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Unveiling correlations between financial variables and topological metrics of trading networks: Evidence from a stock and its warrant

Ming-Xia Li [a,b,c], Zhi-Qiang Jiang [b,c], Wen-Jie Xie [a,b,c], Xiong Xiong [d,e,*], Wei Zhang [d,e], Wei-Xing Zhou [a,b,c,**]

[a] Department of Mathematics, School of Science, East China University of Science and Technology, Shanghai 200237, China
[b] Department of Finance, School of Business, East China University of Science and Technology, Shanghai 200237, China
[c] Research Center for Econophysics, East China University of Science and Technology, Shanghai 200237, China
[d] College of Management and Economics, Tianjin University, Tianjin 300072, China
[e] China Center for Social Computing and Analytics, Tianjin University, Tianjin 300072, China

HIGHLIGHTS

- We construct and investigate time series of security trading networks.
- Correlation relationships are uncovered between trading network metrics and financial variables.
- The structure of trading networks contains rich information about the dynamics of securities.

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ABSTRACT

Traders develop and adopt different trading strategies attempting to maximize their profits in financial markets. These trading strategies not only result in specific topological structures in trading networks, which connect the traders with the pairwise buy–sell relationships, but also have potential impacts on market dynamics. Here, we present a detailed analysis on how the market behaviors are correlated with the structures of traders in trading networks based on audit trail data for the Baosteel stock and its warrant at the transaction level from 22 August 2005 to 23 August 2006. In our investigation, we divide each trade day into 48 rolling time windows with a length of 5 min, construct a trading network within each window, and obtain a time series of over 11,600 trading networks. We find that there are strongly simultaneous correlations between the topological metrics (including network centralization, assortative index, and average path length) of trading networks that characterize the patterns of order execution and the financial variables (including return, volatility, intertrade duration, and trading volume) for the stock and its warrant. Our analysis may shed new lights on how the microscopic interactions between elements within complex system affect the system's performance.

* Corresponding author.
** Corresponding author at: Department of Mathematics, School of Science, East China University of Science and Technology, Shanghai 200237, China.
E-mail addresses: xxpeter@tju.edu.cn (X. Xiong), wxzhou@ecust.edu.cn (W.-X. Zhou).

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1. Introduction

Trading networks, in which the nodes represent the traders and the edges stand for the trading relationships, are much used to model the buy–sell interactions among traders in economic systems. Due to the availability of audit trail data at the transaction level, many effects have been put into the understanding of the topological characteristics of trading networks. Kyriakopoulos et al. find that the Austrian money flow trading network is disassortative and also exhibit low correlation between node degrees and transaction volume [1]. Tseng et al. also discover that the trading network in a web-based experimental prediction market is scale-free and disassortative. Jiang and Zhou reveal that the daily trading networks in Shenzhen stock market exhibit patterns of power-law degree distributions and disassortative architectures [2]. Tseng et al. uncover a power-law correlation between the average degree and the size of placed orders [3,4]. Wang et al. find that the trading networks in the Shanghai Futures Market exhibit similar features such as scale-free, small-world effect, hierarchical organization, and power-law betweenness distribution [5].

Trading networks provide an overall perspective to describe the detailed transactions between pairwise traders, which can be applied to find clues and propose approaches to track and detect the abnormal trades implemented by manipulators in financial markets. Kyriakopoulos et al. report that the random matrix analysis is able to identify accounts with financial misconduct [1]. Tumminello et al. identify clusters of traders with a very high degree of synchronization in trading [6], which probably is also related to price manipulation. By investigating the trading networks of manipulated and non-manipulated stocks in the Shanghai stock market, Sun et al. observe significant differences in the topological properties between manipulated and non-manipulated stocks [7,8]. Jiang et al. find that the abnormal trading motifs (self-loop, two-node loop, and two-node multiple arcs) in trading networks have connections with turbulent market dynamics and can be adopted to develop novel tools for the detection of trade-based price manipulations [9]. Sun et al. also find that trading networks predict stock price movements at the daily level [10].

Trading networks are formed based on the transactions triggered by traders with different trading strategies, which provide two perspectives to understand the trading behaviors of traders. On the one hand, the successful strategies can be followed and copied by other traders and the traders with correlated strategies will lead to similarity both in returns and positions in trading networks. Cohen et al. report that traders' returns are correlated with their positions occupied in the trading networks [11]. They also find that the market shocks at the individual level can be widely transmitted and greatly amplified through the links of trading networks. On the other hand, the specific trading strategies of traders may lead to specific local structures in trading networks and also have some influences on market behaviors. Adamic et al. explore the trading networks constructed from the September 2009 E-mini S&P 500 futures contracts and found that there are contemporaneously correlated relationships between network metrics (centralization, assortative index and average path length) and financial variables (return, volatility, intertrade duration, and trading volume) [12].

In this paper, we follow Ref. [12] to investigate correlations between financial variables and topological metrics of trading networks of a liquid Chinese stock and its warrant. The remaining part of this paper is organized as follows. In Section 2, we briefly describe the data sets we adopt. Sections 3 and 4 define respectively the topological metrics of trading networks and the financial variables investigated in this work. The correlations between financial variables and topological metrics of trading networks are presented in Section 5. We summarize our findings in Section 6.

2. Data sets

We employ a transaction-level database, which contains the actual trades completed on the Shanghai Stock Exchange for stock Baosteel and its warrant, to uncover the potential connection between the equities' behaviors and the topological structures of trading networks. The Shanghai securities market is a pure order-driven market and the observed trades are triggered by matching the market orders or executable limit orders with the orders sitting on the opposite side of limit order book, which is a waiting queue of limit orders sorted by price and time priority. There are totally 3,779,538 transactions for stock Baosteel and 25,483,344 transactions for its warrant during our sampling period from 22 August 2005 to 23 August 2006, covering 243 trading days. Each transaction contains the following information: a unique transaction ID, two unique trader IDs, the trading time, the trade size, the transaction price, and an indicator of buy or sell. We note that the stock (warrant) is traded according to the $T + 1$ ($T + 0$) rule.

3. Trading network metrics

In this section, we describe briefly the construction of trading networks and show several examples of randomly chosen trading networks for the stock and its warrant. Then, five topological metrics based on network centralization, assortative index, and average path length are adopted to quantitatively characterize the structure of each trading network. We further provide explicit definitions of the network metrics, illustrate these time series, and investigate their basic statistics.

3.1. Construction of trading networks

For both securities, we divide each trading day into 48 time windows with an interval of 5 min. In each window, the transaction records are translated into one trading network, in which the nodes represent the traders and the links weighted