

# Herd Behaviors in the Stock and Foreign Exchange Markets

Kyungsik Kim,<sup>\*</sup> Seong-Min Yoon<sup>†</sup>, and Yup Kim<sup>‡</sup>

<sup>\*</sup> *Department of Physics, Pukyong National University,  
Pusan 608-737, Korea*

<sup>†</sup> *Division of Economics, Pukyong National University,  
Pusan 608-737, Korea*

<sup>‡</sup> *Department of Physics and Research Institute for Basic Sciences,  
Kyung-Hee University, Seoul 130-701,  
and Asia Pacific Center for Theoretical Physics, Seoul, Korea*

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The herd behaviors of returns for the won-dollar exchange rate and the KOSPI are analyzed in Korean financial markets. It is shown that the probability distribution  $P(R)$  of price returns  $R$  for three values of the herding parameter tends to a power-law behavior  $P(R) \simeq R^{-\beta}$  with the exponents  $\beta = 2.2$ (the won-dollar exchange rate) and 2.4(the KOSPI). The financial crashes are found to occur at  $h > 2.33$  when the relative increase in the probability distribution of extremely high price returns is observed. Especially, the distribution of normalized returns shows a crossover to a Gaussian distribution for the time step  $\Delta t = 252$ . Our results will be also compared to the other well-known analyses.

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## I. INTRODUCTION

There have been considerable interests[1 – 3] in the microscopic models for the financial markets. The major models which are based on the self-organized phenomena are the herding multiagent model[4, 5] and the related percolation models[6, 7], the democracy and dictatorship model[8], self-organized dynamical model[9], the cut and paste model, the fragmentation and coagulation model[10]. It has been well-known that one of very important microscopic models is the herding model[11, 12], in which some degrees of coordination among a group of agents share the same information or the same rumor and make a common decision in order to create and produce the returns. Recently, a theoretical model[5] for the herding behavior has been suggested. In this model the probability distribution of returns shows a power-law behavior for varying values smaller than a critical herding parameter value, while an relative increase in the probability of large returns is observed in the region of financial crashes for the herding parameter larger than the critical value. In particular, the distribution of normalized returns has the form of the fat-tailed distributions[13] and a crossover toward the Gaussian distribution can be shown in financial markets.

On the other hand, the theoretical models and numerical analyses for the volume of bond futures transacted at Korean futures exchange market were presented in the previous work[14]. In that work we mainly considered the number of transactions for two different delivery dates and found the decay functions for survival

probabilities[15, 16] in our analyses of bond futures. We also studied the tick dynamical behavior of the bond futures price using the range over standard deviation or the R/S analysis in Korean futures exchange market[17]. The recent work[18] on Norwegian and US stock markets has shown that there exists the notable persistence caused by long-memory in the time series. The numerical analyses based on multifractal Hurst exponent and the height-height correlation function have also been used mainly for the long-run memory effects. It was particularly shown that the form of the probability distribution of the normalized return leads to the Lorentz distribution rather than the Gaussian distribution[17].

The purpose of this paper is to study the dynamical herding behavior for the won-dollar exchange rate and the KOSPI(Korean stock price index) in Korean financial markets. In section 2 the financial crashes and the distribution of normalized returns for the tick data of two different delivery dates are analyzed numerically. The results and conclusions are given in the final section.

## II. FINANCIAL CRASHES AND SIMULATIONS

In our analyses, we introduce the won-dollar exchange rate and the KOSPI in Korean financial markets. In this paper, we only consider two delivery dates: The tick data for the won-dollar exchange rate were taken from April 1981 to December 2002, while we used the tick data of the KOSPI transacted for 23 years from April 1981. We show the time series of the won-dollar exchange rate  $P(t)$  in Fig.1, and the price return  $R_\tau(t)$  is defined as

$$R_\tau(t) = \ln \frac{P(t+\tau)}{P(t)}, \quad (1)$$

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\*Electronic address: Kskim@pknu.ac.kr ; fax:+82-51-611-6357

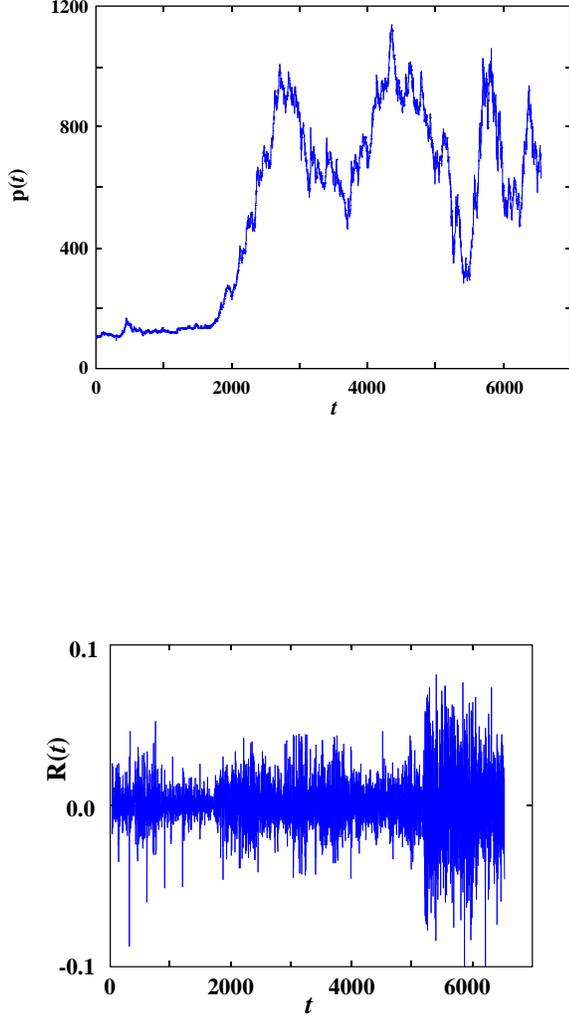


FIG. 2: Plot of the price return  $R_{\tau=1}(t) = \ln[P(t + \tau) - P(t)] / P(t)$  for the KOSPI.

where  $\tau$  denotes the time interval. Our average between ticks is about one day in two types of data, as shown in Fig.1 and 2. From now on, i to describe the averaged distribution of cluster, consider three return states composed by  $N$  agent the continuous tick data of the won-dollar exchange and the KOSPI. From the states of agent  $l$  compute the three states  $\psi_l = \{-1, 0, 1\}$ , the state of cluster given by

$$s(t) = \sum_{l=1}^N \psi_l,$$

where  $\psi_l = 0$  is the waiting state that occurs no transactions or gets no return and  $\psi_l = 1$  ( $\psi_l = -1$ ) is the (buying) states, i.e., the active states of the transaction. Assuming that it belongs to the same cluster between group of agents sharing the same information and

making a common decision, the active states of transaction can be represented by vertices in a network having links of time series. Since the distribution of returns is directly related to the distribution of clusters, the averaged distribution of cluster  $P(s)$  scales as a power law

$$P(s) \simeq |s|^{-\alpha} \quad (3)$$

with the scaling exponent  $\alpha$ . Fig.3 in our model presents the log-log plot of the averaged distribution of cluster against the sizes  $|s|$  of the transacted states from tick data of the KOSPI and the scaling exponents are found to take  $\alpha = 7.68$  (the won-dollar exchange rate) and  $5.72$  (the KOSPI), remarkably different from theoretical and numerical results [4, 5]. To find the distribution of the price return  $R$  for different herding probabilities, the herding parameter of the network of agents can be estimated from  $P(\psi_l = +1, -1) = a = a_+ + a_-$ , where  $P(\psi_l = +1) = a_+$  and  $P(\psi_l = -1) = a_-$  are, respectively, the probability of the selling and buying herd. By introducing  $h \equiv \frac{1-a}{a}$  as the herding parameter that stands for a measure of the herd behaviors, the active herding behavior is observed for  $h > 0$  ( $a < 1$ ), while no herding behavior takes place for  $h = 0$  ( $a = 1$ ). When we perform the simulation of  $P(R)$ , the herding parameter is incorporated into the price return, whose elements are the random numbers generated from the real data in Fig.2.

The probability distribution of returns  $P(R)$  for three herding parameters satisfies the power law

$$P(R) \simeq R^{-\beta} \quad (4)$$

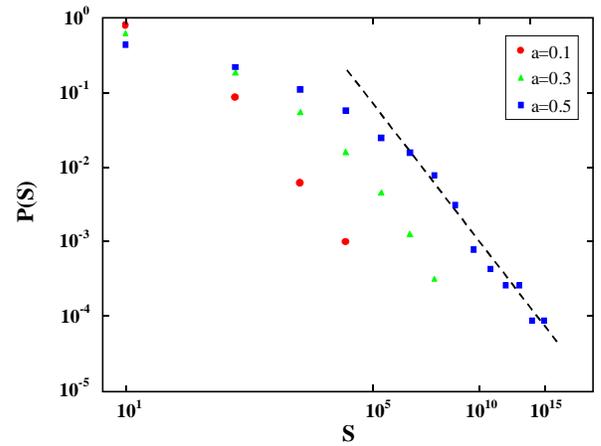


FIG. 3: Plot of the averaged probability distribution of cluster sizes  $|s|$  for the herding probability  $a = 0.5$  ( $h = 1$ ), where the averaged probability distributions for the KOSPI scales as a power law  $|s|^{-\alpha}$  with the exponent  $\alpha = 5.72$  (the dot line).

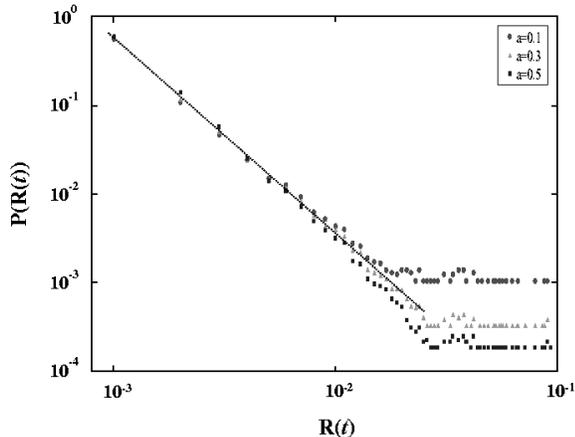


FIG. 4: Log-log plot of the probability distribution of returns for three types of herding probabilities  $a = 0.1, 0.3, 0.5$  ( $h = 9, 2.33, 1$ ), where the dot line scales as a power law  $R^{-\beta}$  with the exponent  $\beta = 2.2$  for the won-dollar exchange rate.

that the financial crashes occur at  $a < 0.3$  ( $h > 2.33$ ). Thus the probability of extremely high returns appears to increase in the crash regime, since the states of the transaction exists to decrease for  $h > h^*$ . Next we calculate the distribution of normalized returns. Since the statistical quantity  $\langle R \rangle$  is the value of returns av-

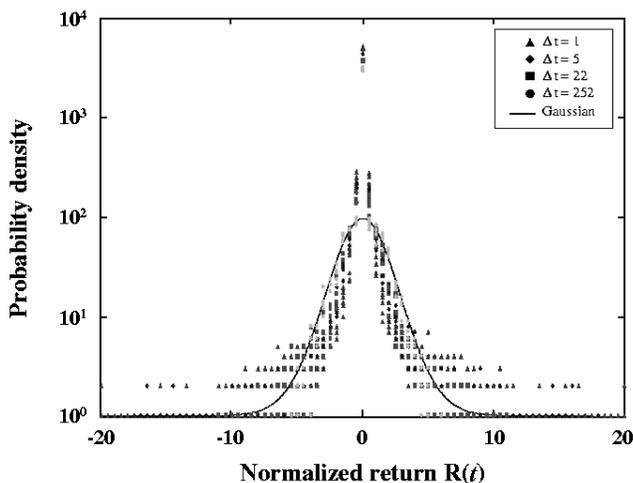


FIG. 5: Semi-log plot of the probability distribution of normalized returns for herding probability  $a = 0.1$  ( $h = 9$ ), where the dot line is the form of Gaussian function ( $B = 2.0$  and  $b = 0.06$ ) for the won-dollar exchange rate.

ity distribution of normalized returns is expected to approach to a Gaussian form, viz.

$$P(R(t)) = B \exp[-bR^2(t)]. \quad (6)$$

In Fig.5, we show the semi-log plot of the probability distribution of the normalized returns for the herding parameter  $a = 0.1$  ( $h = 9$ ), where the time steps are taken as  $\Delta t = 1, 5, 22$ , and  $252$  for the won-dollar exchange rate. In this case the form of the fat-tailed distribution appears for the time intervals  $\Delta t = 1, 5$  and  $22$ , and the probability distribution of normalized returns really reduces to a Gaussian form for the time interval larger than  $\Delta t = 252$ . Hence our results from a Gaussian form are as follows:  $B = 2.0, b = 0.06$  for the won-dollar exchange rate, and  $B = 1.7, b = 0.04$  for the KOSPI.

### III. CONCLUSIONS

In conclusion, we have investigated the dynamical herding behavior for the won-dollar exchange rate and the KOSPI in Korean financial market. Specially, the distribution of the price return scales as a power law  $R^{-\beta}$  with the exponents  $\beta = 2.2$  (the won-dollar exchange rate) and  $2.4$  (the KOSPI). It is in practice obtained that our scaling exponents  $\beta$  are somewhat larger than the numerical  $1.5$  [5]. It would be noted that the returns in the probability existing financial crashes are extremely high, which the active herding behavior occurs with the increasing probability as the herding parameter takes larger value in real financial Markets. We would suggest that the critical value of herding parameter [19] is  $h^* = 2.33$  ( $a = 0.3$ ). It is found that the distribution of normalized returns reduces to a Gaussian form, and there arises a crossover toward a Gaussian probability function for the distribution of normalized returns.

In future, our analyses plan to investigate in detail the herd behavior for the yen-dollar exchange rate, and we hope that the dynamical herd behaviors apply extensively to the other tick data in foreign financial market.

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