Physica A 387 (2008) 6605–6612

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Herd behavior in weight-driven information spreading models for financial market

Soon-Hyung Yook *, Yup Kim

Department of Physics and Research Institute for Basic Sciences, Kyung Hee University, Seoul 130-701, Republic of Korea

ARTICLE INFO

Article history:
Received 11 July 2008
Available online 8 August 2008

PACS:
89.65.-s
89.65.Gh
87.23.Ge
02.50.Le

Keywords:
Econophysics

ABSTRACT

We study two weight-driven information spreading models for financial market. In these models, we find that the activity threshold below which the 'financial crash' occurs can be increased by uneven distribution of information weight, compared with Eguíluz and Zimmermann model [V.M. Eguíluz, M.G. Zimmermann, Phys. Rev. Lett. 85 (2000) 5659]. We also find that below the threshold the normalized return distribution, $P(Z; \Delta t)$ satisfies $P(Z = 0; \Delta t) \sim \exp(-\Delta t/b)$ whereas $P(Z = 0; \Delta t) \sim \Delta t^{-\tau}$ above the threshold. Here Δt is the time interval where the normalized return is defined, $Z(t, \Delta t) = Z(t+\Delta t)-Z(t)$. By approximating the relative increase of $P(Z; \Delta t = 1)$ for large Z as Gaussian distribution with non-zero mean, we show that the non-zero mean of the Gaussian distribution can cause such exponentially decaying behavior of $P(Z = 0; \Delta t)$.

1. Introduction

The analysis of financial systems using standard methods developed in physics has a long tradition [1] and has recently been one of the active research areas in physics [2]. Much of the research interest of physicists has been mainly focused on the analysis of stock markets [2,3] and foreign exchange markets [4] due to the large amount of accessible data. Among those empirical studies, the most remarkable finding is that many different markets share universal properties. For example, the fat-tailed distribution of returns [2,3,5], long-term volatility correlation [2,6,7] and herding behavior [8,9] have been observed in many different markets [3–5,10–14]. The existence of such universal nature in many different markets is striking and suggests that those markets should be governed by the similar underlying mechanisms. In order to investigate the universal phenomena observed in many real markets, many microscopic models such as percolation model [8] and Ising-like spin models [15] have been developed.

Among those studies, Eguíluz and Zimmermann (EZ) recently proposed an interesting model to investigate the relationship between the transmission of information and herding behavior [9]. In EZ model, groups of agents are dynamically formed by random dispersion of information. The agents in the same group make the same decision for trading activity which cause the herding behavior. EZ showed that when the information dispersion is slower than the trading activity the return distribution follows a power-law. On the other hand, if the information dispersion is much faster than the trading activity then the relative increase in the distribution of extremely high return is observed. This relative increase of return distribution is known to be related to the *financial crashes* [9,13,14]. As shall be seen in Section 2 we indeed find that the relative increase in the return distribution is observed during the 9.11 crash. This implies that the information dispersion rate plays a very important role in the market dynamics.

Although the EZ model succeeded to explain many interesting features of the financial market, there are still many important factors which are not reflected in the model. In particular, the "*value*" or "*weight*" of information that each agent

* Corresponding author. Tel.: +82 2 961 0253; fax: +82 2 957 8408.
E-mail addresses: syook@khu.ac.kr (S.-H. Yook), ykim@khu.ac.kr (Y. Kim).

0378-4371/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.physa.2008.08.009

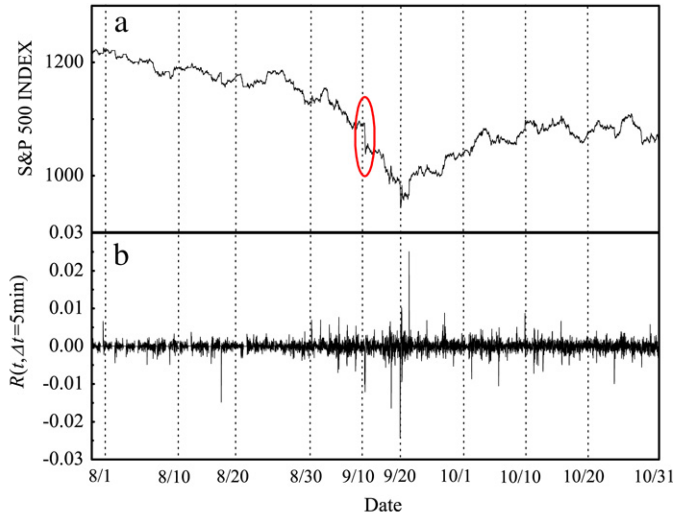

Fig. 1. (a) Change of S&P 500 index during the 9.11 crash period. The circle denotes September 11. (b) $R(t, \Delta t = 5 \text{ min})$ of S&P 500 index for the same period.

has should be different from agent to agent in real markets. A certain piece of information is more important than the others. Moreover, the value of information can be changed with time by combining with other piece of information. The cooperation between agents or individuals should be affected by the value of the information to maximize their profit. In order to investigate the effects of different weights of information, we assume that the profit is proportional to the weight of information for simplicity. Based on this assumption, we introduce two weight-driven information spreading models. One has time independent weight of information. The other one has dynamically changing weight as a result of synergetic cooperation among the agents. From the numerical simulations, we find that the financial crash can occur with higher activity rate compared to EZ model. We also suggest a novel criterion to determine activity threshold below which the financial crash occurs by analyzing the return distribution.

This paper is organized as follows. In Section 2 we provide empirical measurement of return distribution during financial crash. In Section 3 two information spreading models are introduced. And the simulation results are given Section 4. Summary and discussions are presented in the last section.

2. S&P500 index

The financial crashes in stock markets are usually defined by the striking drops of index or price of all stocks [16]. One of recent market crashes has been reported in September 11, 2001 which is known as 9.11 crash. Fig. 1(a) shows the 5-min change of Standards and Poor's (S&P) 500 index from August 1 to October 30 in 2001. The circle indicates the change of index on September 11. The data shows the index starts to decrease from the end of August and reaches the minimum around September 20. Then the rally period begins and the index becomes stable after October 10. For a time series $p(t)$ of price or index value, the logarithmic return (or simply return) over integer time interval Δt, $R(t, \Delta t)$, and the normalized return $Z(t, \Delta t)$ are defined as

$$R(t, \Delta t) = \ln[p(t)] - \ln[p(t - \Delta t)], 0 \tag{1}$$

and

$$Z(t, \Delta t) = \frac{R(t, \Delta t) - \langle R(t, \Delta t)\rangle}{\sigma}, \tag{2}$$

respectively. Here σ is the volatility, $\sigma = \left(\left\langle R(t, \Delta t)^2\right\rangle - \langle R(t, \Delta t)\rangle^2\right)^{1/2}$ and $\langle\cdots\rangle$ denotes the average over time. The logarithmic return in the same period, $R(t, \Delta t = 5 \text{ min})$, is also displayed in Fig. 1(b). As shown in the data, the amplitude of $R(t, \Delta t = 5 \text{ min})$ suddenly increases from the end of August (Fig. 1(b)). Although the financial crash is sometimes observed when the return distribution follows the Gaussian distribution [14], several studies have pointed out the possibility that the return distribution becomes asymmetric when the crash occurs [13] and deviates from the Lévy distribution [13,14]. From the data in Fig. 1 we find a very interesting result. Fig. 2 shows $P(|Z|)$ measured from the data in Fig. 1. The obtained $P(|Z|)$ has two distinctive regimes. When $|Z|$ is small ($|Z| < 0.05$), $P(|Z|)$ monotonically decreases. If we approximate the data to a power-law distribution in this regime, then we obtain $P(|Z|) \sim |Z|^{-1.7}$ (dashed line in Fig. 2). In the large $|Z|$ regime $P(|Z|)$ shows an explicit bump which can be approximated by the Gaussian distribution with a non-zero mean (solid line in Fig. 2). Thus, we expect that $P(|Z|)$ during the 9.11 crash can be regarded as a combination of monotonically decreasing power-law-like distribution and Gaussian distribution which has non-zero mean. (The detailed analysis for this kind of financial crash