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Open dynamic behaviour of financial markets

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Abstract. Open dynamic behaviour of financial markets with internal interactions between agents and with external "fields" from other systems are investigated using the approach of Grossman and Stiglitz for inefficient markets, and Keynes for interference of the market using physics of finance (referred to hereafter as phynance). The simulation results indicate that the NYSE data analyzed in Plerou, V. et al., Nature **421**, 130 (2003) can be fitted by an equation of order parameter Φ and local deviation R of type: $-(R+0.03)\ \Phi + 0.6\,\Phi^3 + 0.02 = 0$, which is shown to be in *remarkable* agreement with Plerou's data.

PACS. 89.65.Gh Economics; econophysics, financial markets, business and management – 87.23.Ge Dynamics of social systems – 05.45.-a Nonlinear dynamics and chaos (see also section 45 Classical mechanics of discrete systems; for chaos in fluid dynamics, see 47.52.-j) – 89.75.Fb Structures and organization in complex systems

Financial markets are known to be complex systems [1–9]. Their dynamic behaviour attracts the attention of researchers in physics. This new frontier discipline, lying within the domain of physics, can be called the physics of finance (short form "phynance"). Empirical and theoretical studies on closed financial markets have been carried out using various methods [10–21] so as to understand their behaviours well in order to make a profit, although the efficient market hypothesis [22] prevalent in economics implies that the long-term average return is zero. Recently, the two-phase behaviour of financial markets has been demonstrated [23], in which the positions of the maxima of the conditional distribution are defined to be the value of order parameter Φ. This indicates that the efficient market hypothesis faces a challenge [1–25].

In accordance with Grossman and Stiglitz [24] for inefficient financial markets and Keynes [25] for interference of financial markets, a dynamic model of an open, interfered financial market with internal interactions between agents and with an external "field" from other systems is proposed. The evolution of the financial market is then studied, which deviated from Walrasian equilibrium. Finally the simulation results according to the model compared with the analyzed data of the NYSE from reference [23].

In this paper, the financial market is assumed to be an open complex system with internal and external interactions. Thus the critical behaviours can be determined by the generalized potential function $F(\Phi,\ R)$ if the order parameter $\Phi = \Phi(R)$ is small and uniform when local deviation R of demand is near critical local deviation R_c, where R_c is a critical threshold of local noise intensity R of demand. R_c is related to a critical point for transition. The order parameter Φ reflects the ordering degree of the system during transition, and is given by the value of the maxima of the volume imbalance between the number of shares traded in buyer- and seller-initiated transactions within a short time interval of the conditional distribution. Furthermore, we should also consider the interactions between the order parameter Φ and the external "field" h (e.g. interference from other system(s), such as, management, regulations, and laws) for this open system.

The generalized potential function $F(\Phi,\ R)$ is thus written as:

$$F(\Phi, R) = F(0,0) + (a(R-R_c)/2!)\,\Phi^2 + (b/4!)\,\Phi^4 + Nh\Phi \quad (1)$$

where a and b are coefficients, N are the transaction volumes, and $F(0,\ 0)$ is the constant generalized potential function for $\Phi = 0$ and $R = 0$. Generally coefficient a is less than zero in a financial market.

The manifold can then be determined from equation (1) as

$$a(R-R_c)\Phi + (b/3!)\,\Phi^3 + Nh = 0. \quad (2)$$

The analyzed data quoted from reference [23] of the Trade and Quote database of the 116 most actively traded stocks in the two-year period 1994–1995 published by the New York Stock Exchange is simulated according to equation (2), as shown in Figure 1. The simulation results

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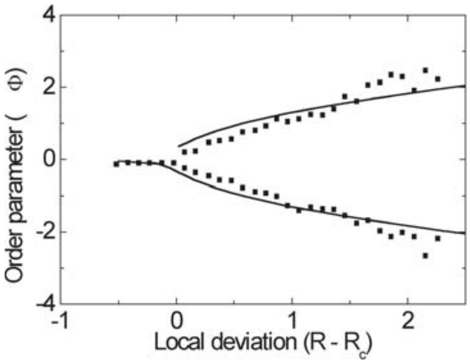

Fig. 1. Local deviation $(R-R_c)$ dependence of order parameter Φ according to equation (2). The value of order parameter Φ is defined to be the positions of the maxima of the conditional distribution. Local deviation R of demand is near critical local deviation R_c, where R_c is a critical threshold of local noise intensity R of demand. Solid lines are drawn from equation: $-(R+0.03)\Phi+0.6\Phi^3+0.02=0$, where $a=-1$, $R_c=-0.03$, $b/3!=0.6$, and $Nh=0.02$ in equation (2). Note that solid square points are the analyzed data quoted from reference [23].

indicate that the data analyzed in reference [23] can be fitted by the following equation:

$$-(R+0.03)\,\Phi+0.6\,\Phi^3+0.02=0,$$

where $a=-1$, $Rc=-0.03$, $b/3!=0.6$, and $Nh=0.02$ in equation (2). In addition, the lack of pro-zero value in the empirical data for the positive local deviation $R-R_c$ may be explained as being due to its metastable state, and the insufficient resolution from the distribution and/or the inadequate period of years.

The simulated results are *extremely* satisfactory, as shown in Figure 1. The evolution of the financial market of the NYSE demonstrates a bifurcation. Hence it can be deduced that there are both internal interactions and external "fields" in this real financial market, which indicate that the efficient market hypothesis cannot be satisfied. These kinds of correlations verify the viewpoint of Grossman and Stiglitz [24]. Therefore this real financial market, that is, the NYSE, should be regarded as an open complex system.

Note that the data analyzed in [23] for the negative local deviation $R-R_c$ is not exactly zero. Therefore Nh is not zero. This implies that the parameter h can be used to interfere in the dynamic behaviours of financial markets, just as Keynes' viewpoint [25]. Consequently it provides another possibility to quantitatively study the effect of management. Furthermore, the bifurcation behaviour implies that the concepts of mean value and variance are invalid. The homogeneous microstructures of financial markets can exhibit bifurcation while the heterogeneous microstructures of financial markets can display multifurcation during evolution. Thus the two-phase behaviour of financial markets [23] is due to the evolution of homogeneous financial markets. Moreover, multiple-phase behaviour of financial markets can also be predicted for the evolution of heterogeneous financial markets. Further studies will be published elsewhere.

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