

Retraction

Retracted: Time-Varying Research on Investors' Trading Psychology Rational and Irrational Market Sentiment Based on the Perspective of 5G Networks and Information Economics

Wireless Communications and Mobile Computing

Received 27 June 2023; Accepted 27 June 2023; Published 28 June 2023

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their

agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] W. Yang, C. Yang, B. Yang, and G. Feng, "Time-Varying Research on Investors' Trading Psychology Rational and Irrational Market Sentiment Based on the Perspective of 5G Networks and Information Economics," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 3594213, 11 pages, 2022.

Research Article

Time-Varying Research on Investors' Trading Psychology Rational and Irrational Market Sentiment Based on the Perspective of 5G Networks and Information Economics

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Received 7 January 2022; Revised 18 January 2022; Accepted 26 January 2022; Published 25 February 2022

Academic Editor: Mohammad Farukh Hashmi

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Amid the ongoing rapid digitalization, consistent advancements in technologies such as 5G have become crucial. The demand for 5G technologies is expected to surge owing to the continued hybrid work culture, and 5G stock will emerge from the stocks of older tech and telecom companies. However, the COVID-19 epidemic continues to spread globally, causing a major impact on China's macroeconomy and the stock market. It has a significant impact on the trading behavior of investors in 5G stock. Based on the framework of information economics and 5G Networks, we use the TVP-VAR model to empirically analyze the time-varying effects of rational and irrational market sentiment on investor herd behavior and overconfidence. The results show that rational market sentiment can always suppress herding behavior and overconfidence, while irrational market sentiment intensifies investors' herd behavior most of the time, suppressing overconfidence in the short term and turning it into a positive effect in the medium term, and its long-term effects have almost disappeared. Compared with rational market sentiment, irrational market sentiment has a more direct and significant impact on herd behavior. The absolute values of the impulse responses of both market sentiments to the impact of overconfidence are relatively close. In addition, both market sentiments have typical characteristics of vulnerability to investor psychology. After the epidemic spread, both market sentiments accelerate the generation of overconfidence, while the positive impact on herd behavior gradually decreases. Our research shows that in the environment of information asymmetry, although investors will restrain their irrational conformity psychology, they still have not demonstrated their reasonable investment capabilities. Our conclusions will provide some references for government regulatory agencies and market investors under the background of the epidemic.

1. Introduction

In the 1990s, the stock market was officially established in China. After nearly 30 years of development, with the continuous development and improvement of the stock market, the multilevel capital market system has been formed, including the Shanghai and Shenzhen Main Board, the Small and Medium Enterprise Board, the Growth Enterprise Market, and the Science and Technology Innovation Board. Among them, the Science and Technology Innovation Board was officially listed on July 22, 2019, through such

measures as the implementation of the pilot registration system and encouraging unprofitable 5G companies in China, including Guangzhou Fangbang Electronics, to gradually list on the stock market, to vigorously support the rapid development of China's 5G industry. However, Yang and Li [1] believed that the Science and Technology Innovation Board has significantly increased market volatility due to its lower barriers to entry, and investors' irrational trading psychology is more susceptible to extreme market volatility. We choose the Science and Technology Innovation Board as the research object to study the impact of market

sentiment on China's 5G industry investors' irrational trading psychology, which not only fills up the research gaps in the relevant fields of the Science and Technology Innovation Board but also finds more deeply the reaction and sensitivity of investors who are affected by market sentiment when making trading decisions, and help relevant departments to reasonably guide investors' trading psychology and protect investors' interests.

The trading operation psychology of most investors will be affected by extreme market volatility in varying degrees. Starting from the beginning of 2020, China's COVID-19 epidemic has continued to spread, causing a great impact on the domestic macroeconomy and stock market. The Shanghai Composite Index plummeted by 7.725% on February 3, 2020, becoming the largest single-day drop in the past five years. However, the Shanghai Composite Index on July 6, 2020, soared 5.711%, becoming the largest single-day gain in the past five years. During the period from 2020 to 2021, the average daily rate of increase and decrease of the Shanghai Composite Index is 0.048%, which is much higher than the 0.016% from 2015 to the present. The above data shows that China's stock market has frequently experienced extreme volatility under the impact of the epidemic. Yang et al. [2] believed that the market panic caused by the extreme volatility caused by the epidemic can affect the original trading psychology of investors and greatly increase the possibility of systemic financial risks in China. Yang and Li [1] found through empirical research that the market sentiment after the epidemic has greatly triggered investor panic, leading to a substantial increase in market development instability and uncertainty, weakening the function of market asset allocation, and significantly increasing the overall financial market's systemic risk. Therefore, we use the COVID-19 epidemic as the background to study the impact of market sentiment on China's 5G industry investors' irrational trading psychology, which has certain significance for relevant departments in preventing and controlling systemic financial risks in the stock market.

Many modern classic financial models usually assume that investors can make completely rational decisions with unlimited resources and cognition. However, due to the scarcity of cognitive abilities and information sources in the real context, individual irrational investment psychology will make asset prices deviate from rational prices in a short period. In the theory of behavioral finance, herding behavior is the volatile irrational behavior of investors, which will greatly increase the abnormal fluctuation of market prices, reduce the accuracy of future price predictions, and significantly increase the risk of investors' decision-making [3, 4]. Overconfidence is considered to be an important factor that causes investors to continue to have decision-making deviations, and it is easy to produce unique psychological investment preferences, which significantly underestimate investment risks and increase the frequency of investors' transactions, ultimately resulting in excessive volatility of returns [5-7].

Existing academic research believes that there is a significant positive correlation between market sentiment and herd behavior [3, 8]. The research on the relationship

between market sentiment and overconfidence suggests that there is significant overconfidence in the Chinese stock market, and positive market sentiment significantly increases the degree of investor overconfidence, which in turn leads to frequent extreme fluctuations in the market [6, 9].

Compared with the above research, we use daily frequency data of listed companies on the Science and Technology Innovation Board market to construct indicators such as rational market sentiment, irrational market sentiment, herding behavior, and overconfidence. Then, we establish the TVP-VAR model and discuss the time-varying effects of rational and irrational market sentiments on herding behavior and overconfidence under different lag periods and time points. Our marginal contribution mainly includes the following points: first, most of the previous literature takes market sentiment indicators directly as the research object, while we subdivide market sentiment into rational and irrational market sentiment, thus more specifically describing how different types of market sentiment affect investors' trading psychology. Second, in the construction of herding behavior indicators, the past academic research is mainly based on the CSAD method and the LSV method. However, the sensitivity of these methods is relatively low, especially when there is no extreme change in the market, the accuracy of these methods to identify herding behavior is at a low level. Therefore, under the framework of information economics, we propose a herding model based on relative entropy to measure the distribution distance of returns between different stocks and use the ordered degree of market information to describe investors' herding behavior, to greatly improve the ability to identify herding behavior. Third, we use the Science and Technology Innovation Board market, which contains a large number of 5G industry stocks, as our research object instead of choosing the Chinese main board market, thus enriching the research in related fields.

2. Experimental Details

2.1. Rational and Irrational Market Sentiment Indicators. According to the principal component analysis and the idea of extracting common factors, Hu and Chi [10] divided market sentiment into "smart" rational market sentiment and "low intelligence" irrational market sentiment. Therefore, we will refer to their method to construct rational market sentiment (RSENT) and irrational market sentiment (IRSENT) based on the Science and Technology Innovation Board and take the median as the standard. If the market sentiment is higher than the median, it is defined as positive market sentiment; otherwise, it is defined as negative market sentiment. The specific definition of the market sentiment agency index is shown in Table 1.

Based on the method of Hu and Chi [10], we first standardize the sequence of each proxy indicator and then perform the KMO (Kaiser-Meyer-Olkin) test and Bartlett's test of sphericity. The results show that the value of the KMO test is 0.671 and the value of Bartlett's test of sphericity is 0.000, both of which are suitable for the principal

component analysis method. After that, we conducted a principal component analysis, and the results are shown in Table 2.

According to Table 2, the eigenvalues of principal components 1 and 2 are, respectively, 2.109 and 1.974, and the values are both greater than 1. The variance ratios of the two principal components are, respectively, 42.172% and 39.472%, and the cumulative variance ratio is 81.643%. The component matrix coefficients of principal component 2 are all positive, and the WSJV coefficient exceeds 0.5. In the component matrix of principal component 1, the proxy indicators with positive coefficients and values exceeding 0.5 are the WT and the RSkew, and the coefficients of the remaining proxy indicators are all negative. Based on the empirical conclusions of Hu and Chi [10], the turnover rate is the most typical indicator of irrational sentiment in China's stock market. Therefore, it can be preliminarily judged that principal component 2 is a rational market sentiment indicator and principal component 1 is an irrational market sentiment indicator. However, because of the small variance ratio between principal components 1 and 2, further judgments and tests are needed. Therefore, we refer to the historical scenario interpretation of Baker and Wurgler [11] to analyze the rational and irrational components of market sentiment. According to Figure 1, there is a more obvious lag relationship between the principal component 1 and the market rate of return, while the trend of the principal component 2 and the market rate of return is more similar. Therefore, principal component 2 has the characteristics of rational sentiment.

In addition, Table 3 gives the descriptive statistical results of the two principal components. It is found that although principal component 1 has a slightly higher variance ratio than principal component 2, its distribution is severely right-skewed and its kurtosis is higher, which shows that compared with principal component 2, the market sentiment represented by principal component 1 is more prone to extreme optimism and pessimism. Therefore, principal component 1 has more irrational market sentiment characteristics, and principal component 2 has more rational market sentiment characteristics.

Finally, Hu and Chi [10] proposed that, compared with irrational market sentiment, rational market sentiment can predict future market returns more accurately. Therefore, we conduct regression predictions for the principal component and the future market return, while Table 4 gives the specific regression results. It is found that although the significance of the model is not high, there is a more significant relationship between the principal component 2 and the future market return. So, they have a more obvious positive correlation, indicating that principal component 2 is more representative of rational market sentiment, and principal component 1 is more representative of irrational market sentiment.

In summary, principal component 1 is an indicator of irrational market sentiment, and principal component 2 is an indicator of rational market sentiment. Therefore, the rational (RSENT) and irrational market sentiment

(IRSENT) indicators can be specifically calculated by the principal component analysis method:

$$\begin{aligned} \text{IRSENT}_t = & (-0.405) \times \text{ADLine}_t + 0.426 \times \text{WT}_t + (-0.121) \\ & \times \text{WSJV}_t + 0.428 \times \text{RSkew}_t + (-0.142) \times \text{NF}_t, \end{aligned} \quad (1)$$

$$\begin{aligned} \text{RSENT}_t = & 0.119 \times \text{ADLine}_t + 0.045 \times \text{WT}_t + 0.373 \\ & \times \text{WSJV}_t + 0.058 \times \text{RSkew}_t + (-0.347) \times \text{NF}_t. \end{aligned} \quad (2)$$

2.2. Herd Behavior Indicator. Compared with the traditional economic theories, information economics, as an interdisciplinary subject in the field of information science and economics, emphasizes the key role of factors such as information in the investment psychology-making process. The concept of information entropy originated in the field of thermodynamics, and its measurement depends on the probability distribution function $p(x)$ of information X . If information X is a continuous random variable, its probability distribution is recorded as $p(x) = P(X = x)$, then the information entropy $H(X)$ of X is as follows:

$$H(X) = - \int_{-\infty}^{+\infty} p(x) \log_2 p(x) dx. \quad (3)$$

It can be found that the larger $H(X)$, the larger the amount of information contained in X , and the greater the uncertainty in the process of outputting information. When the system is more ordered, the value of $H(X)$ is smaller, and when the distribution of the system is more uneven, the value of $H(X)$ is larger.

According to the principle of maximum entropy proposed by Jaynes [12], without any external force, random events always develop in the direction of the most chaotic and least constrained. Therefore, under known conditions, when the value of entropy reaches the maximum, it is closest to the true state. Similarly, when predicting the probability distribution of random events, if the probability distribution is more uniform, the more it has the characteristics of unbiasedness and authenticity, and the greater the information entropy of the probability distribution at this time is.

After that, we construct the basic model—the maximum information entropy optimization model based on finite random events and constraints:

$$\begin{aligned} \max \quad & H(X) = - \int_a^b p(x) \log_2 p(x) dx \\ \text{s.t.} \quad & \begin{cases} \int_a^b p(x) g_j(x) dx = c_j, j = 1, 2, \dots, n \\ \int_a^b p(x) dx = 1 \\ p(x) \geq 0 \end{cases} \end{aligned} \quad (4)$$

where c_1, c_2, \dots, c_n are constants and $g_1(x), g_2(x), \dots, g_n(x)$ are given constraints. Therefore, the

TABLE 1: The specific definition of market sentiment agency index.

Agency index	Symbol	Expression	Definition
A:D-Line	ADLine	$ADLine_t = \sum_{i=1}^t (Z_i - D_i)$	Number of stocks rising
Weight-based turnover rate	WT	$WT_t = (Q_{i,t} / \sum_{i=1}^{N_t} Q_{i,t}) \times T_{i,t}$	Handover frequency value
Symbol-based jump	WSJV	$SJV_t = \sum_{i=1}^{N_t} R_{i,t}^2 \times D_{i,t}^1 - \sum_{i=1}^{N_t} R_{i,t}^2 \times D_{i,t}^2$	Discontinuous jumps in prices
Realized skewness	RSkew	$RSkew_t = \sqrt{N_t} \sum_{i=1}^{N_t} R_{i,t}^3 \times \frac{1}{\sum_{i=1}^{N_t} R_{i,t}^2 \sqrt{2/3}}$	Market return asymmetry index
Number of price limits	NF	$NF_t = NU_t - ND_t$	The net value of stock price limit

TABLE 2: The results of principal component analysis.

Component	Characteristic number		Variance (%)		Cumulative variance (%)
1	2.109		42.172		42.172
2	1.974		39.472		81.643
Component	Component matrix				
	ADLine	WT	WSJV	RSkew	NF
1	-0.784	0.824	-0.234	0.828	-0.274
2	0.245	0.092	0.771	0.120	-0.718

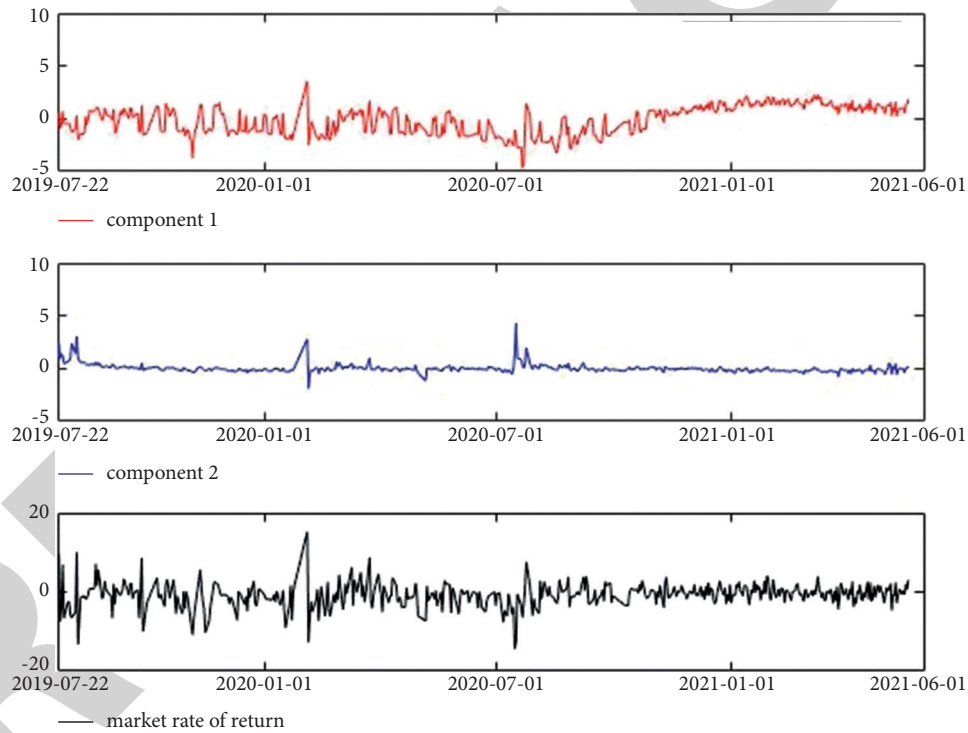


FIGURE 1: Results of the impulse response in different lag periods.

TABLE 3: Descriptive statistics of principal components 1 and 2.

Component	Mean	Variance	Skewness	Kurtosis	ADF unit root test (t value)
1	0.000	2.376	2.815	11.301	-5.377***
2	0.000	1.387	-1.001	10.390	-14.388***

Note: the numbers in the table are Newey-West's t statistic; the symbol *** indicates that the regression coefficients are significant at the levels of 1%.

TABLE 4: The regression result of the component and the future rate of return of the market.

	$R_{m,t+1}$	$R_{m,t+2}$	$R_{m,t+3}$	$R_{m,t+4}$	$R_{m,t+5}$	$R_{m,t+6}$	$R_{m,t+7}$
Component 1	0.618	0.833	0.081	0.065	0.535	0.199	0.191
Component 2	0.931	1.258	1.273	1.150	1.311	1.236	1.326
Adj. R^2	0.009	0.025	0.025	0.029	0.035	0.034	0.053

Note: the numbers in the table are Newey–West's t statistic.

Lagrangian function of information entropy $H(X)$ is as follows:

$$L(p, a) = - \int_a^b p(x) \log_2 p(x) dx + (a+1) \left(\int_a^b p(x) dx - 1 \right) + \sum_{j=1}^n \left(\int_a^b p(x) g_j(x) dx - c_j \right), \quad (5)$$

where $a = (a_0, a_1, \dots, a_n)^T$ and a_1, a_2, \dots, a_n are the Lagrange multipliers of the constraints $\int_a^b p(x) g_j(x) dx = c_j$ ($j = 1, 2, \dots, n$), respectively. a_0 is the Lagrange multipliers of the constraint $\int_a^b p(x) dx = 1$.

Considering the nature of convex programming, the optimal solution can be calculated directly from the stationary value condition of $L(p, a)$. First, let the partial derivative of $L(p, a)$ for $p(x)$ be 0:

$$\frac{\partial L(p, a)}{\partial p(x)} = 0. \quad (6)$$

The closed-form solution of the maximum information entropy optimization model can be obtained:

$$p(x) = \exp \left[a_0 + \sum_{j=1}^n a_j g_j(x) \right]. \quad (7)$$

When the market is in a state of disorder, assuming that the mean of the probability distribution is μ and the variance is σ^2 , then the maximum information entropy optimization model and its constraints can be transformed into the following:

$$\begin{aligned} \max \quad & H(X) = - \int_a^b p(x) \log_2 p(x) dx \\ \text{s.t.} \quad & \begin{cases} \int_a^b x p(x) dx = \mu \\ \int_a^b (x - \mu)^2 p(x) dx = \sigma^2 \\ \int_a^b p(x) dx = 1 \\ p(x) \geq 0 \end{cases} \end{aligned} \quad (8)$$

By constructing the Lagrange equations, the probability density function of the smallest deviation can be solved:

$$p(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp \left[-\frac{(x - \mu)^2}{2\sigma^2} \right], \quad a \leq x \leq b. \quad (9)$$

It shows that when the market is in a state of disorder, its probability distribution function obeys the normal distribution.

There are trading processes at every moment in the stock market, and each trading process contains the subjective beliefs formed by investors after processing their information, and this process is also realized through the transmission of information. The transmission of information relies on the collection and processing of information, and the collection while processing information requires the investor's background and costs, but different investors have different psychology in processing information. Therefore, when the investors produce herding psychology, their investment behavior will show a significant increase in consistency and convergence, and thus the dispersion of the market's stock returns will be significantly reduced. At this time, the market will show obvious characteristics of the order, and its information entropy value will be at a lower level.

Therefore, we will use the relative entropy indicator of stocks to measure the degree of herd behavior based on the concept of information entropy according to the property that the probability distribution function of the random variable obeys the normal distribution when the market is disordered. If there is no significant herding behavior in the market, the less orderly market information is, the probability distribution of its stock returns obeys the normal distribution, and the information entropy of the market reaches its maximum value. When there is significant herding behavior in the market, the greater the order of market information at this time, the more scattered the return distribution of market stocks, and the smaller the value of its information entropy. Therefore, we construct the herd behavior indicator based on the distance between the information entropy in different states.

The theory of information entropy has the following three advantages: as an indicator to measure the degree of disorder in the stock market, information entropy does not require any theoretical assumptions and preconditions; based on the principle of maximum entropy, it can accurately predict the probability of the unknown distribution rate of return; in an incompletely developed stock market, information entropy can still accurately predict the degree of disorder in the market.

Based on the information entropy, we construct the relative entropy indicator. Assuming that there are two different probability distributions $p(x)$ and $q(x)$ in the continuous random variable X , the relative entropy of $p(x)$ to $q(x)$ is as follows:

$$D(P\|Q) = - \int_{-\infty}^{+\infty} p(x) \log_2 \frac{p(x)}{q(x)} dx. \quad (10)$$

Relative entropy is an indicator to measure the distance between two different probability distributions in the same random variable, so based on the concept of relative entropy, we record the value of information entropy when the distribution obeys the normal distribution as H_a and the actual value of information entropy as H and then define the relative entropy indicator of the stock market as RH_t :

$$RH_t = 1 - \frac{H_t}{H_a}, \quad (11)$$

where RH_t is the relative entropy indicator of herd behavior at time t and H_t is the information entropy indicator at time t . The greater the value of RH_t , the greater the order of information in the market at time t , and the more significant the herd behavior.

2.3. Overconfidence Indicator. Li et al. [13] argued that although historical return information is not the only information available to overconfident investors, it is the most accessible and most significant information for investors in the Chinese stock market, where individual investors are dominant in trading. Therefore, we believe that the use of this variable can effectively describe the overconfidence level of market investors. So, we refer to the method of Li et al. [13] to construct an indicator of overconfidence.

$$\begin{aligned} Y_{i,t} &= O_{i,t} + NO_{i,t} = \left(\sum_{j=1}^{12} b_j R_{i,t-j}^a \right) + (b_0 + \varepsilon_{i,t}) \\ &= b_0 + \sum_{j=1}^{12} b_j R_{i,t-j} + \varepsilon_{i,t} \end{aligned}, \quad (12)$$

where $Y_{i,t}$ is the logarithm of the trading volume of the i -th stock at time t , $R_{i,t-j}^a$ is the excess return rate of the i -th stock at time $t-j$, $O_{i,t}$ is the overconfidence part of the i -th stock trading volume at time t , and $NO_{i,t}$ is the nonoverconfidence part of the i -th stock trading volume at time t . Therefore, the overconfidence indicator (O_t) can be constructed based on the weight of the total market value of the stock:

$$O_t = \frac{Q_{i,t}}{\sum_{i=1}^{N_t} Q_{i,t}} \times O_{i,t}, \quad (13)$$

where $Q_{i,t}$ is the total market value of the i -th stock at time t .

2.4. Stationarity Test. We take the Science and Technology Innovation Board market as the research object and select daily frequency data from July 2019 to May 2021 to construct relevant indicators and TVP-VAR models, and the data comes from the Wind database. In the empirical study, we eliminate the remaining stocks whose trading days are less than 100 days, and to prevent the outliers from having an adverse impact on the model calculation, we use the boxplot method to delete the calculated outliers directly. In response to missing data caused by stock suspension and other

reasons, we use interpolation methods to directly replace the missing data. After that, to avoid spurious regression in the model regression process, we use the ADF unit root test method to test the stationarity of the above indicators; as shown in Table 5, all indicator series are stationary.

2.5. Establishment of the TVP-VAR Model. The parametric vector autoregressive model (VAR model) assumes that the variances of all parameters and disturbance terms remain constant, but this assumption is usually contrary to reality. In contrast, the TVP-VAR model can not only analyze the time-varying characteristics between variables but also deal with abnormal changes in time series and enhance the stability of the model results. Therefore, we choose to use the TVP-VAR model to analyze how rational and irrational market sentiment affects a series of investor behaviors such as herding behavior and overconfidence. First of all, we refer to the TVP-VAR model of Nakajima [14] and expand the parameters in the standard VAR model to time-varying parameters:

$$\begin{aligned} z_t^i &= c_t^i \beta_t^i + D_{i,t}^{-1} \sum_t \varepsilon_t^i \\ \varepsilon_t^i &\sim N(0, I_s), \end{aligned} \quad (14)$$

where $t = s+1, \dots, n$, $i = 1, 2, 3$, $z_t^1 = (\text{IRSENT}, \text{RSENT}, \text{RH})^T$, $z_t^2 = (\text{IRSENT}, \text{RSENT}, O)^T$, $z_t^3 = (\text{IRSENT}, \text{RSENT}, L)^T$, z_t^1, z_t^2 , and z_t^3 are both time-varying intercept sample vectors, c_t^i is the time-varying parameters $\beta_t^i = I_3 \otimes (z_{t-1}^i, \dots, z_{t-s}^i)$, s is the lag period, \otimes is the Kronecker product, I_3 is the 3-dimensional unit vector,

$$D_{i,t} = \begin{bmatrix} 1 & 0 & 0 \\ d_{i,t}^{21} & 1 & 0 \\ d_{i,t}^{31} & d_{i,t}^{32} & 1 \end{bmatrix}, \quad \Sigma_t = \begin{bmatrix} \sigma_{i,t}^1 & 0 & 0 \\ 0 & \sigma_{i,t}^2 & 0 \\ 0 & 0 & \sigma_{i,t}^3 \end{bmatrix}, \quad \text{and } \varepsilon_t^i \text{ is the structural shock.}$$

Refer to the processing method of Nakajima [14], the non-0 and 1 element in $D_{i,t}$ are stacked into a column vector $d_t^i = (d_{i,t}^{21}, d_{i,t}^{31}, \dots, d_{i,t}^{s-1})$, define $l_{s,t}^i = \log \sigma_{i,t}^s$ and $l_t^i = (l_{1,t}^i, \dots, l_{s,t}^i)$, and assuming that the time-varying parameters are independent of each other and subject to the random walk process, the following results are obtained:

$$\begin{aligned} c_{t+1}^i &= c_t^i + \eta_{c_t^i}, \\ d_{t+1}^i &= d_t^i + \eta_{d_t^i}, \\ l_{t+1}^i &= l_t^i + \eta_{l_t^i}, \end{aligned} \quad (15)$$

$$\begin{pmatrix} \varepsilon_t^i \\ \eta_{c_t^i} \\ \eta_{d_t^i} \\ \eta_{l_t^i} \end{pmatrix} \sim N \left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_c^i & 0 & 0 \\ 0 & 0 & \Sigma_d^i & 0 \\ 0 & 0 & 0 & \Sigma_l^i \end{pmatrix} \right),$$

where $t = s+1, \dots, n$, $i = 1, 2, 3$.

After that, based on the AIC criterion, we use Markov Chain Monte Carlo (MCMC) algorithm to iterate 10,000 samples and discard the initial 1000 samples as the expected

TABLE 5: The results of the stationarity test.

	IRSENT	RSENT	RH	O	L
0th-order difference	-5.38*** (0.00)	14.39*** (0.00)	-13.16*** (0.00)	-16.51*** (0.00)	-20.388*** (0.000)

Note: the numbers in the table are Newey–West’s t statistic; the number in parentheses is the p value. The symbols *, **, and *** indicate that the regression coefficients are significant at the levels of 10%, 5%, and 1%, respectively.

simulated value of the samples. The posterior estimation results of parameters based on the MCMC algorithm are shown in Table 6 in the appendix.

Table 6 shows that all the Geweke diagnostic values of the models are less than the critical value of 1.96, failing to reject the null hypothesis of the 5% confidence level, which tends to the posterior distribution of the respective models, indicating that the sampled data have validity characteristics. In addition, compared with the simulation times of 10000, the values of all invalid influence factors are lower than 213, indicating that the sampling of the MCMC algorithm has the characteristics of validity, and the number of irrelevant samples obtained under the predetermined sampling times is small, which can meet the needs of the posterior estimation of the model.

3. Results and Discussion

In this part, we conduct the empirical analysis on the time-varying effects of rational and irrational market sentiments on herding behavior and overconfidence. Then, we give two types of impulse response results based on different lag periods and time points. Among them, the lag period selects the length of 3 days, 6 days, and 9 days, which represent the short-term, medium-term, and long-term effects of variable shocks. And we selected the impulse response curves at three-time points: $t = 20$ (August 19, 2019), $t = 300$ (October 16, 2020), and $t = 500$ (May 15, 2021). They are located in the early, mid, and late stages of the entire time series, which correspond exactly to the early, mid, and late stages of the development process of the Science and Technology Innovation Board, thus ensuring the comprehensiveness of the empirical analysis.

3.1. Time-Varying Effects of Market Sentiments on Herd Behavior. The left column of Figure 2 reflects the impact of changes in rational market sentiment based on different lag periods on herd behavior. In the entire sample period, the positive impact of rational market sentiment on herd behavior is negative, and after May 2020, the inhibitory effect of rational market sentiment on herd behavior gradually becomes greater. As the number of lag periods increases, the impact of rational market sentiment gradually decreases. This shows that in the entire sample period, the more positive the rational market sentiment, the more restrained the herd behavior of investors. With the continuous development of the market, the inhibitory effect of rational market sentiment on herd behavior has increased significantly, and compared with the long-term impact, the short-term rational market sentiment’s inhibitory effect is more obvious.

The right column of Figure 2 reflects the time-varying impact of irrational market sentiment based on different lag periods on herd behavior. The short-term impact of irrational market sentiment on herd behavior is positive, and the short-term positive impact of irrational market sentiment increases as the market develops. As the lag period increases, the irrational market sentiment shock response gradually decreases and even changes from positive to negative when the lag is 9 periods, but its absolute value is relatively small. This shows that the more positive the irrational market sentiment is, the easier it is for investors to produce herding behavior, and compared to the long-term impact, its short-term impact is the most significant, indicating that the positive impact of irrational market sentiment on herding behavior is more rapid and direct.

So, rational market sentiment always inhibits the generation of investor herd behavior, while irrational market sentiment promotes the generation of herd behavior most of the time. Moreover, compared with rational market sentiment, the absolute value of impulse response of irrational market sentiment to the impact of investor herd behavior is greater. The impact of irrational market sentiment on herd behavior is more direct and significant. It may be because rational market sentiment needs to influence investor transactions through various channels, while irrational market sentiment can directly play a role in generating investor herd behavior [4].

The left column of Figure 3 reflects the impact of changes in rational market sentiment based on different time points on herd behavior. Except for the lag 2 period, the impulse response of rational market sentiment to herd behavior at different time points is negative. As the number of lag periods increases, the absolute value of its impulse response gradually decreases, and the impulse response of rational market sentiment is consistent at different time points. This shows that the more positive the rational market sentiment is, the less likely it is for investors to produce herd behavior, and this inhibition is mainly reflected in the short-term impact. Its long-term impact has almost disappeared. In addition, the consistent performance of impulse response impact at different time points also shows that there may be no significant differences in the trading methods of investors who are subject to rational market sentiment at different times, and the trading psychology of investors has not changed significantly.

The right column of Figure 3 reflects the time-varying impact of irrational market sentiment based on different time points on herd behavior. Irrational market sentiment has the same response to the shock of herd behavior at different time points, showing a “W-shaped” change with the increase of the lag period: before the lag 1 period, the

TABLE 6: The results of posterior estimation.

Parameter	Mean	Standard deviation	95% confidence interval	Geweke diagnostic value	Invalid impact factor
$(\Sigma_c^1)_1$	0.0023	0.0003	[0.0019, 0.0029]	0.894	28.43
$(\Sigma_c^1)_2$	0.0023	0.0003	[0.0018, 0.0029]	0.370	25.44
$(\Sigma_d^1)_1$	0.0053	0.0015	[0.0033, 0.0091]	0.669	100.80
$(\Sigma_d^1)_2$	0.0064	0.0026	[0.0035, 0.0144]	0.308	212.90
$(\Sigma_l^1)_1$	0.1567	0.0334	[0.1014, 0.2294]	0.857	28.02
$(\Sigma_l^1)_2$	0.5665	0.0593	[0.4578, 0.6897]	0.712	24.23
$(\Sigma_c^2)_1$	0.0023	0.0003	[0.0019, 0.0030]	0.003	24.87
$(\Sigma_c^2)_2$	0.0023	0.0003	[0.0018, 0.0028]	0.378	31.18
$(\Sigma_d^2)_1$	0.0051	0.0014	[0.0032, 0.0089]	0.361	141.31
$(\Sigma_d^2)_2$	0.0069	0.0019	[0.0040, 0.0113]	0.845	85.73
$(\Sigma_l^2)_1$	0.1450	0.0314	[0.0893, 0.2130]	0.870	126.19
$(\Sigma_l^2)_2$	0.5605	0.0578	[0.4537, 0.6785]	0.296	25.03
$(\Sigma_c^3)_1$	0.0023	0.0003	[0.0018, 0.0029]	0.728	21.60
$(\Sigma_c^3)_2$	0.0023	0.0003	[0.0018, 0.0028]	0.877	26.70
$(\Sigma_d^3)_1$	0.0052	0.0012	[0.0034, 0.0082]	0.718	93.19
$(\Sigma_d^3)_2$	0.0056	0.0017	[0.0034, 0.0100]	0.530	139.52
$(\Sigma_l^3)_1$	0.1693	0.0352	[0.1147, 0.2542]	0.071	61.72
$(\Sigma_l^3)_2$	0.5655	0.0622	[0.4542, 0.6939]	0.455	29.28

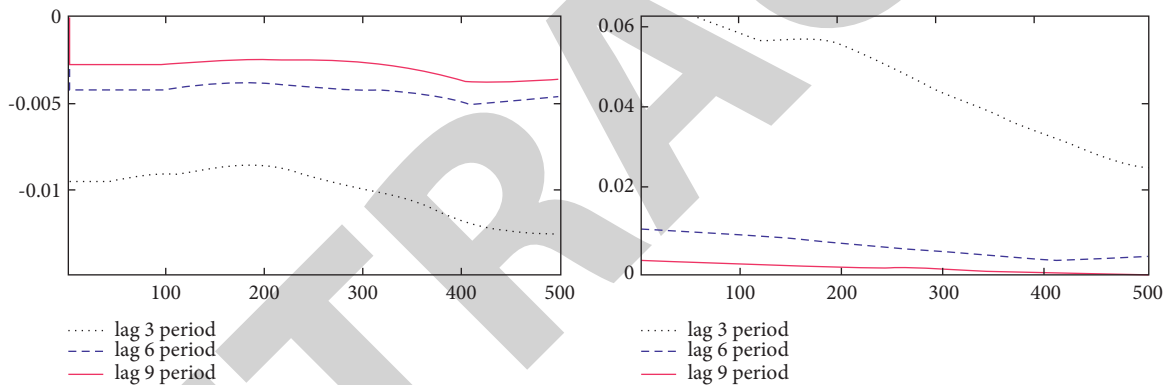


FIGURE 2: Results of the impulse response to herd behavior in different lag periods.

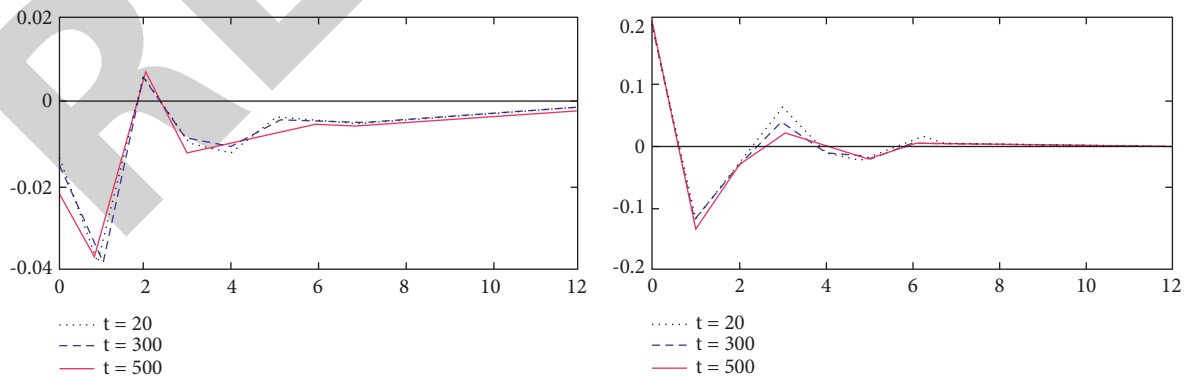


FIGURE 3: Results of the impulse response to herd behavior in different time points.

shock decreases with the increase of the lag period, and the trough is also reached in the lag 1 period; while in the lag 1 to 3 periods, the shock begins to increase gradually; but in the

lag 3 to 5 periods, the shock response changes from positive to negative; then with the increase in the lag period, the impact of the shock gradually increases to zero. This shows

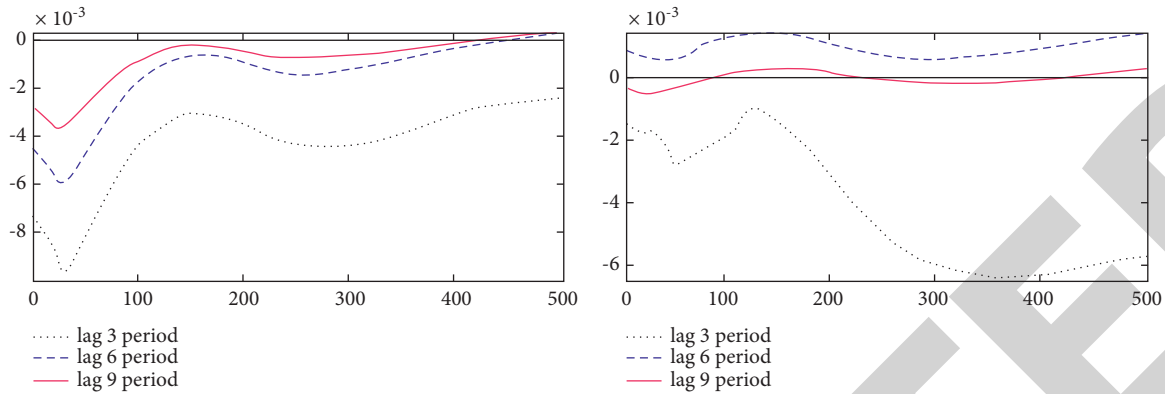


FIGURE 4: Results of the impulse response to overconfidence in different time points.

that during the entire sample period, positive irrational market sentiment can immediately stimulate the formation of investor herd psychology. As investors gradually become calmer, their herd psychology has gradually turned into antiherd psychology, and then herding psychology gradually occupies the main influencing factor in the decision-making process. As time accumulates, its influence will gradually diminish and nearly disappear in the later stage.

In summary, consistent with the previous analysis, positive rational market sentiment inhibits investor herd behavior, while positive irrational market sentiment promotes herd behavior. Moreover, their short-term effect on herding behavior was significantly stronger than the long-term effect. However, the influence of different market sentiments on herd behavior shows some heterogeneity and time-varying characteristics in the early stage of the market: compared with rational market sentiment, irrational market sentiment has a more direct and significant impact on herd behavior; rational market sentiment always suppresses the generation of herding behavior; after positive irrational market sentiment stimulates herding behavior, investors gradually developed antiherd psychology but then restimulated herding behavior, indicating that irrational market sentiment is more volatile and vulnerable to herding behavior.

3.2. Time-Varying Effects of Market Sentiments on Overconfidence. The left column of Figure 4 reflects the impact of changes in rational market sentiment based on different lag periods on overconfidence. In the entire sample period, the impact of rational market sentiment on overconfidence is negative, and there are some time-varying characteristics: taking September 2019 as the cut-off point, the inhibitory effect of rational market sentiment gradually decreases after the cut-off point, and with the increase of lag, the inhibitory effect gradually tends to disappear. It shows that in the early period of the whole period, the impact of rational market sentiment significantly inhibited excessive self-confidence, but in the later period of the sample, this inhibitory effect was significantly reduced. In addition, the short-term impact of rational market sentiment on overconfidence was more significant.

The right column of Figure 4 reflects the time-varying impact of irrational market sentiment based on different lag periods on overconfidence. In the entire sample period, the short-term impact of irrational market sentiment on overconfidence is negative, and especially after September 2019, the short-term negative impact of irrational market sentiment is more significant; the mid-term impact of irrational market sentiment on overconfidence is positive, but the absolute value of its impact response is small; in addition, the later impact of irrational market sentiment on overconfidence is insignificant; as the lag period increases, the impact response gradually decreases. It shows that positive irrational market sentiment will immediately stimulate investors to have overconfidence, but as investors will gradually return to rationality in the decision-making process, this overconfidence will gradually change into overconservative psychology, which will accumulate over time. The influence of irrational market sentiment will gradually diminish and disappear in the later stage.

So irrational market sentiment will inhibit investors' overconfidence in the short-term most of the time. In the mid-term, it turned to promote overconfidence. However, rational market sentiment always inhibited investors from producing overconfidence. Different from herding behavior, the absolute values of the two market sentiments to overconfidence shocks are relatively close. In addition, in the early stage of the sample, rational market sentiment has a more significant impact on the short-term suppression of overconfidence, while in the later stage of the sample, the short-term impact of irrational market sentiment on overconfidence is more significant. It shows that the short-term impact of rational market sentiment on overconfidence is more direct and rapid. The impact of the two market sentiments on overconfidence is relatively close, of which the long-term impact is relatively limited.

The left column of Figure 5 reflects the impact of changes in rational market sentiment based on different time points on overconfidence. Except for the lag zero period, the impulse response of rational market sentiment to overconfidence at different time points is negative, and the absolute value of its impulse response begins to gradually decrease with the increase of lag period. Compared to the later period of the sample, the early period of the sample is more

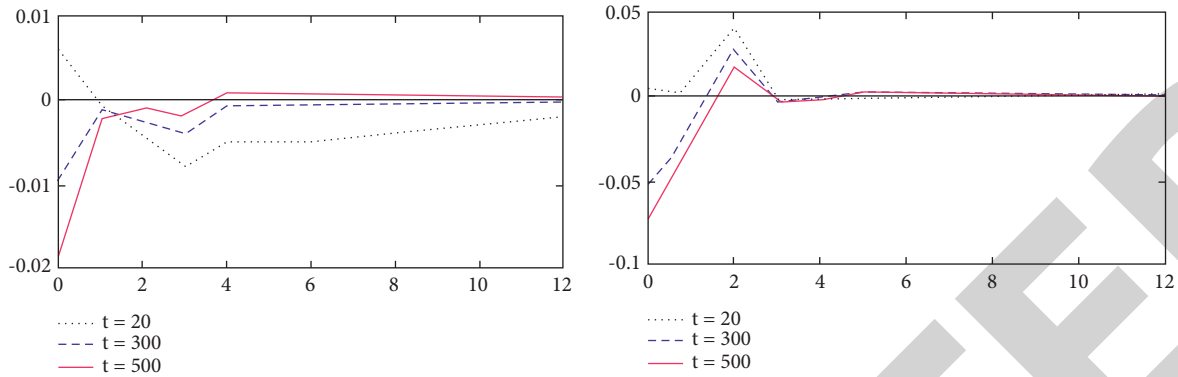


FIGURE 5: Results of the impulse response to overconfidence in different time points.

significantly affected by rational market sentiment. It shows that in the early stage of the sample, rational market sentiment has a significant inhibitory effect on overconfidence but significantly diminishes to disappear after a lag of 3 periods.

The right column of Figure 5 reflects the time-varying impact of irrational market sentiment based on different time points on overconfidence. The irrational market sentiment at different time points has the same response to the shock of overconfidence. The inhibitory effect before the lag 2 period decreases with the increase of the lag period, but the subsequent shocks decrease significantly with the increase of the lag period. This shows that in the whole sample cycle, the impact of irrational market sentiment on overconfidence remains consistent, showing a significant inhibitory effect in the early stage, and the inhibitory effect is significantly reduced to disappear after a lag of 2 periods.

In summary, both positive rational and irrational market sentiments suppress the generation of investor overconfidence in the short term, and their short-term effects are significantly stronger than long-term effects, indicating that they have the characteristics of short-term vulnerability. However, in the early stage of the sample, there was partial heterogeneity: irrational market sentiment had a greater absolute value in response to the impact of overconfidence, indicating that its impact was more significant.

4. Conclusions

Based on the framework of behavioral finance and starting from the perspective of 5G industry stocks, we have studied the time-varying relationship between different types of market sentiment and investor trading psychology. The main results are as follows:

- (1) Rational market sentiment always suppresses herding behavior, while irrational market sentiment promotes herding behavior most of the time. The short-term impact of the two market sentiments is significantly stronger than the long-term, but the two exhibited partial heterogeneity and time-varying characteristics in the early stage of the market: compared with rational market sentiment, irrational market sentiment has a more direct impact on herd

behavior; rational market sentiment has always suppressed herding behavior, while irrational market sentiment has turned to antiherding behavior after promoting investors' herding behavior but then reproduced herding behavior, indicating that irrational market sentiment is more volatile in the production of herd behavior.

- (2) Rational market sentiment also always suppresses the generation of overconfidence, while irrational market sentiment has a short-term inhibitory effect on overconfidence, but the medium-term shift promotes the generation of overconfidence and its long-term effects have almost disappeared. Different from herding behavior, the absolute values of the impulse responses of the two market sentiments to overconfidence shocks are relatively close. In addition, the short-term impact of rational market sentiment in the early stage is more significant, while the short-term impact of irrational market sentiment in the later stage is more significant, indicating that the short-term impact of rational market sentiment is more direct and rapid and it has fragility characteristics. In addition, the two market sentiments have similar effects on overconfidence, and their long-term effects are relatively limited.

The above conclusions indicate that compared with irrational market sentiment, investors affected by rational market sentiment are less likely to exhibit herding behavior, but the two market sentiments have a similar effect on overconfidence, which is consistent with the empirical conclusion of Lan et al. [15]. In addition, the short-term impact of the two market sentiments on investor psychology is more direct and rapid, indicating that they have typical fragility characteristics, reflecting that most of the existing investors in the Chinese stock market cannot quickly process and interpret market information. They are extremely sensitive and concerned about changes in market sentiment and are more likely to have irrational trading psychology.

Finally, after the spread of the epidemic, both market sentiments accelerated the generation of overconfidence, while the positive impact on herding behavior gradually decreased. This conclusion shows that in the environment of information asymmetry, although investors will restrain

their irrational conformity psychology, they are still prone to irrational behavior and have not shown reasonable investment ability.

Therefore, based on the research of information economics and 5G Networks, the relevant Chinese regulatory authorities should strengthen the disclosure of the Science and Technology Innovation Board's 5G industry stocks declaration of severely abnormally volatile stocks to prevent the adverse effects of irrational behavior. For investors, they should learn and train to understand the characteristics of their trading psychology deviations, reduce the constraints of psychological factors, and reduce the magnitude and possibility of deviations.

Data Availability

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

This work was supported by a project grant from the National Natural Science of China (Grant No. 71903079).

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