International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Diffusion Entropy Analysis: Stability of Indian Stock Market

Sushil Kumar, Sunil Kumar, Pawan Kumar

Abstract: ***The large amount of available data of stock markets becomes very beneficial when it is transformed to valuable information. The analysis of this huge data is essential to extract out the useful information. In the present work, we employ the method of diffusion entropy to study time series of different indexes of Indian stock market. We analyze the stability of Nifty50 index of National Stock Exchange (NSE) India and SENSEX index of Bombay Stock Exchange (BSE), India in the vicinity of global financial crisis of 2008. We also apply the technique of diffusion entropy to analyze the stability of Dow Jones Industrial Average (DJIA) index of USA. We compare the results of Indian Stock market with the USA stock market (DJIA index). We conduct an empirical analysis of the stability of Nifty50, Sensex and DJIA indexes. We find significant drop in the value of diffusion entropy of Nifty50, Sensex and DJIA during the period of crisis. Both Indian and USA stock markets show bull market effects in the pre-crisis and post-crisis periods and bear market effect during the period of crisis. Our findings reveal that diffusion entropy technique can replicate the price fluctuations as well as critical events of the stock market.***

Keywords: Diffusion entropy, Stability of stock market, conditional entropy, Global Financial crisis.

I. INTRODUCTION

Following the global financial crisis of 2008, extensive research is carried out in the fields of Econophysics, mathematics and statistical physics to understand the stability of stock markets by analyzing the big databases [1]-[26]. Different models based on the physics and mathematical concepts are proposed to study database related to economic systems. The stock markets are manmade complex systems having a lot of available data which is useless until it can be transformed into useful information. The stock markets are governed by many interrelating components and investigated using random matrix theory (RMT), complex network approach;hierarchical clustering and entropy analysis [14]-[20] .The global financial crisis has caused abnormal events in the financial systems and led to the need of determination of dominant relevant factors to minimize the adverse effects to the financial systems. So the analysis of database related to financial systems becomes very important. Entropy is one of many physics concepts which have been utilized to understand the abnormal behavior of financial systems [23], [27]-[33]. McCauley[27] have used the concept of entropy to discuss the disorderness and uncertain behavior of stock markets. Bentes and Menezes [28] have studied different stock indexes using the concept of Shannon entropy. Oh et al. [29] have studied many market indices using entropy and analyze the systemic risk in the market in the stock returns. They have measured states of different markets using correlation among stocks and indices. They found that stability measures; entropy and volatility are similar to each other if stock prices are described by the random walk [29].

Zhou et al.[30] have utilized the concept of information entropy and found it superior in the management of risk as compare to conventional methods. They have represented the return pattern of the data of the indexes by binary variable; +1 for the profit and 0 for the loss. In financial system volatility is broadly accepted as measure of market risk and its prediction is highly difficult. Standard deviation is also used to study market risk but mainly in highly random market conditions. W Chen et al. [31] have analyzed the global financial system using multiracial volatility approach.

In the present paper we analyze the stability of dominant stock market indexes of India and compare with stability of DJIA of USA using diffusion entropy and conditional entropy [32]. The diffusion entropy is based on the physical phenomenon 'diffusion'. We find out the patterns and their distribution function in the returns of time series of Nifty50, Sensex and DJIA indexes.

The organization of investigation is as follows: in Section-2, we discuss database used in the analysis and explain the techniques used; Diffusion entropy and conditional entropy. In section-4, we discussthe results and conclude the findings.

II. DATA STUDIED

In this investigation we study databases of two Indian Stock Market indexesi.e Nifty50 index of NSE, Sensex index of BSEand compare the results with analyzed database of DJIA index of USA [32]. The daily data of NSE Nifty50 index, BSE Sensex and Dow Jones Industrial Average (DJIA) is downloaded from finance@yahoo.co.in. We apply the two methodologies; diffusion entropy and conditional entropy for analyzing the stability of markets. The daily logarithmic returns of time series are computed as

$Ret(t) = \log \mathrm{CP}(\tau + 1) - \log \mathrm{CP}(\tau)$, where CP ($\tau$) is the closing price at time 'τ'.

Manuscript published on November 30, 2019.
* Correspondence Author
Sushil Kumar*, School of Basic & Applied Sciences, K R Mangalam University, Gurugram, Haryana, India-122103.
Dept. of Physics and Electronics,Hansraj College, University of Delhi, Delhi-7, India. Email: sushil8207@gmail.com
Sunil kumar,Ramjas College, University of Delhi, Delhi-7, India Email:du.sunil@gmail.com
Pawan Kumar*, School of Basic & Applied Sciences, K R Mangalam University, Gurugram, Haryana, India-122103.Email: pawangk@gmail.com

The closing price and variance of the logarithmic returns i.e volatility of Nifty50, BSE Sensex and DJIA is shown in the Fig.1 and Fig.2 respectively.

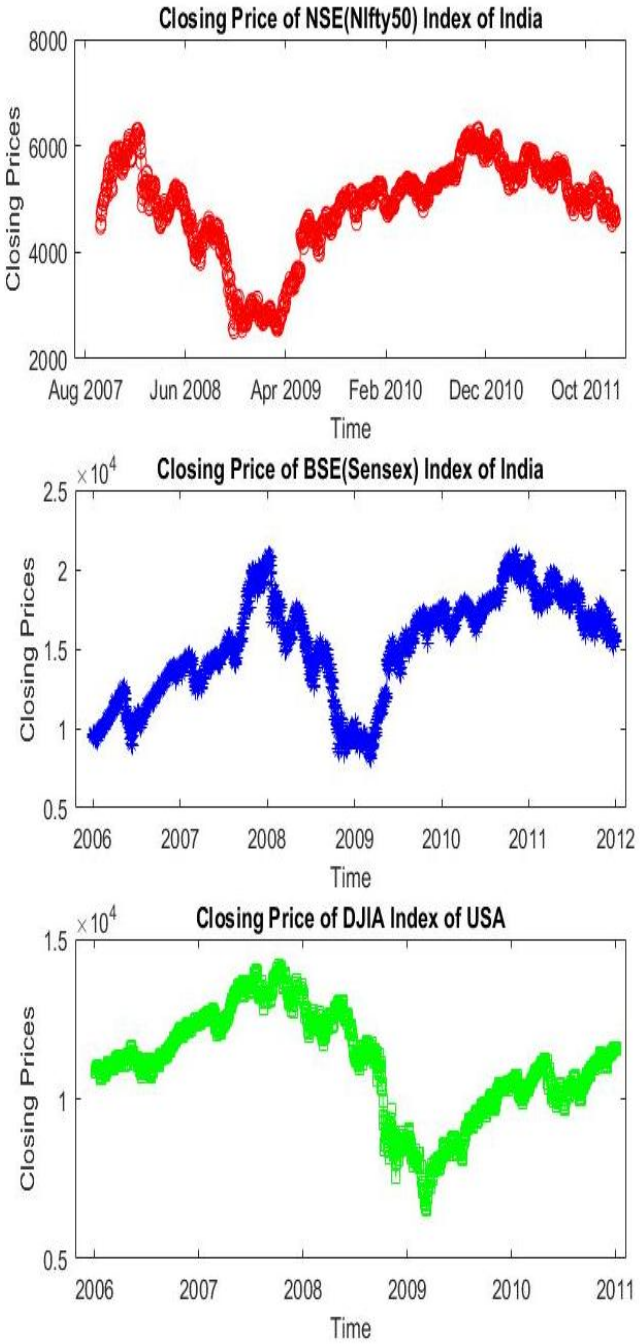

Fig.1: Closing Price ofNSE Nifty50,BSE Sensex of India and DJIA index of USA.

Consider $\{\chi_j\}_{j=1}^{K}$ is the time series of stock market index.

The closing price of the index on j[th]day is considered as the position 'χ_j' of the particle. We use diffusion algorithm as discussed in ref [33] and compute the diffusion entropy in the similar way as done in the ref [32].

From the sequence of K numbers of $\{\chi_j\}_{j=1}^{K}$, we derive maximum permissible diffusing trajectories using the technique of moving window of size 'τ'. So for diffusion time 'τ', the possible numbers of subsequence are K- τ+1, defined by

$$\chi_j^m = \chi_{j+m} \text{with m=0,1,2…….K- } \tau$$

The mth diffusion trajectory for any of subsequence can be defined as

$$y^{(m)}(\tau) = \sum_{j=1}^{\tau} \chi_j^m$$

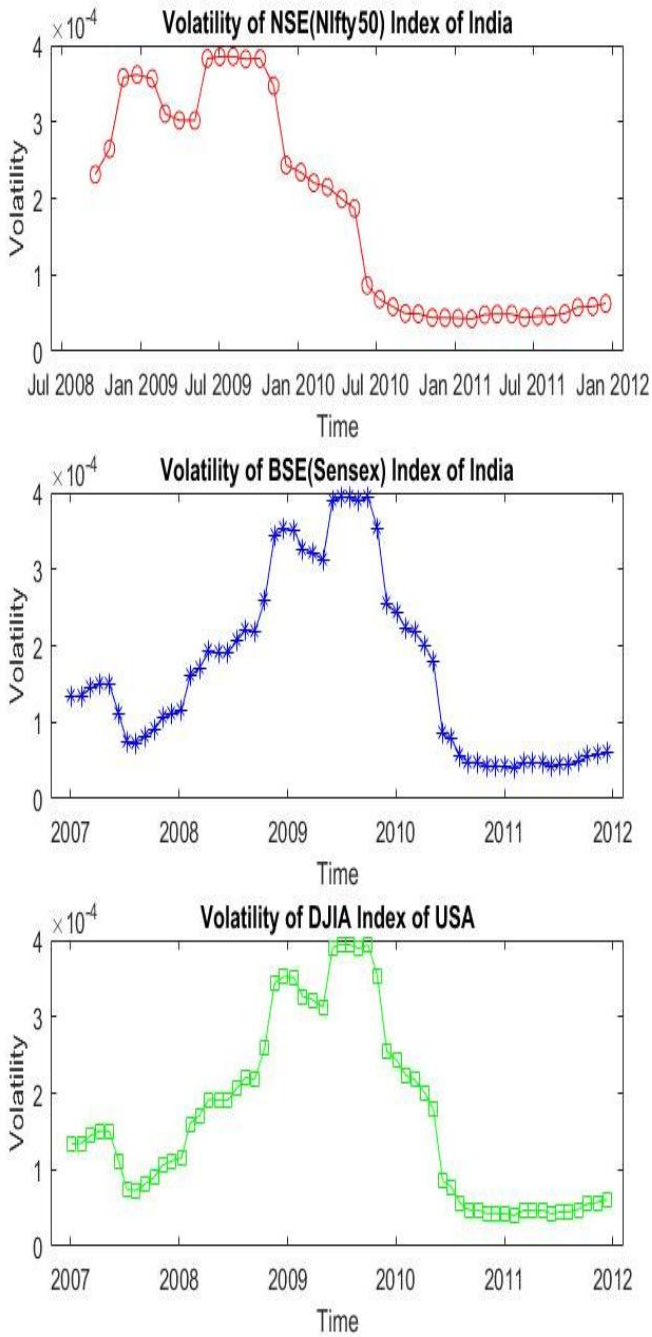

Fig.2: Volatility ofNSE Nifty50, BSE Sensex of India and DJIA index of USA.

The K-τ+1 subsequences are considered as collection of particles such that $y^{(m)}(\tau)$ is position of sth particle at time 'τ'. The particle jumps 'τ' times before reaching the position at time 'τ'. To compute the entropy of the diffusion process, we divide the x axis into 'p' cells. The size of the cell is taken as a fraction of square root of variance of the fluctuation of closing price.

The probability of a particle to be found in j[th] cell at time 'τ'is given by

$P_j(\tau) = \frac{K_j(\tau)}{K-\tau+1}$, where $K_j(\tau)$ is number of particle in j[th] cell.

The diffusion entropy at time at time 'τ' is given by

$S(\tau) = -\sum P_j(\tau)\ln(P_j(\tau))$.

The conditional entropy is defined as

$$Con(\tau) = 1 + \beta[1 - S_{norm}(\tau)]$$

where$S_{norm}(\tau) = \frac{S(\tau)}{\tau}$ is normalised diffusion entropy and β is positive (negative) for bull (bear) market. The conditional entropy (Con (τ)) values lies in the interval [0 2] and for a random time series the conditional entropy is unity. The diffusion entropy and conditional entropy are shown in the Fig.3 and Fig.4 respectively.

III. RESULTS AND DISCUSSIONS

We apply the technique of diffusion entropy discussed in previous section to study the unevenness of uncertainty of the time series of returns of NIFTY50, SENSEX and DJIA. We investigate the stability of dominant Indian stock market indexes and compare with DJIA index of USA. To carry out the empirical analysis, we consider the daily close price of NIFTY50, SENSEX and DJIA. We compute the average volatility for the indexes over a moving time window of one year i.eapproximately 250 trading days with a shift of one month i.e21 trading days. The closing price and volatility for NIFTY50, SENSEX and DJIA indexes are shown in the Fig.1 and Fig.2 respectively. From Fig.1, we can see fall in the closing prices of the indexes during the period of global financial crisis of 2008 and rise in post-crisis period.

We find large fluctuations in the closing prices as indicated by the volatility plots. On the basis of volatility we divide the complete period of study into three sub periods; pre-crisis, during crisis and post-crisis periods. We categories the period from Jun, 2006 to Nov, 2007, as 'Pre-Crisis', from Dec, 2007 to Jun, 2009 as 'During Crisis' and from Jan, 2010 to Jun, 2011 as 'Post-Crisis'. In the pre-crisis period, stock market has normal states while post crisis period is the period of repossession from the crisis. From diffusion entropy analysis we find that for diffusion time of 6 days, the variations in the entropy values matches with the financial crisis [29]. Thus in our analysis, we fixed the diffusion time (τ) =6 days. In present work, we use diffusion time of one week i.e. (τ) =6 daysto detect the weekly rise and fall in the returns of stocks. Taking (τ) =5,6 and 7 days hardly makes any significant difference in the rise and fall patterns.

The normalized diffusion entropy ($S_{norm}(\tau)$) for different indexes is shown in the Fig.3. In pre-crisis period, the stock market is in developing stage, so the diffusion entropy attains significantly high values indicating the stability of the Index or stock market in the particular period. During the period of the financial crisis, the entropy value has substantial fluctuations and it falls to the minimum value. This reveals sharp drop in the closing price of stocks during the period of crisis. The stock market re-establishes certain vitality in post crisis period but the changes in entropy values are not steady. From diffusion entropy analysis we conclude that stability of the stock market has strongly affected from global crisis. We find that diffusion entropy and degree of the stock market stability are strongly related. Oh et al. obtained similar results using the concept of Shannon Entropy. They estimated stability of stock markets using Shannon entropy and found that it matches with the global financial crisis of 2008.

The conditional entropy ($Con(\tau)$ for the Nifty50, SENSEX and DJIA is shown in the Fig.4.

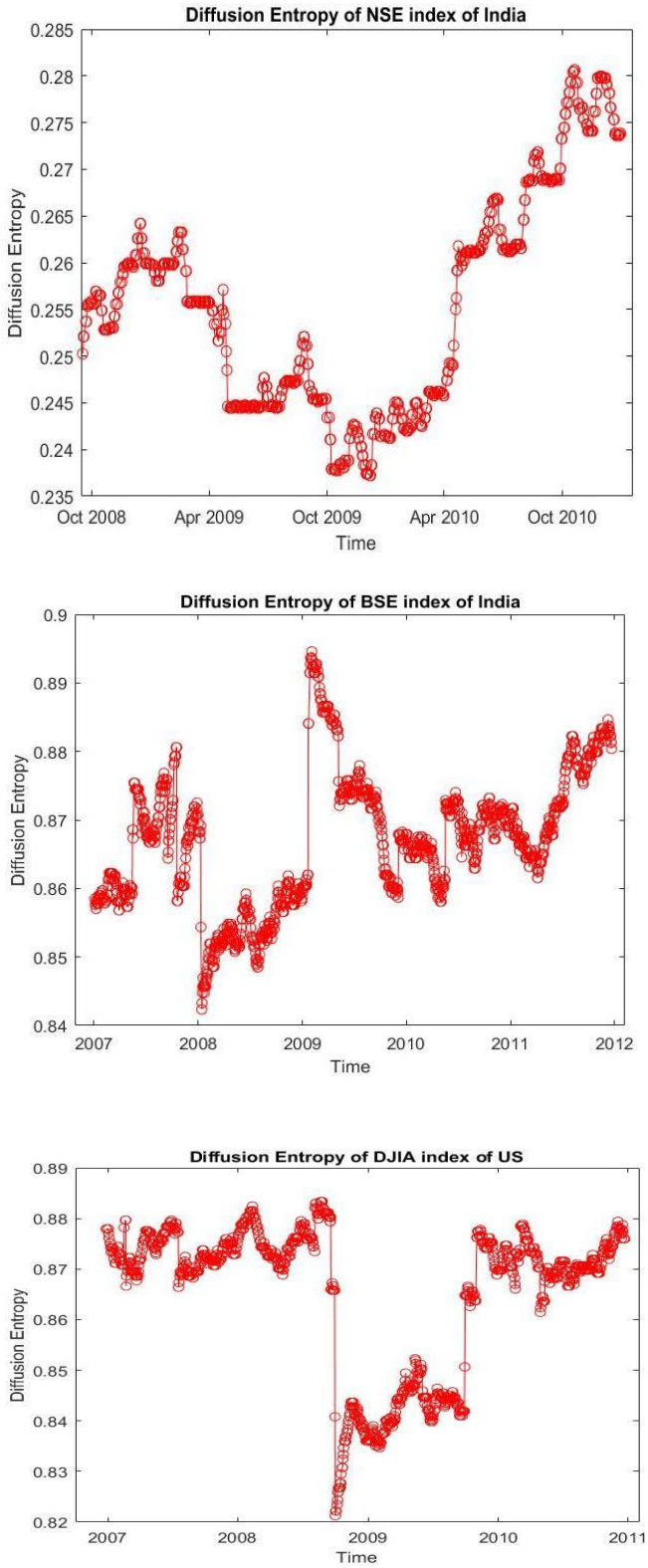

Fig.3: Diffusion Entropy of NSE Nifty50,BSE Sensexof India and DJIA index of USA.

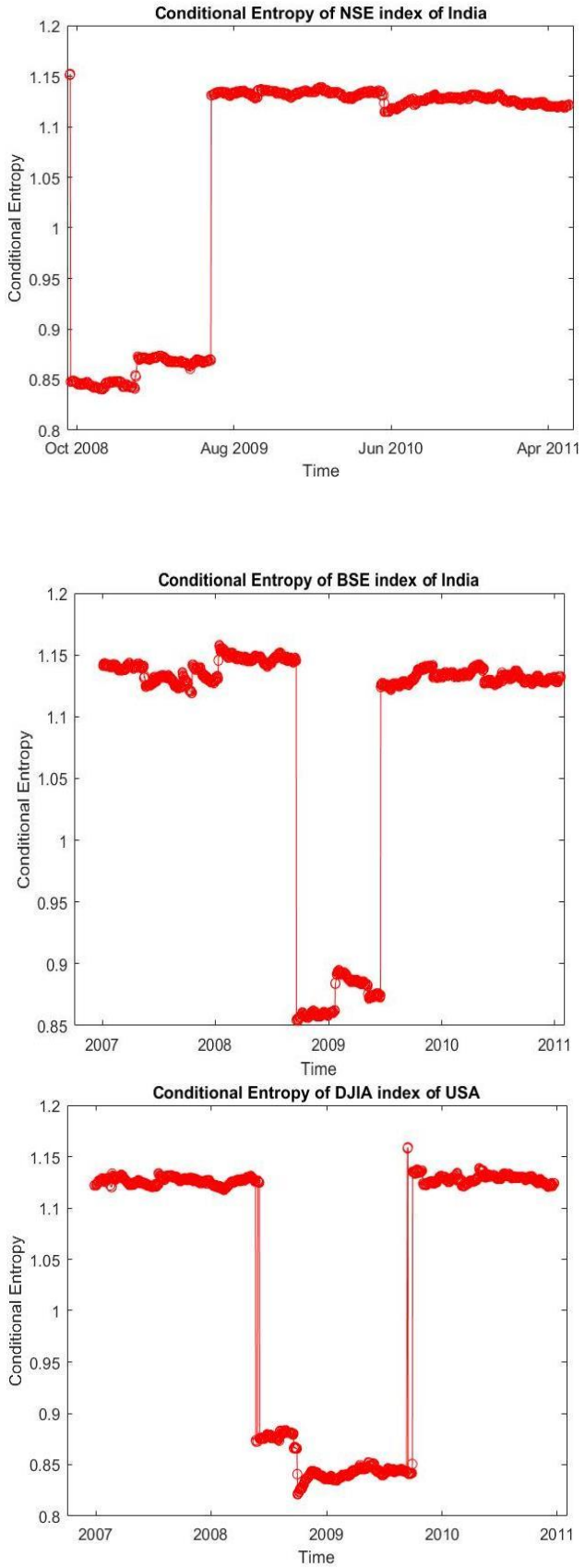

Fig.4: Conditional entropy ofNSE Nifty50,BSE Sensexof India and DJIA index of USA.

From the conditional entropies plots shown in the Fig.4, we find that the Indian stock market show bull market effects in the pre-crisis and post-crisis periods and bear market effect during the period of crisis. The conditional entropy is more than unity in the pre and post crisis period while it is less than unity during the period of crisis. Therefore, we find that values of conditional entropy matches with the state of the stock market.

IV. CONCLUSIONS

In present investigation, we study the stability of stock market using the techniques of diffusion entropy and conditional entropy. We have computed diffusion and conditional entropyNIFTY50, SENSEX and DJIA indexesto examine their stability in the vicinity of global financial crisis of 2008 empirically. We observe large fluctuations in the closing prices as indicated by the volatility plots (shown in Fig.2). In the pre-crisis period, stock market has normal states while it is in the state of repossession in post crisis period. We find that variations in the entropy values match with the financial crisisfor diffusion time of 6 days. The normalized diffusion attains significantly high values in pre-crisis period indicating the stability of the index. We find significant fall in the diffusion entropy values during the period of crisis.The stock market re-establishes certain strength in post crisis period but the changes in entropy values are not steady. So from diffusion entropy analysis we conclude that stability of the stock market has strongly affected from global crisis of 2008. From conditional entropyplots shown in the Fig.4 we conclude that the Indian stock market show bull market effects in the pre-crisis and post-crisis periods and bear market effect during the period of crisis. We also find that values of conditional entropy matches with the state of the stock market.From this empirical study, we conclude that market fluctuations and extreme market states can be analyzed using diffusion and conditional entropy techniques.

References

1. M.C. Münnix, T. Shimada, R. Schäfer, F. Leyvraz, T.H. Seligman, T. Guhr, H.E. Stanley, Identifying sates of a financial market, *Sci. Rep.* **2** (2012) 644.
2. G.-H. Mu, W.-X. Zhou, W. Chen, J. Kertesz, Order flow dynamics around extreme price changes on an emerging stock market, *New J. Phys.* 12 (2010) 075037.
3. M. Raberto, S. Cincotti, Modeling and simulation of a double auction artificial financial market, *PhysicaA*,355 (2005) 34–45.
4. K. Yamasaki, L. Muchnik, S. Havlin, A. Bunde, H.E. Stanley, Scaling and memory in volatility return intervals in financial markets, *Proc. Natl. Acad. Sci.*102 (2005) 9424–9428.
5. F. Wang, K. Yamasaki, S. Havlin, H.E. Stanley, Multifactor analysis of multiscaling in volatility return intervals, *Phys. Rev. E* 79 (2009) 016103.
6. A. Ponzi, F. Lillo, R.N. Mantegna, Market reaction to a bid–ask spread change: a power-law relaxation dynamics, *Phys. Rev. E* 80 (2009) 016112.
7. C. Liu, Z.-Q. Jiang, F. Ren, W.-X. Zhou, Scaling and memory in the return intervals of energy dissipation rate in three-dimensional fully developed turbulence, *Phys. Rev. E* 80 (2009) 046304.
8. F. Ren, W.-X.Zhow, Recurrence interval analysis of trading volumes, *Phys. Rev. E 81* (2010) 066107.
9. Y. Tao, Competitive market for multiple firms and economic crisis, *Phys. Rev. E 82* (2010) 036118.
10. Z.-Q. Jiang, W.-X. Zhou, D. Sornette, R. Woordard, K. Bastiaensen, P. Cauwels, Bubble diagnosis and prediction of the 2005–2007 and 2008–2009 Chinese stock market bubbles, *J. Econ. Behav.Organ.* 74 (2010) 149–162.
11. F. Lillo, R.N. Mantegna, Power-law relaxation in a complex system: Omori law after a financial market crash, *Phys. Rev. E* 68 (2003) 016119.

12. F. Lillo, R.N. Mantegna, Dynamics of a financial market index after a crash, *PhysicaA* 388 (2004) 125–134.
13. F. Selcuk, Financial earthquakes,aftershocks and scaling in emerging stock markets, *Physica A* 333 (2004) 306–316.
14. F.M. Siokis, Stock market dynamics: before and after stock market crashes, *PhysicaA* 391 (2012) 1315–1322.
15. L.S. Junior, I.D.P. Franca, Correlation of financial markets in times of crisis, *PhysicaA* 391 (2012) 187–208.
16. F.O. Redelico, A.N. Proto, Empirical fractal geometry analysis of some speculative financial bubbles, *PhysicaA* 391 (2012) 5132–5138.
17. W. Yan, R. Woodard, D. Sornette, Leverage bubble, *Physica A* 391 (2012) 180–186.
18. K. Watanabe, H. Takayasu, M. Takayasu, Random walker in temporally deforming higher-order potential forces observed in a financial crisis, *Phys.Rev. E* 80 (2009) 056110.
19. A.M. Peterson, F. Wang, S. Havlin, H.E. Stanley, Quantitative law describing market dynamics before and after interest-rate change, *Phys. Rev. E* 81(2010) 066121.
20. A.M. Peterson, F. Wang, S. Havlin, H.E. Stanley, Market dynamics immediately before and after financial shocks: quantifying the Omori, productivity and Bath laws, *Phys. Rev. E* 82 (2010) 036114.
21. J. Tenenbaum, D. Horvatic, S.C. Bajic, B. Pehlivanovic, B. Podobnik, H.E. Stanley, Comparison between response dynamics in transition economies and developed economies, *Phys. Rev. E* 82 (2010) 046104.
22. V. Filimonov, D. Sornette, Quantifying reflexivity in financial markets: toward a prediction of flash crashes, *Phys. Rev. E* 85 (2012) 056108.
23. C.E. Shannon, A mathematical theory of communication, *Bell Syst. Tech J.* 27 (1948) 379.
24. C.R. Shalizi, K.L. Shalizi, J.P. Crutchfield, Pattern discovery in time series, part I: theory, algorithm, analysis, and convergence, SFI Working Paper (2002).
25. J.-S. Yang, W. Kwak, T. Kaizoji, I. Kim, Increasing market efficiency in the stock markets, *Eur. Phys. J. B 61* (2008) 241.
26. J.-S. Yang, T. Kaizoji, W. Kwak, Temporal evolution into a more efficient stock market, *PhysicaA*390 (2011) 2002.
27. J.L. McCauley, Thermodynamic analogies in economics and finance: instability of markets, *PhysicaA* 329 (1) (2003) 199–212.
28. S.R. Bentes, R. Menezes, Entropy: A new measure of stock market volatility? *J. Phys. Conf. Ser*. 394 (1) (2012) 012033.
29. G. Oh, H.Y. Kim, S.W. Ahn,W. Kwak, Analyzing the financial crisis using the entropy density function, *Phys. A* 419 (2015) 464–469.
30. R. Zhou, J. Zhang, M. Xiong, F. Yang, M. Yu, Using information entropy to measure bond risk: an empirical investigation, *J. Inf. Comput. Sci. 12 (3) (2015) 1089–1100.*
31. W. Chen, Y. Wei, Q. Lang, Y. Lin, M. Liu, Financial market volatility and contagion effect: a copula-multifractal volatility approach, *Physica A* 398 (2014) 289.
32. Shouwei Li, Yangyang Zhuang, Jianmin He. Stock market stability: Diffusion entropy analysis, *Physica A* 450, (2016) 462-465.
33. N. Scafetta, P. Grigolini, Scaling detection in time series: diffusion entropy analysis, *Phys. Rev. E* 66 (3) (2002) 036130.

AUTHORS PROFILE

I am Sushil kumar, working as Assistant professor in the department of Physics and Electronics, Hansraj College, University of Delhi, India-110007. Before joining the Hansraj College I have worked as 'Scientist C' in the Inter University Accelerator Centre, New Delhi, India-110016. I have completed my post-graduation in Physics from IIT Roorkee, India-247667 and graduation from HPU Shimla,India-177023. I am awarded with 'TEACHING EXCELLENCE AWARD IN INNOVATION' by university of Delhi for innovation project 'Designing and Optimization of Auto-Tracking Solar Energy based Energy Conversion Module for Rechargeable Appliances. I have 12 research papers in national, international journals/conference proceedings. I have co-authored a book on Basic Concept on calculus on variation and written two e-chapters on "Interpolation" and "Matrices and System of Linear Equations", Virtual Learning Environment, Institute of Life Long Learning, University of Delhi. I have completed two research projects under Innovation Project schemes, University of Delhi.

I am Sunil Kumar, working as Assistant professor in the department of Physics,Ramjas College, University of Delhi, India-110007. I have completed my Doctor in Philosophy in Physics from University of Delhi. I have completed my post-graduation in Physics and Garduation from University of Delhi, Delhi-110007. I have more than 4 research papers in national and international journals. I have delivered more than 5 invited talks in national and internationalconferences.I have completed one research projects under Innovation Project schemes, University of Delhi. I am guiding two Ph.D students as co supervisor. My area of research interests are complex systems, Econophysics, socio-economic systems and non -linear dynamics.

I am DrPawan Kumar working as Assistant Professor in the School of Basic & Applied Sciences, K. R. Mangalam University, Gurugram, Haryana, India-122103. Before joining K. R. MangalamUniversity, I have worked as assistant professor at SITM, Lucknow, India.I have completed my Doctor in Philosophy in Physics from Jaypee Institute of Information Technology, Noida, GautamBuddh Nagar-201307, Uttar Pradesh, India. I have done my Master's Degree in physics and Bachelor's Degree from University of Delhi. I have published more than 25 papers in reputed international and national journals. My areas of interest are Experimental Condensed Matter Physics, Strongly Correlated Systems, Disordered Systems, and Econophysics.