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Scaling of the Price Fluctuation in the Korean Housing Market

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We study the scaling of the price fluctuation in the Korean housing market. From the numerical analysis, we show that the normalized return distribution of the housing price, $P(r)$, has a fat-tail and is well approximated by a power-law, $P(r) \sim r^{-(\alpha+1)}$, with $\alpha \simeq 3$ for the whole data set. However, if we divide the data into groups based on the trading patterns, then the value of α for positive tail and negative tail can be different depending on the trading patterns. We also find that the autocorrelation function of the housing price decays much slower than that of the stock exchange markets, which shows a unique feature of the housing market distinguished from the other financial systems.

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I. INTRODUCTION

For the last two decades, nontrivial behaviors of financial markets have attracted the interest of physicists from various disciplines [1–3]. One of the reasons for this interest is the scientific challenge to understand the nontrivial dynamical properties of the strongly fluctuating complex system which is composed of a large number of interacting elements. Such scientific challenges have been mainly focused on the analysis of the stock exchange markets [4–8] and foreign exchange markets [9] due to a large volume of accessible data. Among the empirical studies based on the financial data, the most notable finding is that the different markets share some universal features. Such universal features are generally called as the stylized facts [5,8,10]. Thus, investigating such universal features is important to understand the underlying principles and symmetries in various complex financial systems.

The real estate and housing markets are another important complex systems, which significantly affect our daily life. The real estate and housing markets are closely related to many other exogenous economical factors such as gross domestic product (GDP), per capita income, interest rates, inflation, tax policies, *etc.* [11–19]. They continuously interact with each other and evolve in time. Their complex interactions sometimes cause tragic economic crashes such as the subprime mortgage loan crisis in 2007. However, despite their practical importance, the complex behaviors of the housing market have been rarely studied in physics and is not fully understood yet. Therefore, it is natural to ask a question whether the real estate and housing markets share the same universal features with other financial markets or not.

In this paper, we numerically analyze the Korean housing market data for the periods Jan. 1, 2006 to May 31, 2018. Since about 20% of the total population of the Republic of Korea live in Seoul, capital city [20] and it's gross regional domestic product (GRDP) amounts to 22% GDP of the Korea [21], the housing market of Seoul significantly affects the other domestic housing markets. Therefore, we focus on the behavior of price changes in the housing market of Seoul to understand the overall behavior of the housing market in Korea. From the numerical analysis, we show that the return distribution of the housing price has a fat-tail as in other financial markets. However, we find that the autocorrelation function of housing price in Seoul decays much slower than that of stock exchange markets. This means that it might be possible to devise a theoretical model to expect the housing price for the relatively long period compared to the price of stocks.

II. DATASET AND METHODOLOGY

In order to study the behavior of the housing market in Seoul, we use the "real estate price list" data from the

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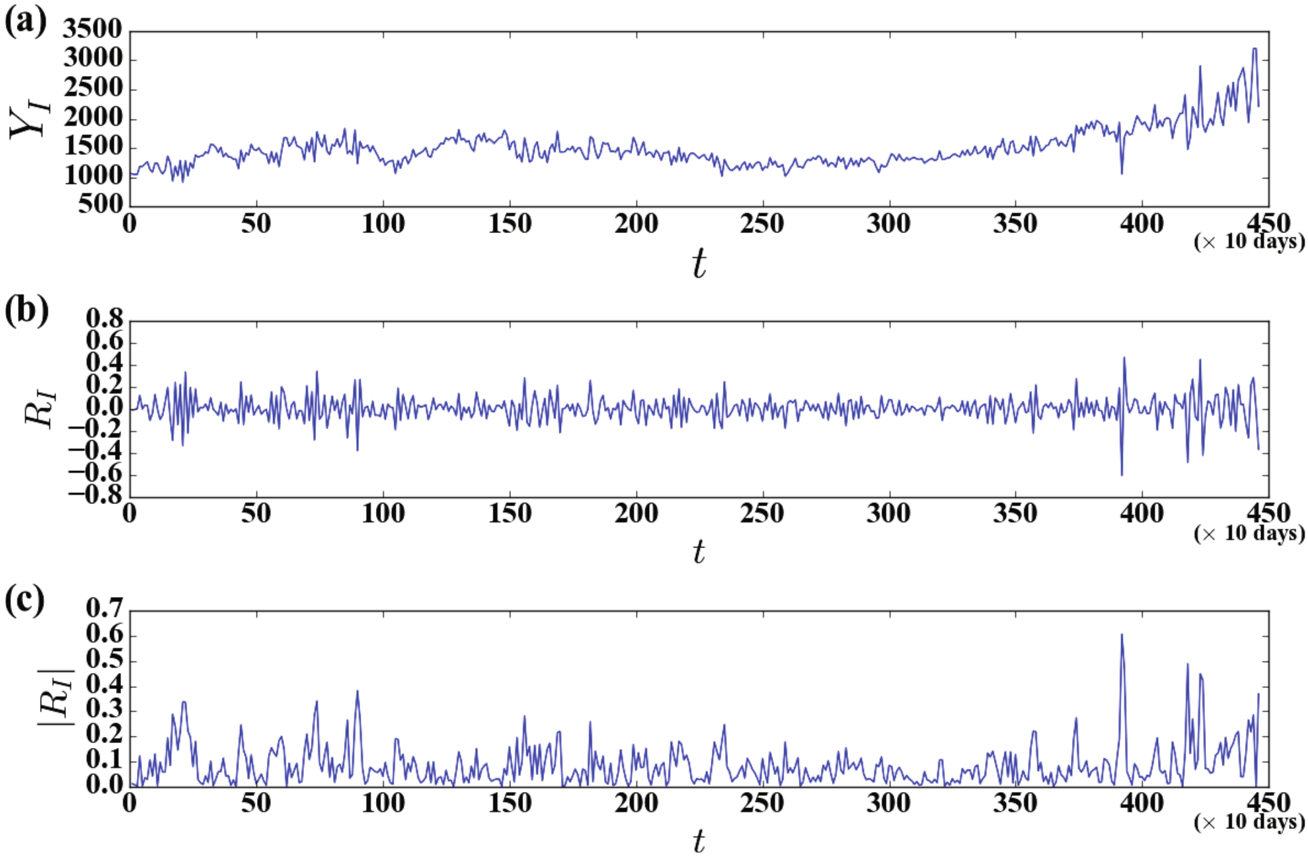

Fig. 1. (Color online) Plots of (a) $Y(t)$, (b) $R(t)$, and (c) $|R(t)|$ for Gaepo-dong district.

open data portal of National Information Society Agency (NIA) for the period Jan. 1 2006 to May. 31 2018 [22]. The data contains the prices of all kinds of residential types such as apartments, detached houses, townhouses, *etc.* Since the apartment is the most popular residential types in Korea, the real estate transaction data from NIA is mostly composed of the apartments tradings. Thus, we focus only on the apartment trading data in the following analysis. NIA trading data is stored at the interval of 10 days, *i.e.*, the first day, eleventh day, and twenty-first day of each month. To specify the geographical location of each apartment, we use the administrative district of Seoul (gu and dong). The data for Seoul has 25 gus (intermediate size of the administrative districts) and 108 dongs (the smallest size of the administrative districts). Then we group each district into three different area depending on the trading patterns in housing market based on the criteria provided by the Korean Ministry of Land, Infrastructure and Transport: (i) The inflation rate of house prices in the last month is more than 1.3 times of the consumer price inflation rate. (ii) The average inflation rate of house prices in the last two months exceeds 1.3 times of the average national inflation rate for house prices during the last two months, or the house prices inflation rate for the previous year is larger than the average annual inflation rate of house prices for the last three years [23].

Gangnam area (GA) is composed of traditional speculative superheating districts. Emerging area (EA) represents newly added speculative superheating districts. The remaining districts belong to the other area (OA) [23]. Each group and corresponding adminitrative districts are listed in Table 1. We use the price per square meters as the standard price of a given district for the analysis. Then we average the traded price of the apartments over each administrative district. For the case of missing transaction records in a given area at a given time interval, we assume that the price of the apartment remains unchanged, *i.e.*, we insert the last price of the apartment for each deficit value [24].

Let the average price of apartment in dong district I at time t be $Y_I(t)$. From the obtained time series of each $Y_I(t)$, we define the logarithmic return of $Y_I(t)$ as

$$R_I(t) = \ln(Y_I(t)) - \ln(Y_I(t - \Delta t)), \tag{1}$$

where Δt = 10-days. In Fig. 1, we display the measured $Y(t)$, $R(t)$ and $|R(t)|$ for Gaepo-dong as an example. Gaepo-dong is one of the most active traded areas in Seoul. As shown in Fig. 1(a), $Y(t)$'s in Korean housing market hardly decreases as t increases. Thus, the behavior of the Korean housing market resembles the bull market. Since the price is usually determined by the

Table 1. In the first column three different groups in Korean housing market is listed. In the second and third column have gu districts and dong districts which belong to each group.

Gangnam Area	Gangnam-gu	Nonhyeon-dong, Gaepo-dong, Dogok-dong, Suseo-dong, Samseong-dong, Yeoksam-dong, Apgujeong-dong, Cheongdam-dong, Daechi-dong, Irwon-dong
	Seocho-gu	Banpo-dong, Bangbae-dong, Seocho-dong, Jamwon-dong
	Songpa-gu	Bangi-dong, Munjung-dong, Garak-dong, Geoyeo-dong, Sincheon-dong, Songpa-dong, Jamsil-dong, Ogeum-dong, Pungnap-dong
Emerging Area	Gangdong-gu	Cheonho-dong, Gil-dong, Myungil-dong, Sangil-dong, Godeok-dong, Dunchon-dong, Amsa-dong, Seongnae-dong
	Mapo-gu	Singongdeok-dong, Gongdeok-dong, Dohwa-dong, Seongsan-dong
	Seongdong-gu	Eungbong-dong, Haengdang-dong, Majang-dong, Hawangsimni-dong, Oksu-dong
	Yongsan-gu	Ichon-dong
Other Area	Dobong-gu	Ssangmun-dong, Chang-dong, Banghak-dong, Dobong-dong
	Dongdaemun-gu	Dapsipni-dong, Jeonnong-dong, Imun-dong, Jangan-dong, Hwigyeong-dong
	Dongjak-gu	Sindaebang-dong, Daebang-dong, Sangdo-dong, Sadang-dong
	Eunpyeong-gu	Nokbeon-dong, Sinsa-dong, Eungam-dong, Gusan-dong
	Gangseo-gu	Banghwa-dong, Hwagok-dong, Gayang-dong, Deungchon-dong, Naebalsan-dong, Yeomchang-dong
	Geumcheon-gu	Doksan-dong, Siheung-dong
	Gwanak-gu	Sillim-dong, Bongcheon-dong
	Gwangjin-gu	Guui-dong, Jayang-dong, Gwangjang-dong
	Gangbuk-gu	Beon-dong, Mia-dong, Suyu-dong
	Guro-gu	Gaebong-dong, Oryu-dong, Gocheok-dong, Sindorim-dong, Guro-dong
	Jongro-gu	Changsin-dong
	Jung-gu	Sindang-dong
	Jungrang-gu	Sinnae-dong, Muk-dong, Sangbong-dong, Myeonmok-dong
	Nowon-gu	Sanggye-dong, Hagye-dong, Gongneung-dong, Wolgye-dong, Junggye-dong
	Seodaemun-gu	Hongje-dong, Yeonhui-dong, Hongeun-dong, Namgajwa-dong
	Seongbuk-gu	Gaebong-dong, Gireum-dong, Jongam-dong, Donam-dong, Hawolgok-dong
	Yangchun-gu	Sinjeong-dong, Mok-dong, Sinwol-dong
	Yeongdeungpo-gu	Shingil-dong, Yeouido-dong, Daerim-dong, Dangsan-dong 4(sa)-ga, Yeongdeungpo-dong, Yangpyeong-dong 3(sam)-ga

sellers in the Korean housing market, the price of the apartments hardly decreases. In Fig. 1(b) and (c), we show the time evolution of $R(t)$ and $|R(t)|$ for Gaepo-dong. The data in Fig. 1(b) and (c) behave in the very similar fashion with those in stock exchange markets [1], in which the intermittent occurrences of large bursts in $R(t)$ separated by relatively long periods of quiescence compared to the random fluctuations.

III. RESULTS

The studies on the financial market have shown that the return distributions of the stock price or/and market index are characterized by the fat-tailed distribution [25]. Thus, we first investigate the return distribution of the housing market. In order to keep the consistent definition of return over the different districts, we use a normalized return,

$$r \equiv \frac{R - \langle R\rangle}{v}. \tag{2}$$

Here the time averaged volatility $v \equiv v(\Delta t)$ is defined through $v^2 \equiv \langle R^2\rangle - \langle R\rangle^2$, and $\langle ...\rangle$ denotes an average over entire length of the corresponding time series. By changing the return to the normalized return, we can aggregate all transaction data for different dong districts into a single time series of normalized return.

In the many financial markets, the cumulative distribution, $P_>(r) \equiv P(x > r)$, of the normalized returns of the stock price can be well approximated by a power-law,

$$P_>(r) \sim r^{-\alpha}, \tag{3}$$

with an exponent $\alpha \approx 3$ [4,5,25]. The fat-tailed or power-law distribution of price return is one of the well-known universal features for financial markets. Therefore, it is an intriguing question whether the Korean housing market shows the same behavior with other financial markets or not. In Fig. 2, $P_>(r)$ measured from the aggregated normalized return data is displayed. The data clearly shows that $P_>(r)$ (or equivalently $P(r)$) has a fat-tail. Furthermore, from the best fit to Eq. (3) we obtain the exponent $\alpha = 3.0 \pm 0.1$ both for the positive and negative tails. The obtained values of α are well outside the stable Lévy regime [26]. Consistent results for the value

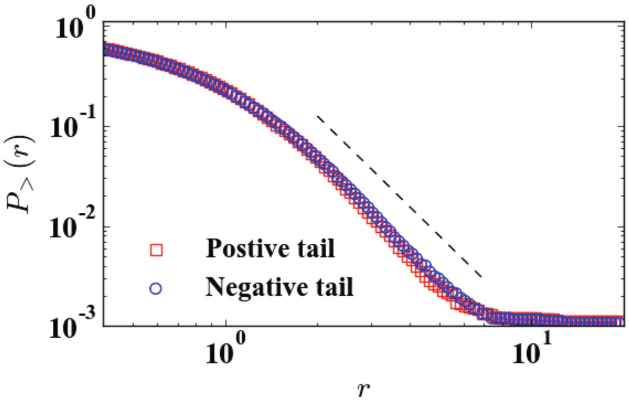

Fig. 2. (Color online) Plot of the cumulative distribution of the normalized returns, measured from the aggregated normalized return. The dashed line represents the relation $P_>(r) \sim r^{-\alpha}$ with $\alpha = 3.0$.

of α in the range $2 \leq \alpha \leq 4$ had been reported by the studies on various financial markets [25,27–29].

In order to measure the accurate value of α for each group, we use the Hill estimator [30]. The basic idea of Hill estimator is to calculate the inverse of the local logarithmic slope ζ of the cumulative distribution $P_>(r)$,

$$\zeta = -\left(\frac{d \ln P_>}{d \ln r}\right)^{-1}. \tag{4}$$

We estimate the inverse asymptotic slope $1/\alpha$ by extrapolating ζ as $1/r \to 0$.

To apply the Hill estimator to the measurement of α, we first sort the normalized returns r in descending order. The sorted returns are denoted r_k, $k = 1, ..., N$. Here $r_k > r_{k+1}$ and N is the total number of events. Using Eq. (4), $\zeta(r_k)$ is computed. We then compute an average of the inverse slopes over m points,

$$\langle\zeta\rangle \equiv \frac{1}{m}\sum_{k=1}^{m}\zeta(r_k) \tag{5}$$

where the choice of the averaging window length m varies depending on the number of events N available. We plot the locally averaged inverse slope $\langle\zeta\rangle$ as a function of $1/r$. Then $\alpha = 1/\langle\zeta(1/r \to 0)\rangle$ [30].

Figs. 3(a) - (c) shows the obtained values of α for each group from Hill estimator. The data in Fig. 3 clearly shows that the asymptotic value of α strongly depends on the trading patterns. For GA and OA the value of α's obtained from the positive tail, α_+, and from the negative tail, α_-, are almost the same (see Figs. 3(a) and (c)). On the other hand, for EA we find that $\alpha_+ < \alpha_-$ as shown in Fig. 3(b). This suggests that the symmetry of the normalized return distribution can be used as a simple proxy to test the trading pattern in given districts.

In addition to the probability distribution of return, the autocorrelation provides important clues to understand the behavior of the financial market. For example, the autocorrelation function of return in the stock

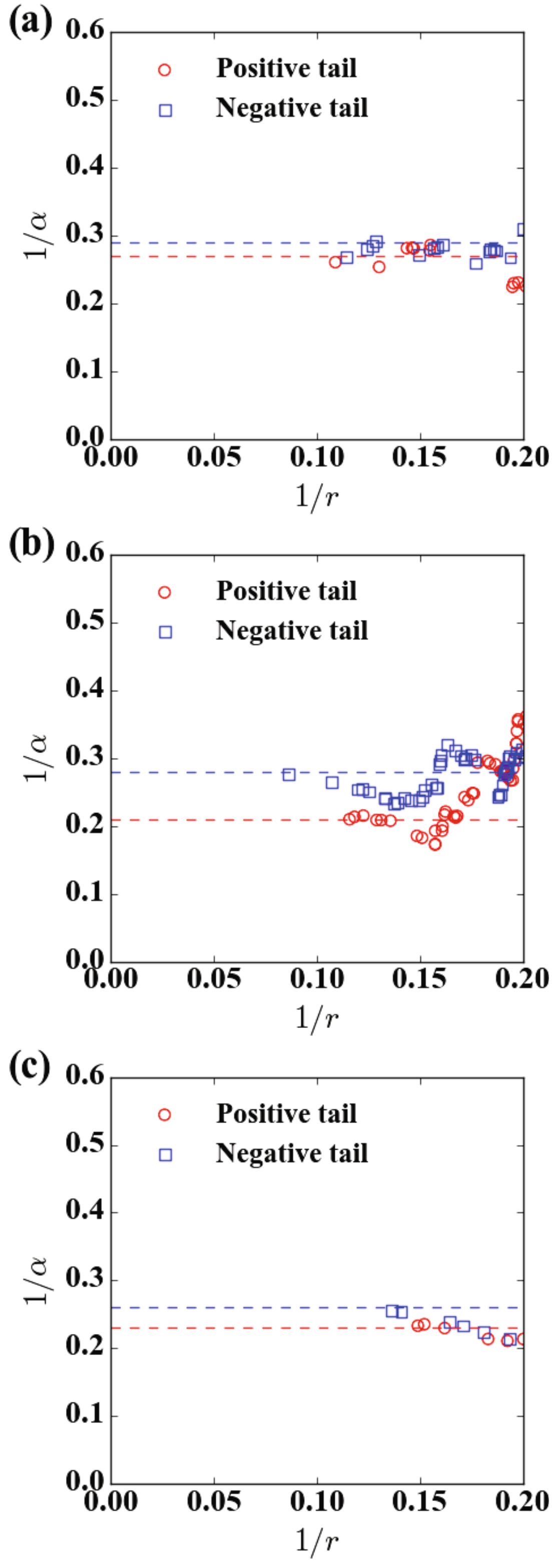

Fig. 3. (Color online) Hill estimator for the positive return and negative return of (a) Gangnam Area, (b) Emerging Area and (c) Other Area with $m = 30$. The circle symbol (red) denote positive return and square symbol (blue) represent negative return and each dashed line represent the extrapolated line.

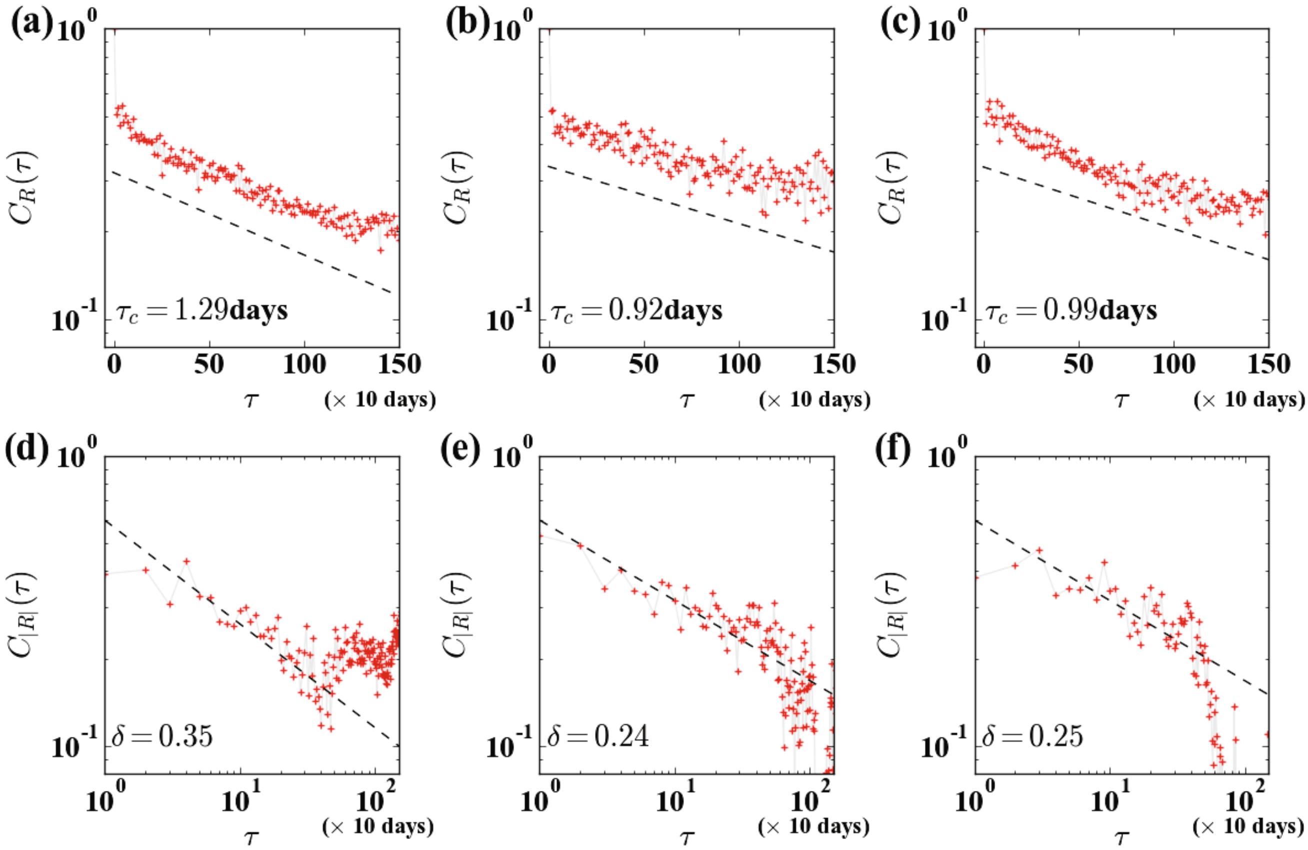

Fig. 4. (Color online) Semilog plot of the $C_R(\tau)$ for (a) Gaepo-dong in GA, (b) Gongduck-dong in EA, and (c) Shindorim-dong in OA. Log-log plot of $C_{|R|}(\tau)$ for (d) Gaepo-dong in GA, (e) Gongduck-dong in EA, and (f) Shindorim-dong in OA.

exchange market is known to decay exponentially with very short characteristic time, $\tau_c \simeq 4.0$ min [5,31]. This results are consistent with the efficient market hypothesis which states that it is not possible to predict the future stock price from their previous values [32]. On the other hand, if the price correlations were not short range, one could devise a way to predict the change of price. More interestingly, the autocorrelation function for the absolute value of the return is known to be well described by a power-law [25].

The autocorrelation function for $R_I(t)$ and $|R_I(t)|$ of district I are defined as

$$C_{R_I}(\tau) = \frac{\langle R_I(t)R_I(t+\tau)\rangle - \langle R_I(t)\rangle^2}{\langle R_I(t)^2\rangle - \langle R_I(t)\rangle^2}, \tag{6}$$

and

$$C_{|R_I|}(\tau) = \frac{\langle |R_I(t)|\,|R_I(t+\tau)|\rangle - \langle |R_I(t)|\rangle^2}{\left\langle |R_I(t)|^2\right\rangle - \langle |R_I(t)|\rangle^2}, \tag{7}$$

respectively. Here $\langle ... \rangle$ denotes the average over the entire time series.

In Figs. 4(a) - (c) $C_{R_I}(\tau)$'s for three dong-districts selected from each group in Table 1 are displayed as an example. The data shows that $C_{R_I}(\tau)$ for all dong-districts exponentially decays as

$$C_{R_I}(\tau) \sim \exp\{-\tau/\tau_c\}. \tag{8}$$

From the best fit of the data to Eq. (8), we obtain $\tau_c = 1.29 \pm 0.02$ for Gaepo-dong, $\tau_c = 0.92 \pm 0.03$ for Gongduck-dong, and $\tau_c = 0.99 \pm 0.02$ for Shindorim-dong. The obtained values of τ_c's are much larger than those values obtained from stock exchange markets. This indicates that it might be possible to devise a way to predict the change of price in the Korean housing market for relatively long time scale, *e.g.*, up to $\tau = 1500$ days for Gaepo-dong in Fig. 4(a).

We display $C_{|R_I|}(\tau)$ in Figs. 4(d) - (e) for the same dong districts with Figs. 4(a) - (c). As for the stock exchange markets [25], we find that $C_{|R_I|}(\tau)$ for the Korean housing market scales as

$$C_{|r|}(\tau) \sim |\tau|^{-\delta}. \tag{9}$$

From the best fit of the data to Eq. (9), we obtain $\delta = 0.35 \pm 0.02$ for Gaepo-dong, $\delta = 0.24 \pm 0.02$ for Gongdeok-dong, and $\delta = 0.25 \pm 0.03$ for Shindorim-dong.

IV. CONCLUSIONS

We numerically analyze the behavior of the return in the Korean housing market. From the measurement of aggregated or whole return distribution, we find that the return distribution for the Korean housing market also has a fat-tail and is well approximated by the power-law like the other financial markets. However, the autocorrelation function for return of the housing market shows correlation in much larger time scale than that for other financial markets such as stock exchange market, which is a unique feature of the housing market distinguished from the other financial systems. This unique feature of the housing market indicates that it might be possible to predict the change of price up to about 1500 days in the Korean housing market. Furthermore, from the accurate measurement of the normalized return distribution for three distinctive groups, we find that the trading pattern affects the symmetry of the return distribution. Therefore, return distribution can be used as a proxy to test the trading pattern in a given district.

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REFERENCES

[1] H. E. Stanley and R. N. Mantegna, *An Introduction to Econophysics* (Cambridge University Press, Cambridge, 2000).
[2] S. Sinha, A. Chatterjee, A. Chakraborti and B. K. Chakrabarti, *Econophysics An Introduction* (Wiely-VCH, Weinheim, 2011).
[3] J-P. Bouchaud and M. Potters, *Theory of Financial Risk and Derivative Pricing: From Statistical Physics to Risk Management* (Cambridge University Press, Cambridge, 2003).
[4] X. Gabaix, P. Gopikrishnan, V. Plerou and H. E. Stanley, Nature **423**, 267 (2003).
[5] Y. Liu, P. Gopikrishnan, P. Cizeau, M. Meyer, C-K. Peng and H. E. Stanley, Phys. Rev. E **60**, 1390 (1999).
[6] P. Cizeau, Y. Liu, M. Meyer, C-K. Peng and H. E. Stanley, Physica A **245**, 441 (1997).
[7] P. Gopikrishnan, M. Meyer, L. A. N. Amaral and H. E. Stanley, Eur. Phys. J. B **3**, 139 (1998).
[8] Y. Liu, P. Gopikrishnan, P. Cizeau, M. Meyer, C-K. Peng and H. E. Stnaley, Phys. Rev. E **59**, 1390 (1999).
[9] U. A. Müller, M. M. Dacorogna, R. B. Olsen, O. V. Pictet, M. Schwarz, C. Morgenegg and J. Banking, Finance **14**, 1189 (1995).
[10] R. N. Mantegna and H. E. Stanley, Nature **376**, 46 (1995).
[11] C. R. Cunningham, Journal of Urban Economics **59**, 1 (2006).
[12] Z. Adams and R. Fss, Journal of Housing Economics **19**, 38 (2010).
[13] D. DiPasquale and W. C. Wheaton, Real Estate Economics **20**, 181 (1992).
[14] P. Englund and Y. M. Ioannides, Journal of Housing Economics **6**, 119 (1995).
[15] J. M. Poterba, D. N. Weil and R. Shiller, Brookings Papers on Economic Activity **1991**, 143 (1991).
[16] O. Lamont and J. C. Stein, Leverage and house-price dynamics in US cities (No. w5961). National bureau of economic research (1997).
[17] J. M. Quigley, Real estate prices and economic cycles (2002).
[18] J, Aizenman, Y. Jinjarak and H. Zheng, Real estate valuations and economic growth: The cost of housing cycles, VoxEU.org, 24 (2016).
[19] G. Meen, Journal of housing economics **11**, 1 (2002).
[20] http://www.mois.go.kr.
[21] http://www.index.go.kr.
[22] https://www.data.go.kr.
[23] http://www.molit.go.kr.
[24] There are 5.21 missing transaction data for each dong-district on the average. We also checked other methods to interpolate the price of the apartments for the missing transaction data, which include the methods of middle or median price approximation between two transactions. However, we obtain the same market behavior.
[25] P. Gopikrishnan, V. Plerou, L. A. Amaral, M. Meyer and H. E. Stanley, Phys. Rev. E **60**, 5305 (1999).
[26] P. Gopikrishnan, M. Meyer, L. A. N. Amaral and H. E. Stanley, Eur. Phys. J. B **3**, 139 (1998).
[27] V. Plerou, P. Gopikrishnan, L. A. Amaral, M. Meyer and H. E. Stanley, Phys. Rev. E **60**, 6519 (1999).
[28] T. Lux, M. Marchesi, Nature **397**, 498 (1999).
[29] S. Galluccio, G. Caldarelli, M. Marsili and Y-C. Zhang, Physica A **245**, 423 (1997).
[30] B. M. Hill, Ann. Stat. **3**, 1163 (1975).
[31] F. Lillo and R. N. Mantegna, Phys. Rev. E **62**, 6126 (2000).
[32] E-F. Fama, J. Finance **25**, 383 (1970).