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Grafting of higher-order correlations of real financial markets into herding models

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ABSTRACT

In this work, we graft the volatility clustering observed in empirical financial time series into the Equiluz and Zimmermann (EZ) model, which was introduced to reproduce the herding behaviors of a financial time series. The original EZ model failed to reproduce the empirically observed power-law exponents of real financial data. The EZ model ordinarily produces a more fat-tailed distribution compared to real data, and a long-range correlation of absolute returns that underlie the volatility clustering. As it is not appropriate to capture the empirically observed correlations in a modified EZ model, we apply a sorting method to incorporate the nonlinear correlation structure of a real financial time series into the generated returns. By doing so, we observe that the slow convergence of distribution of returns is well established for returns generated from the EZ model and its modified version. It is also found that the modified EZ model leads to a less fat-tailed distribution.

1. Introduction

Fluctuations are very interesting to physicists as macroscopic observation provides many clues about the microscopic structure of a system, which is composed of many constituents. According to the critical phenomena, when a system is placed in a critical state, even a minute shock can change the structure of the whole system. This critical transition is often observed in financial markets. When the national economy or the global economy becomes unstable, a mere rumor can induce collective behavior that can lead the whole economic system into a situation such as a market crash. For this reason it is imperative to understand market dynamics. Thus far, numerous models have been proposed to reproduce the so-called stylized facts [1,2], such as a fat-tailed distribution of returns, long-range correlation of absolute returns, volatility clustering, the two-phase phenomenon, etc. Among these models, agent-based models are the most realistic, because they incorporate a mechanism for decision-making by traders into the market dynamics model. In virtual terms, a financial market is composed of thinking atoms, for example, agents, and they are, in a very complicated manner, interwoven via various portfolios and investment strategies. This accounts for the extreme complexity of price fluctuations.

The goal of this work is to graft empirically observed facts into a model, which is specified for a few of the many stylized facts. To this end, we examine two financial databases that are quoted min-by-min and daily, respectively, for the KOSPI 200 index and KRW-USD exchanges. First, the KOSPI 200 is a composite index of 200 stocks, which are selected for index-based

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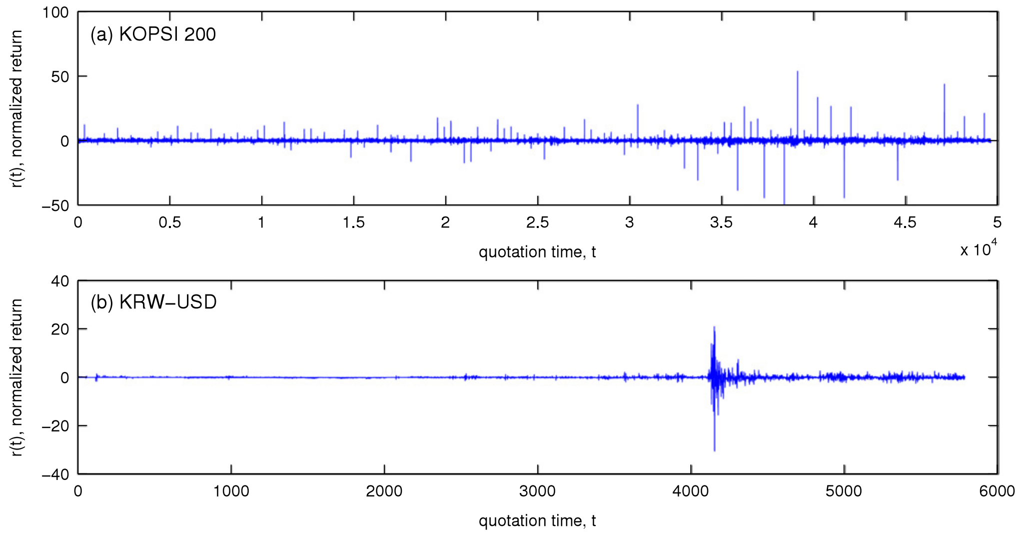

Fig. 1. Normalized returns are presented for the (a) KOSPI 200 index, and (b) KRW-USD exchanges. The volatile fluctuations observed in (b) are due to the Asian financial crisis in 1997.

derivatives, such as futures and options, and covers the period from March through October of 2004. KRW-USD exchanges cover the period from 1981 through 2004. From these databases, we extract the nonlinear temporal correlations and graft them onto the time series generated from an EZ model. Furthermore, for comparison, we present a modified EZ model that incorporates the sustaining of activated clusters. This modification leads to a less fat-tailed cumulative distribution.

The organization of this paper is as follows. In the following section, some stylized facts of our databases, such as the fat-tailed distribution of returns and long-range correlation of absolute returns, are presented. The effects of nonlinear correlation between price fluctuations on the slow decay to a Gaussian distribution are examined in terms of scaling of the moments [3]. In Section 3, a brief description of a pure EZ model is presented and a modified version is proposed, and numerical results are given. Section 4 presents concluding remarks.

2. Empirical analysis of financial time series

For the analysis, we define the return

$$R(t, \Delta t) \equiv \log P(t + \Delta t) - \log P(t), \tag{1}$$

where Δt is the lag time, in order to avoid differences in magnitudes of price fluctuations, we take the normalized return, $r(t, \Delta t)$ as

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

where $\sigma(t)$ is the standard deviation of returns $R(t, \Delta t)$. In following sections, when we compute moments over different lag times, we take the quotation time t not to be overlapped in order to avoid a short-range correlation. Fig. 1 shows price fluctuations of both time series.

2.1. Distribution of returns

Fig. 2 shows the positive/negative complementary cumulative distribution functions of returns $r(t, \Delta t)$ for $\Delta t = 1$ min for KOSPI 200, and for $\Delta t = 1$ day for KRW-USD. Now, we examine how the nature of the distribution of returns with an increasing time scale Δt changes. As shown in Fig. 2, the central regime of returns shows a power-law form belonging to the stable Levy regime $0 < \alpha < 2$ while the tails extend outside the Levy regime, i.e., it resembles a truncated Levy distribution. Therefore, it is significant to find the onset of convergence to Gaussian behavior by increasing the time scale Δt. In Fig. 3, we show that the KOSPI 200 index sustains its functional form of distribution of returns, from 1 min up to, at least, 100 min. For further long time scales, the finite size of the database restricts the reliability of results. In the following, we examine the convergence to Gaussian behavior in terms of scaling of moments. For time scales $\Delta t \gg 1$ day, we use the KRW-USD