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Traders' behavioral coupling and market phase transition

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HIGHLIGHTS

- Investigate rare market event from the viewpoint of behavioral consensus of market traders.
- Give a mechanism of behavioral consensus: traders' behavioral coupling through "marking" the market index.
- Present three kinds of market phase transition: the degree of behavioral consensus, the correlation of returns of different stock, and the volatility of market index all vary discontinuously with the behavioral coupling strength parameter.

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ABSTRACT

Traditional economic theory is based on the assumption that traders are completely independent and rational; however, trading behavior in the real market is often coupled by various factors. This paper discusses behavioral coupling based on the stock index in the stock market, focusing on the convergence of traders' behavior, its effect on the correlation of stock returns and market volatility. We find that the behavioral consensus in the stock market, the correlation degree of stock returns, and the market volatility all exhibit significant phase transitions with stronger coupling.

1. Introduction

Traders in the Chinese stock market were shocked by the price swings on the first trading day of 2016 when the circuit breaker was triggered twice and trading halted until the stock market closed. In fact, the Chinese stock market experienced violent fluctuations from June 2015 to August 2015. Similar phenomena are not rare in the global stock markets. For example, the US stock market experienced a "flash crash" on May 6, 2010, when sell orders flocked, causing the Dow Jones Industrial Average (DJIA) to drop nearly 5% and at least 30 component stocks of the S&P 500 stock index to decline by 10% or more within 5 min [1]. Even earlier, on October 19, 1987 ("Black Monday"), the DJIA dropped approximately 22.6%.

Although these crashes may be in different forms, they have some common characteristics: first, the original heterogeneous trading behavior trends toward consensus, and sell orders become dominant [2]. This behavioral consensus causes the stock price to fall, or, more seriously, it causes "liquidity black holes" [3]. In fact, some researchers just regard market crash as an event arising from severe mismatch in liquidity [4,5]. Second, when the market is down, the individual stocks would have a higher positive correlation than the normal condition [6,7]. Third, the negative price returns further increase the future volatility, which is so-called leverage effect [8–10]. Reigneron et al. propose that the index leverage effect is stronger than individual stocks because the average correlation between stocks is increasing [11].

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Market crashes can definitely bring huge losses to investors and hit the market sentiment. Therefore, lots of researchers have tried to explore the causes of these stock market disasters and provided empirical or theoretical supports for this issue. According to the efficient market hypothesis, these crashes should be attributed to drastic exogenous fundamental shocks. However, Johansen et al. find that most crashes are associated with an endogenous origin rather than external shocks [12]. Because the exogenous reasons cannot give a persuasive explanation for such sudden systemic collapses of financial systems, some researchers turn to explore endogenous mechanism.

From some scholars' point of view, certain trading strategies are blamed for these crashes. For example, Yim et al. propose a double auction agent-based model and conclude that the strategy of chartists decreases the market stability [13]. Kim and Markowitz use an agent-based model to explore the source of the 1987 crash, and they find that the portfolio insurance strategies destabilize the market [14]. Fagiolo et al. find that high-frequency trading increases market volatility and generates flash crashes by either generating high bid–ask spreads or synchronizing on the sell side of the limit order book [15].

While other scholars give some behavioral or psychological explanations to these crashes. Sornette proposes that large market crashes are just as critical points in the statistical physics, and he emphasizes the positive feedbacks, i.e., self-reinforcement, lead to collective behavior, such as herding in sells during a financial crash [16]. Johansen et al. develop a rational expectation model to study the crash, and make a conclusion that the crash may be caused by the local self-reinforcing imitation among noise traders, which will lead traders to submit the same order(sell) [17]. Westerhoff develops a multi-agent model which contains fundamentalists and chartists, and he find that the chartists will be panic when the stock price drops sharply, then the selling pressure may cause a next panic and finally lead to a severe market crash [18].

In fact, these phenomena can be regarded as ''stampedes'' (escape panics) in the stock market, somewhat similar to the pedestrian crowds in panic [19,20]. In the situations of escape panics, the pedestrian would get nervous, they all tend to move faster to the exit when compared to the normal situations. And then the interactions among individuals become physical, they start pushing each other, causing jams and large pressure. The escape will slow down when the injured people forming obstacles [21–23]. Similarly, in the condition of market stress, the trading behavior tends to be highly homogeneous, which means the sell side order will be overwhelming. Meanwhile, the traders are more likely to submit the sell order with a lower price in order to ''escape'' the market quickly. Indeed, we think one of the origins of these phenomena is just traders' behavior are coupled together by the stock index itself. As a matter of fact, Shiller makes some questionnaire surveys to study investors' behavior around the crash of 1987. He finds that investors react to the market drops themselves rather than any other specific news [24]. Besides, we can easily observe that many intraday traders in the real stock market do care about the stock index fluctuation especially when the market drops a lot.

So in this paper we use agent-based modeling to test the impact of the market ups and downs on traders' behavior [25]. We emphasize the traders' behavior will converge spontaneously based on the idea that the traders all take the whole market quotation into account. At last, this behavioral consensus would lead to a bad market liquidity and a strong correlation among individual stocks. High correlation means the stocks tend to go up or down together, so it is inevitable that the market volatility or systematic risk would increase. This paper starts from the coupling behavior based on the stock index and considers how it affects the correlation of stock returns and market volatility. Revealing the mechanism of the behavioral consensus of the traders would be helpful to prevent such financial risks.

2. Market model

We use a multi-agent model based on the double auction mechanism to simulate transactions in a multi-asset market. We have some assumptions in our model:

(1) There are M stocks on the market, and we define a stock index weighted by share capital.

(2) N traders exist, and each trader only trades one stock. Because we do not want to consider the influence of asset portfolio, we assume that each agent chooses one kind of stock to trade randomly at the beginning and fix it in the whole simulation.

(3) Short-selling or margin-buying is not permitted, which means traders cannot sell stocks more than they hold, or submit bids more than they can afford.

(4) Each agent has one opportunity to submit an order in a single trading day, and the type of the order is limit order.

(5) The traders' decisions are equally spaced, and the potential transaction happens instantly.

(6) At the end of a trading day, the unsettled orders are canceled.

Note that some hypotheses in our model seem impractical (for example, one order at most in a single trading day, or equally spaced decision-making), but these assumptions simplify the model design [26] and have little influence on the qualitative conclusion of our concern.

2.1. Trading mechanism

On a typical trading day $t\,(t = 1, 2, \ldots, T)$, the trading sequence is randomly determined. Then agents take turns to submit order according to the determined sequence. Agent i chooses the type of order by the following formula:

$$z_i(\tau; t) = b\upsilon(\tau; t) + (1 - b)\upsilon_i(\tau; t) \tag{1}$$