IPO long-run performance. And if the sentiment of individual investor is higher than a particular value, the IPOs long-run underperformance will change to long-run outperformance.
(4) As time goes by, the wealth of individual sentiment investors is encroached by institutional investors. But unlike what Friedman's Hypothesis predicts, the number of sentiment investors will not decrease all the way to zero.

This article shows that different kinds of investor behavior have different impact on IPOs first-day underpricing and long-term performance. In contract to individual investors, institutional investors are more rational and have less impact on stocks through their behavior, which can improve the market's stability. Therefore, government should pay more attention on investor education so as to reduce the proportion of noise traders, alleviate the IPOs first-day underpricing and keep the IPOs market running smoothly. The pre-IPO companies should issue their stocks when investors' sentiment is relatively high. And investors can make decisions of buying or selling by using some indexes of investor sentiment introduced in this article.

This article makes research based on the method of agent-based computational finance from the view of behavior finance, which is an innovative work and effectively compensate for the method of econometric and stochastic dynamic equilibrium when study behavior finance. But this research system is not mature. Therefore, the work should be perfected in many aspects.

Some future research could be done. In the near future, the impact of individual investors and institutional investors' studying behavior on IPOs market can be studied. In the long-term, developing the theory and methods of agent-based computing finance and building a better artificial financial market according to the real market through introducing more representative factors, changing intelligence algorithm or some other methods will be the future direction.

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