Diffusion Entropy Analysis: Stability of Indian Stock Market

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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 disorderliness 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 work 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 discuss the results and conclude the findings.

II. DATA STUDIED

In this investigation we study databases of two Indian Stock Market indexes i.e Nifty50 index of NSE, Sensex index of BSE and 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

\[
Ret(\tau) = \log CP(\tau + 1) - \log CP(\tau),
\]

where \(CP(\tau)\) is the closing price at time ‘\(\tau\)’.

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.
Consider \( \{x_i\}_{i=1}^{K} \) is the time series of stock market index. The closing price of the index on \( j^{th} \) day is considered as the position \( \gamma_j \) 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 \( \{x_i\}_{i=1}^{K} \), we derive maximum permissible diffusing trajectories using the technique of moving window of size ‘\( \tau \)’. So for diffusion time ‘\( \tau \)’, the possible numbers of subsequence are K-\( \tau+1 \), defined by

\[
x^{m}_{j} = x_{j+m}, \text{with } m=0,1,2, \ldots, K-\tau
\]

The \( m^{th} \) diffusion trajectory for any of subsequence can be defined as

\[
y^{(m)}(\tau) = \sum_{j=1}^{K-\tau+1} x^{m}_{j}
\]

The K-\( \tau+1 \) subsequences are considered as collection of particles such that \( y^{(m)}(\tau) \) is position of \( s^{th} \) particle at time ‘\( \tau \)’. The particle jumps ‘\( \tau \)’ times before reaching the position at time ‘\( \tau \)’. 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 fluctuation of closing price. The probability of a particle to be found in \( j^{th} \) cell at time ‘\( \tau \)’ is given by

\[
P_{j}(\tau) = \frac{K_{j}(\tau)}{K-\tau+1}, \text{ where } K_{j}(\tau) \text{ is number of particle in } j^{th} \text{ cell.}
\]

The diffusion entropy at time at time ‘\( \tau \)’ is given by

\[
S(\tau) = -\sum P_{j}(\tau) \ln(P_{j}(\tau)).
\]
The conditional entropy is defined as

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

where \( S_{\text{norm}}(\tau) = \frac{S(\tau)}{\tau} \) is normalised diffusion entropy and \( \beta \) is positive (negative) for bull (bear) market. The conditional entropy \( Con(\tau) \) 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.e. approximately 250 trading days with a shift of one month i.e. 21 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 \( (\tau) = 6 \) days. In present work, we use diffusion time of one week i.e. \( (\tau) = 6 \) daysto detect the weekly rise and fall in the returns of stocks. Taking \( (\tau) = 5, 6 \) and 7 days hardly makes any significant difference in the rise and fall patterns.

The normalized diffusion entropy \( S_{\text{norm}}(\tau) \) 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.
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Fig. 4: Conditional entropy of NSE Nifty50, BSE Sensex of 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 entropy of NIFTY50, SENSEX and DJIA indexes to 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 repossessions in post crisis period. We find that variations in the entropy values match with the financial crisis for 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 entropy plots 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


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