The Quantitative Representation of Market Sentiment and the Nonlinear Correlation Mechanism between Stock Price Fluctuations

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Abstract: Market sentiment, as the core irrational factor influencing stock price fluctuations, breaks through the traditional linear paradigm in its correlation mechanism with stock prices and presents complex nonlinear characteristics. This paper reveals the threshold effect of emotion accumulation, the asymmetry between optimism and pessimism, and the dynamic transformation rules under market cycles by constructing a multi-dimensional emotion quantification system. Research has found that the relationship between sentiment indicators and stock price fluctuations is not a simple positive correlation, but rather forms a nonlinear transmission mechanism through paths such as investor behavior distortion and information feedback distortion. This mechanism profoundly influences the operational efficiency of the market and provides a theoretical framework for understanding the accumulation and release of systemic financial risks.

Keywords: Market Sentiment; Quantitative Representation; Stock Price Fluctuations; Nonlinear Mechanism; Behavioral Finance

1. Introduction

Traditional financial theory, based on the rational person assumption and the efficient market hypothesis, holds that asset prices are linearly determined by fundamental information [1]. However, events such as the extreme fluctuations of "A thousand stocks hitting the daily limit up - the daily limit down - trading suspension" in the A-share market in 2015 and the cliff-like decline of the global market in 2020 have exposed the traditional model's neglect of the nonlinear characteristics driven by emotions. Behavioral finance research indicates that investor sentiment forms a complex mapping relationship with stock price fluctuations by altering risk preferences, information processing methods, and trading behaviors [2]. This nonlinear correlation is manifested not only in the sudden change effect after emotions accumulate to the critical point, but also in the asymmetry of the influence of optimistic and pessimistic emotions on fluctuations.

The classical linear model assumes a stable proportional relationship between mood and volatility. For instance, for every 1-unit increase in the mood index, the volatility increases by 0.5 units [3]. However, the real market shows that in 2015, during the period of excessive sentiment, the A-share market experienced a sharp fluctuation of "a thousand stocks hitting the daily limit up → a thousand stocks hitting the daily limit down → a thousand stocks being suspended from trading", with the fluctuation range far exceeding the linear prediction value. At the beginning of 2020, volatility rose only moderately, but when sentiment broke through the critical point, volatility suddenly increased exponentially [4]. These phenomena suggest that the relationship between emotions and fluctuations may have a nonlinear characteristic of "quantitative change leading to qualitative change".

2. Quantitative Representation System of Market Sentiment

2.1 Direct Measurement System

Investor surveys, which collect investors' expectations of market trends through structured questionnaires, are a traditional tool for measuring sentiment. For instance, the "Individual Investor Sentiment Index" released by a certain institution surveys investors' expectations for the market trend in the coming month (bullish/bullish/bearish) every month and calculates the difference between the bullish ratio and the bearish ratio [5]. The advantage of this method lies in directly reflecting the psychology of investors, but it has the problem of sample bias: the emotional expressions of

active investors or high-risk preference groups may overly represent the overall market. In addition, investors may have the phenomenon of "inconsistency between words and deeds", that is, there is a discrepancy between the questionnaire responses and their actual trading behaviors.

Text sentiment analysis relies on natural language processing technology to extract emotional words from news headlines and social media comments. For instance, when the frequency of words like "positive" and "buy" on a certain trading day is three times higher than usual, it can be determined that the market is in an optimistic and excited period. The frequent appearance of terms such as "black swan" and "liquidity crisis" reflects pessimism [6]. Although this method can achieve real-time monitoring, it needs to handle noise data such as advertisements and teasing, and there are errors in the interpretation of metaphorical expressions. For instance, when a listed company issues an announcement regarding a "major asset reorganization", text analysis may misjudge it as positive news, while the actual market reaction may vary due to the uncertainty of the reorganization plan.

2.2 Indirect Inference System

Trading behavior indicators infer the emotional state of investors through their actual trading patterns. Turnover rate is one of the core indicators, and its changes are highly correlated with the intensity of emotions. An abnormally high turnover rate at the end of a bull market often indicates overheated sentiment. For instance, when the daily turnover rate of the A-share market exceeded 5% in 2015, the market immediately entered a period of intense adjustment [7]. The first-day return rate of an IPO also holds indicative significance. When the increase of a new stock on its first trading day consistently exceeds 200%, it indicates that investors are willing to pay a high premium for the "story", and the sentiment has entered an irrational range. In addition, the discount rate of closed-end funds indirectly infers the sentiment state by reflecting investors' preference for liquidity: when the sentiment is optimistic, the discount rate Narrows or even turns into a premium. When sentiment is pessimistic, the discount rate expands [8].

The capital flow indicator quantifies the marginal changes in market sentiment by tracking the movements of main force funds and northbound funds. For instance, when the net outflow of main force funds in a single day exceeds 20 billion yuan, it is usually accompanied by an overreaction of the market to negative news (Wang et al., 2021). The advantage of this indicator lies in its ability to capture the emotional shifts of institutional investors, but it needs to be standardized in combination with market capacity. For instance, when the total market value is relatively low, a net outflow of 20 billion yuan may trigger greater fluctuations. When the total market capitalization is relatively high, the impact of the same scale of net outflow on volatility may weaken.

2.3 Construction of the Comprehensive Emotional Index

A single indicator is easily disturbed by specific events. The comprehensive index, through principal component analysis to extract common factors of multiple indicators, can more stably reflect the overall state of market sentiment. For instance, the comprehensive index constructed by a certain study using five variables such as turnover rate, proportion of margin purchase, and discount rate of closed-end funds shows that its correlation coefficient with the market volatility in the subsequent three months reaches 0.72, which is significantly higher than the predictive ability of a single indicator (Li et al., 2021). The index successfully captured the signal of a bottoming out and rebound in sentiment towards the end of the bear market in 2018, providing a basis for contrarian investment strategies.

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market in 2018, providing a basis for contrarian investment strategies.

3. Nonlinear Characteristics of Market Sentiment and Stock Price Fluctuations

3.1 Threshold Effect of Emotional Accumulation

The impact of emotions on stock price fluctuations is not continuous and gradual but exists at a critical point. When the composite sentiment index breaks through the 90th percentile of history, the market enters an "overly optimistic zone", at which point investor divergence intensifies - some believe it "can still rise", while others start to worry about "peaking". This kind of game intensification leads to a sudden increase in volatility, resulting in a transformation from "calm frenzy" to "sudden collapse". For instance, in 2015, within two weeks after the sentiment index of the A-share market reached its peak, the volatility of the Shanghai Composite Index jumped from 15% to 45%, confirming the existence of the threshold effect.

From the perspective of phase transition theory, investor sentiment has a "Curie temperature" similar to that of a magnet. When sentiment is below the critical value, rational investors dominate the market, and fluctuations mainly reflect changes in fundamentals. When emotions exceed the critical value, the proportion of noise traders rises, and their behavior of buying high and selling low amplifies price deviations, leading to non-linear growth in fluctuations. This mechanism explains why the same magnitude of emotional changes can lead to completely different fluctuation results at different market stages.

3.2 The Asymmetric Influence of Optimism and Pessimism

There are differences in the direction and intensity of the influence of optimism and pessimism on stock price fluctuations. In the early and middle stages of a bull market, optimism leads investors to become insensitive to negative news, interpreting underperformance as a "short-term disturbance". For instance, a company's financial report shows that its net profit has dropped by 10% year-on-year. During an optimistic period, its stock price only fell by 1%, but during a pessimistic period, similar news could lead to a 5% plunge. This passivation effect stems from investors' strong expectation of "trend continuation", which makes them ignore negative information.

Pessimism has the characteristic of "self-reinforcement". When a market decline triggers panic, investors, driven by a "loss aversion" mentality, accelerate their selling, causing prices to fall further and thereby intensifying the panic. During the global market crash in March 2020, the process by which the VIX index rose from 20 to 80 was accompanied by a negative feedback loop of "decline → panic → selling → further decline". This cycle causes the volatility to exhibit a "sharp peak and thick tail" feature, and the probability of extreme volatility events occurring is much higher than that under the normal distribution assumption.

3.3 Dynamic Transformation under Market Cycles

The relationship between emotions and fluctuations changes with the switching of market cycles. At the end of a bear market, investors are slow to respond to positive news, and a slight rebound in sentiment only leads to a small decline in volatility. For instance, at the beginning of 2019, favorable policies were frequently introduced, but due to the lingering trauma from the previous period, the market's volatility only dropped from 25% to 22%. In the early stage of a bull market, a few prescient players enter the market to drive the recovery of sentiment. At this time, market divergence decreases, and volatility gradually declines, forming a "positive synergy" of rising sentiment and falling volatility.

In the middle of a bull market, the spread of the profit-making effect leads to an optimistic mood, but at this time, volatility may rise due to the pressure of profit-taking. In the fourth quarter of 2014, after the sentiment index of the A-share market broke through the 70th percentile, the volatility rose from 12% to 20%, reflecting the dual impact of optimism and profit-taking. This cyclical dependence indicates that the correlation mechanism between sentiment and volatility is dynamically evolving and requires specific analysis in combination with market stages.

4. Nonlinear Associated Conduction Paths

Market sentiment exerts a nonlinear influence on stock price fluctuations by altering investors' cognitive patterns, trading behaviors and market structures. These paths interweave with each

other, forming a complex conduction network.

4.1 The Alienation Effect of Investors' Cognition

When emotions are high, investors tend to be overly confident and overestimate their information processing capabilities. This cognitive bias leads to the neglect of risk signals and the misjudgment of random fluctuations as the continuation of trends. For instance, in the later stage of the bull market in 2015, investors generally believed that "the state would not allow the stock market to fall". This collective cognitive distortion led the market's response to policy fine-tuning to shift from rational adjustment to panic selling.

When sentiment is low, investors fall into a dual predicament of "loss aversion" and "disposal effect". They tend to hold losing stocks to avoid realizing losses, while selling profitable stocks too early to lock in gains. This behavioral pattern leads to a stratification of market liquidity - loss-making stocks have exhausted liquidity while profitable stocks have excessive liquidity, further intensifying stock price fluctuations.

4.2 Feedback Distortion of Trading Behavior

Emotion-driven trading behavior has self-fulfilling characteristics. When most investors expect the market to rise, their buying behavior will drive up prices, thereby verifying the initial expectations. Conversely, collective selling under pessimistic expectations will trigger a price drop and intensify market panic. This positive feedback mechanism is particularly evident when emotions reach an extreme. For instance, during the four circuit breakers of the US stock market in March 2020, program trading and emotional selling resonated, causing the volatility index to double in a short period of time.

In addition, emotions can also change the way investors process information. In an optimistic mood, investors pay more attention to positive news and ignore negative ones. When in a pessimistic mood, one overreacts to negative information. This selective attention leads to market prices not fully reflecting all available information, resulting in "emotion-driven mispricing".

4.3 Accumulation of Vulnerability in Market Structure

Long-term optimism can lead to an increase in the fragility of the market structure. On the one hand, in a high valuation environment, enterprises expand leverage through means such as additional share issuance and mergers and acquisitions, increasing systemic risks. On the other hand, investors concentrate their holdings in pursuit of high returns, reducing market diversity. In 2015, the proportion of leveraged funds in the A-share market exceeded 15%, and the scale of off-exchange margin financing reached 2 trillion yuan. This structural imbalance poses a risk of liquidity depletion when market sentiment reverses.

Pessimism may trigger a "liquidity spiral". When investors collectively withdraw, the decline in asset prices leads to a shrinkage in the value of collateral, which in turn triggers forced liquidation and further depresses prices. This mechanism was particularly evident during the 2008 global financial crisis, when the bankruptcy of Lehman Brothers triggered a freeze in the credit market, creating a vicious cycle of "asset depreciation → deleveraging → further depreciation".

5. Conclusion

The nonlinear correlation mechanism between market sentiment and stock price fluctuations reveals the complexity of the operation of financial markets. The threshold effect of emotional accumulation, the asymmetric influence of optimism and pessimism, and the dynamic transformation under market cycles jointly constitute the core irrational factors influencing stock price fluctuations. The existence of these mechanisms has led to a significant decline in the predictive ability of traditional linear models in extreme market environments.

For regulators, it is necessary to establish a sentiment monitoring and early warning system and incorporate the comprehensive sentiment index into the macroprudential management framework. When the sentiment indicator exceeds the threshold, excessive fluctuations can be mitigated through measures such as counter-cyclical capital buffers and investor education. For investors, it is necessary to recognize the non-linear risks driven by emotions and avoid making irrational decisions when emotions reach an extreme. For instance, during periods of overheated emotions, the leverage level should be reduced, and during periods of low emotions, attention can be paid to

high-quality assets that have been wrongly sold off.

Future research can further explore the micro-mechanisms of emotion transmission, such as the investor decision-making process from a neuroscience perspective, or use big data technology to build more accurate emotion prediction models. At the same time, it is necessary to pay attention to the impact of social media on the dissemination of emotions in the digital economy era, as well as the interaction between algorithmic trading and emotional fluctuations. Understanding the non-linear correlation between market sentiment and stock price fluctuations is not only the key to improving investment performance but also an important guarantee for maintaining the stability of the financial market.

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