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Effect of trading momentum and price resistance on stock market dynamics: a Glauber Monte Carlo simulation

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Abstract

A Monte Carlo computer simulation model is presented to study the evolution of stock price and the distribution of price fluctuation. The resistance is described by an elastic energy $E_e = e \cdot x^2$ resulting from the price deviation x from an initial value and the momentum trading by the potential energy $E_p = -b \cdot y$ in a price gradient y field. The distribution of price fluctuation ($P(y)$) is symmetric and shows a long time tail compatible over some range with a power-law, $P(y) \sim y^{-\mu}$ with $\mu \simeq 4$ at $e = 1.0$, $b = 5$. The volatility auto-correlation function ($c(\tau)$) is positive for several iterations. © 2001 Elsevier Science B.V. All rights reserved.

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Studying stock markets by computer simulation models has attracted a considerable interest in recent years [1–4]. In some models, it is assumed that the trading is executed in groups with a size distribution similar to cluster size in percolation [5–8] which seem to provide a reasonable agreement with the power-law distribution of short-time market fluctuations. The trend in the distribution of price fluctuation seem to be one of the important indicators in risk assessment of various derivatives particularly in *predicting*

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bubbles and crashes [9–11]. For example, a theoretical prediction has been recently proposed for the Japanese stock market with a log-periodic fits [12–15] of the pattern over a decade of years just after the crash. Unlike the model systems in physics, it is difficult to develop a self-consistent model based on the first principle. Therefore, it is desirable to develop and explore models that incorporate some basic characteristics of market.

In stock trading, the price variation depends on two general factors among numerous parameters/conditions characterizing the market conditions: the resistance in the price deviation from an initial (or appropriate mean) price and the herding nature of trade [16] (due to adequate knowledge, favorable or adverse, or lack of it). In a recent communication [17], we modeled the price resistance by the generalized elastic probability and the momentum or inertial trading probability by a price gradient with corresponding coefficients. It would be interesting to explore how the stock price responds if we model the price resistance and the momentum trading by appropriate energies such as elastic energy and the potential energy in a gradient field. This may allow us to apply the Boltzmann-like distribution, Glauber dynamics in particular (see below) to use energy as an input variable to evaluate the trade probability. In fact, a similar attempt has been recently made by Ponzi and Aizawa [18] that we noticed after this work was under way.

Trades are executed in groups where trading is performed via the herding percolation model [5–8]. We concentrate here on the random sequential group trading. In herding, all traders in a group (cluster) sell together or buy together which drives the price up or down proportionally to the number of traders in the group. Since the number (n_s) of groups (clusters) depend on the size of the group, i.e., the number of traders (s), by a power-law at the percolation threshold,

$$n_s = N/s^{\tau} , \tag{1}$$

where N is the size of the market and $\tau = 2.5$. This group distribution is used by Chowdhury and Stauffer [6] and we will use it also in our group trading. At each time step $t = 1, 2, 3, \ldots$, traders buy with probability $a/2$, sell with probability $a/2$ and are inactive with probability $1 - a$.

Let us define a trading energy

$$E = e \cdot x \cdot |x| - b \cdot y , \tag{2}$$

where $x = (p(t) - p(0))/x_m$, $y = (p(t+1) - p(t))/y_m$ with the stock price at time t, $p(t)$, and x_m and y_m are the maximum absolute values up to the current time step. e and b are elastic and momentum bias coefficients. We use Glauber dynamics for the probability to execute the trade. Since this is a complex non-equilibrium system, we assume (based on our empirical observation of the data trend) that the energy described by Eq. (2) is appropriate. The first term leads to rational or conservative trading. The second term describes the momentum trading, i.e., market hysteria, when trading is done with the trend regardless of profit or loss. Thus, the method consists of selecting the activity a to trade i.e., no trade is made with probability $1 - a$. If instead a trade is made, then we buy with probability W_b and sell with probability $W_s = 1 - W_b$, where

$$W_b = \mathrm{e}^{-E}/[1 + \mathrm{e}^{-E}] . \tag{3}$$