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Evolving dynamics of trading behavior based on coordination game in complex networks

Yue-tang Bian [a,*], Lu Xu [b], Jin-sheng Li [a]

[a] School of Business, Nanjing Normal University, Nanjing, Jiangsu 210023, China

[b] Nanjing Institute of Railway Technology, Nanjing, Jiangsu 210031, China

HIGHLIGHTS

- The evolution model of trading behavior considering coordination game in network is proposed.
- The dynamical equations of evolution model by using the mean-field method are derived.
- The evolution of trading behavior is affected by its risk dominance degree and the network structure of the stock market.
- The greater the connectivity degree and the heterogeneity of the network, the more inclined of investors to choose the corresponding behavior.

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ABSTRACT

This work concerns the modeling of evolvement of trading behavior in stock markets. Based on the assumption of the investors' limited rationality, the evolution mechanism of trading behavior is modeled according to the investment strategy of coordination game in network, that investors are prone to imitate their neighbors' activity through comprehensive analysis on the risk dominance degree of certain investment behavior, the network topology of their relationship and its heterogeneity. We investigate by mean-field analysis and extensive simulations the evolution of investors' trading behavior in various typical networks under different risk dominance degree of investment behavior. Our results indicate that the evolution of investors' behavior is affected by the network structure of stock market and the effect of risk dominance degree of investment behavior; the stability of equilibrium states of investors' behavior dynamics is directly related with the risk dominance degree of some behavior; connectivity and heterogeneity of the network plays an important role in the evolution of the investment behavior in stock market.

1. Introduction

In behavioral finance literature, investors are considered to be limited rational, especially for the less sophisticated ones, who always attempt to mimic financial gurus or follow the activities of successful investors, since using their own information/knowledge might incur a higher cost [1]. The most typical example is that during the financial crisis, agents were rushed to sell shares in the same direction, leading the market behavior to herding critically. More imitation behavior among the investors is probe to result in herding behavior in financial market, as Nofsinger and Sias [2] note, "a group of investors trading in the same direction over a period of time", and introducing big fluctuations easily, particularly in bull

* Corresponding author.
E-mail address: nnubianyt@163.com (Y. Bian).

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or bear states. Therefore, mechanism of dynamic and herding behavior of stock markets has attracted much academic and industrial attention.

In recent years, there have been numerous empirical and theoretical studies on the herding behavior phenomenon. The literature about herding behavior phenomenon of stock markets can be classified into two categories. One category focuses on the empirical investigations of herding behavior in financial markets.

In Ref. [3], the authors conclude that the nature of herding differs across exchanges and is not universal. Specifically, in emerging markets investors exert herding patterns different from those in developed countries. Zhou and Lai [4] discover that herding activity in Hong Kong's market tends to be more prevalent with small stocks and that investors are more likely to herd when selling rather than buying stocks. In Ref. [5], Chiang and Zheng extend the investigation of herding behavior from domestic markets to global markets and find evidence of herding in advanced stock markets (except the USA) and in Asian markets. Turing to the Chinese markets, Demirer and Kutan [6] investigate whether investors in Chinese markets, in making their investment decisions, are following market consensus rather than private information during periods of market stress. Tan et al. [7] report that herding occurs under both rising and falling market conditions and is especially present in A-share investors. In all cases, herding behavior is proved to be a common state of stock behavior's evolving into.

The other one focuses on the evolution dynamics of trading behavior in financial market. By developing a Cellular Automata model of investment behavior in the stock market, Wei et al. find that increased imitation among investors leads to a less stable market [8]. In Ref. [9], Liang and Han find that evolvement of investors' trading behavior in stock market emerges most of stylized facts, such as clustered volatility, bubbles and crashes, in artificial stock market. By incorporating stock price into investor decisions, L. Bakker et al. construct a social network model of investment behavior in stock market and find that real life trust networks can significantly delay the stabilization of a market [10]. Chen et al. show that stock price bubbles or crashes are caused by synergy herding behavior through imitation agent and market sentiment signals [11]. Falbo and Grassi propose a market with two kinds of agents: speculators and rational investors to analyze the dynamics of a financial market when agents anticipate the occurrence of a correlation breakdown, and finds that the market equilibrium results depend on the prevalence of one of the two types of agents [12]. Consequently, it has a great important chance to study the evolvement of the trading behavior, for it affects the market critically and vice versa.

All the above-mentioned models and methods have captured some feature of investor trading behavior and its impact on the market, but most of the studies mainly focus on the macro level of trading behavior through quantitative analysis. This paper differs from previous research in the following respects. In this work, the evolution mechanism of individual investors' trading behavior and its collective dynamics is investigated from microscopic perspective by the theory and methods in the field of complexity science. Meanwhile, all traders around the world can be seen as a network organized from family, friends, colleagues, incorporated not only by the source of opinion but also the local influence among them [13]. We consider a network of interacting agents whose trading behavior is determined by the action of their peer neighbors, according to the payoff of using coordination game strategy. By means of mean-field approach and simulation analysis, the evolvement equilibrium of investors' trading behavior is analyzed and it crucially depends on two components: the connectivity distribution of the network and the risk dominance degree of a certain investment behavior, which play an important role in the stability of equilibrium states of investors' behavior dynamics.

The rest of the paper is organized as follows. In Section 2, we introduce the model and define the evolvement rules of investor's trading behavior. In Section 3, the evolvement characteristics of the trading behavior are presented by the method of mean-field equation. In Section 4, the comparison between analytic and simulation results is conducted. And the conclusion is drawn in Section 5.

2. The model

2.1. The network

Due to the difficulties of finding the relevant data to determine the network of exposures, financial network theory has been forced to either use important assumptions (like maximum entropy) or to resort to different theories and tools, like random graphs (see Ref. [13]) or scale-free networks (see Ref. [14]). Random graphs are important because most network formation models are based on variations of random graphs. On the other hand, scale-free networks are described in a simplistic way as networks in which the distribution of the nodes' degree follows a power law distribution. Scale-free networks are a popular subject of study as many of the well-known networks possess this property (for example, the WWW, Wikipedia and the citation networks).

Nature, society, and many technologies are sustained by numerous networks that are not only too important to fail but paradoxically for decades have also proved too complicated to understand [15]. Based on the viewpoint posted by Johansen and Sornette in Ref. [16], the evolution system of investors' behavior in stock markets can be described as a network, while nodes represent investors, the edges between every two nodes represent their relationship, such as, social relations, trade association, or something.

Consider a finite but large population of individuals $N = \{1, 2, \dots, i, n\}$. Each investor $i \in N$ interacts with a subset of the population which form a complex network $G = (N, V)$, where $(i, j) \in V$ means that i and j are linked in network. We consider undirected networks, i.e., if $(i, j) \in V$ then $(j, i) \in V$. Let N_i be the set of individuals with whom i is linked. Formally, $N_i = \{j \in N, s.t.\ (i, j) \in L\}$, where $k_i = |N_i|$ is the number of neighbors of i, often referred as his connectivity.