Published in: Decision. 34(1); 2007; 149-182.

PARAMETERS FOR ESTIMATION OF ENTROPY TO STUDY PRICE* MANIPULATION IN STOCK MARKET

Dr. Y.V.Reddy
Reader,
Department of Commerce,
Goa University,
GOA-403306
INDIA
yvreddy3@ rediffmail.com
yvreddy@unigoa.ac.in

A.Sebastin
Astt.Vice-President
National Stock Exchange of India Limited
Mumbai

ABSTRACT

The information theoretic concept of entropy is a useful tool in studying price manipulation in stock market. Sample entropy values computed for the price data of a scrip, for various trading days in the period during which the scrip is reported to be subject to price manipulation, prove to be potential evidence for manipulation of the scrip's price. An attempt is made in this paper to select appropriate values for the parameters used for computation of sample entropy of a short time series of stock prices.

Key words : Stock price manipulation, sample entropy, template size, tolerance limit, mutual information, relative error
Jel Classification : C02, C65, G19

*****Paper presented at 10th Capital Markets Conference organized by Indian Institute of Capital Markets(Formerly known as UTIICM),Mumbai, held on 18-19 December, 2006

PARAMETERS FOR ESTIMATION OF ENTROPY TO STUDY PRICE MANIPULATION IN STOCK MARKET

1. INTRODUCTION

Stock price manipulation has been studied by various authors over periods under different situations like insider trading, asymmetric information, corners, short squeezes, imperfect competition, financial signaling, equity offerings, takeover bids, ‘talking down’ the firm, bluffing and front running. Though literature abound the study of market microstructure in general and market manipulation in particular, there is a lot of scope for in-depth study of manipulation of prices in the stock market, using the concepts of stochastic calculus, game theory and information theory.

Mathematical modeling and statistical analysis of stock price movements has become a field of its own, starting from the Louis Bachelier’s Brownian motion model of 1900 to price warrants traded on the Paris bourse to the recent dynamical systems theory and neural networks. However, pollutants such as fraud and market manipulation seem nearly impossible to be modelled, yet are real and significantly alter price movements without any economic reasons. Simply incorporating fraud into a random effects component of a model fails because the extent of fraud is rarely chronic but is much more interrupted with the outcomes of a complicated game between regulatory efforts and corruptive creativity. So, a model independent (providing qualitative inferences across diverse model configurations) analytic tool to study price manipulation will be of effective utility.

As a path-breaking development in the field of game theory, researchers have presented the feasibility of online correlation in the strategies adopted by a group of players in a repeated game which is concealed from a player and discussed the conditions for the existence of concealed strategy in terms of entropy, in a theoretical game environment (Gilad Bavly and Abraham Neyman, 2003). It may be noted that trading in a stock market is similar to adopting mixed strategies in a repeated game and manipulating the price of a scrip is similar to building concealed correlation by a player or a group of players. Hence entropy of the bidding / offering strategies of the stock market participants may be analysed to study price manipulation in stock market.

2. ENTROPY – CONCEPT AND HISTORY

Entropy is a measure of uncertainty in a data set. The concept of entropy arose in physical sciences during the 19^{th} century. Clausius, building on the previous intuition of Carnot, introduced for the first time in 1867 a mathematical quantity S, which he called entropy that describes heat exchanges occurring in thermal processes via the relation $dS = dQ / T$ where Q denotes the amount of heat and T is the absolute temperature at which the exchange takes place. Ludwig Boltzmann derived that the Clausius entropy S associated with a system in equilibrium is proportional to the logarithm of the number W of microstates which form the macrostate of this equilibrium i.e. $S = k * \ln(W)$. Since then, the concept of entropy was extended to study microscopically unpredictable processes in a number of fields like stochastic processes and random fields, information and coding, data analysis and statistical inference, partial differential equations and rational mechanics. This led to the employment of diverse mathematical tools in dealing with the concept of entropy.

The theoretical foundation of entropic methods used in modern finance was formalised by the mathematicians Jacob Bernoulli and Abraham de Moivre. The concept of entropic analysis of equity prices was first proposed by Louis Bachelier in 1900, which anticipated many of the mathematical discoveries made later by Norbert Wiener and A.A.Markov in early nineties. J.L.Kelly, Jr. established the relationship between the information rate in a binary symmetric channel and speculation under uncertainty and made the large mathematical infrastructure of information theory, which was further developed by Claude Shannon in the mid 1940's. The Shannon's definition of entropy of a random variable X with p(x) as the probability mass function, is

$$H(X) = H(p) = - \sum_{x} p(x) \log p(x) = E [\log \{1/ p(x)\}]$$

where the base of the logarithm is 2 and 0 log 0 is taken as 0. Entropy is measured in bits and $0 \leq H(X) < \infty$. If logarithm is taken to the base e, then entropy is measured in nats. $H_a(X)$ denotes the entropy of X when logarithm is taken to some base a.

The introduction of metric entropy and the extension of classification theory of measure-preserving transformations, by Kolmogorov in the 1950's, led to significant advances. The uncertainty about the actual state of a system or process is measured by Shannon entropy. If the uncertainty is about predictions concerning the future of a process, it may be decreased by gaining information from the evolution of time itself. However, the dynamics of the process may go on producing new information at each successive stage so that forecasting is not made more reliable by knowledge of the past and this kind of uncertainty about the future is measured by Kolmogorov – Sinai (KS) entropy.

3. SELECTIVE STUDIES OF ENTROPIC ANALYSIS IN STOCK MARKET

The concept of entropy has been applied to describe financial market disequilibrium (David Nawrocki, 1984).

Entropy has been applied in devising a methodology for programmed trading of equities (John Conover, 1994).

The analysis of entropy tops and bottoms has been found as a useful addition to the buy and sell points of cyclic analysis (David T.Marantette, 1998).

The prices of stock options have been used to find a probability measure for the underlying stock and it has been derived that the probability vector with maximal entropy seems to be theoretically more justified than others (Wolfgang Kispert, 1999).

The stock market returns have been predicted by employing a new metric entropy measure which is capable of detecting non-linear dependence within the returns series (Esfandiar Maasoumi and Je Racine, 2000).

The utility of approximate entropy to assess subtle and potentially exploitable changes in the serial structure of a financial variable has been demonstrated (Steve Pincus and Rudolf E.Kalman, 2004).

It has been shown that most empirical evidences about market behaviour may be explained by a new information theory generalised from Shannon's entropy theory of information (Jing Chen, 2005).

4. ENTROPY AND STOCK PRICE MANIPULATION

Stock market analysts normally study shifts in mean levels and in variation (in various notations) to understand the state of the market, however the persistence of certain patterns or shifts may provide critical information. It may be noted that formulae to directly quantify randomness have not been used in market analysis perhaps due to the lack of a quantification technology until recently. So, excluding sequential patterns or features which presented themselves, subtler changes in serial structure would remain undetected largely. Volatility is generally equated to the variability of a scrip's price, with large swings normally denoted as highly volatile or unpredictable. However, there are two fundamentally distinct means by which data deviate from central tendency – (i) they have high variation (as may be measured by standard deviation) (ii) they appear highly irregular or unpredictable. These two non-redundant means have important consequences. The point is that the extent of variation in scrip prices is generally not feared but what concerns is the unpredictability in time and quantity of the variation. If a market participant is assured of a typical model, with large amplitude for future changes in the price of a scrip, it will not be frightening because future prices and resultant strategies may be planned. Thus a quantification technology to separate the concepts of classical variation and irregularity is of paramount importance.

In the electronic stock trading system, as market participants place orders for buying or selling the shares of a scrip at different prices and for various quantities, trades are effected by matching these orders according to price – time priority. A scrip's price is expected to change from time to time based on the fundamental factors of the scrip, its past history and the demand for the scrip. The prices at which, the times at which and the quantities for which, orders are placed by a participant, are expected to be in accordance with the prevalent market conditions and towards investment / speculative purpose. As the information related to and the perception on the price of a scrip change with time, a participant assigns values to these variables – price, time and quantity - with certain probabilities, while placing orders. Hence the order price, time and quantity in respect of a scrip may be considered as random variables with probability distributions.

Since Shannon's entropy is defined for a random variable with probability mass function p(x) as

$$H(p) = -\sum_{x} p(x) \log p(x)$$

we may compute the entropy for the random variables of order price, order time and order quantity in respect of a scrip for every participant, if only we can fit a probability distribution for each of these variables. So long as a participant places orders in the normal course of business, the entropy values of these variables will be in some ranges. Just as volatility of price differs from scrip to scrip and from time to time, the entropy also will vary from scrip to scrip, depending on the trading activity.

However, when a participant repeatedly places orders for buying / selling a scrip according to some pattern in the price or time or quantity, with a motive of manipulating the price of the scrip, the probability distributions of these variables undergo changes which will get reflected in the corresponding entropy values. It may be noted that such orders placed for manipulating the stock market will induce more regularity or persistence in the distributions and consequently entropy is likely to decrease. Large decrease in the entropy value from usual ranges for the respective variables may lead to potential evidence of price manipulation by a participant. Of course, regularity of such nature in the order related data may occur by chance rarely. However, repeated drops in the entropy values of the order related variables of a scrip in a span of a few trading days point to likely manipulation in the price of the scrip. As mentioned already, while volatility is an estimate of the variation of a scrip's price, entropy is concerned with the irregularity or randomness of the price fluctuations. Hence entropy is more suited than any measure of variation, to study manipulation of stock market.

5. APPROXIMATE ENTROPY AND SAMPLE ENTROPY

In the absence of publicly available participant-wise order data for buying / selling a stock, fitting probability distributions for order price, order time and order quantity is not possible and hence there is no way of computing Shannon entropy values. For any scrip, the only publicly available information are price, time and quantity of all trades resulting out of the orders placed by the market participants on any day and without the identity of the participants who are parties to the trades. Further, the number of trades per day in a particular scrip subject to manipulation, is typically in the range 25 – 200. Under the circumstances, tools for computing the entropy of short and noisy time series are required.

Traditional methods for estimating the entropy of a system represented by a time series are not well suited to analysis of short and noisy data sets. Various estimates such as plug-in estimates, sample spacing estimates, nearest neighbour estimates and tree estimates are used to approximate the entropy of a dynamical system. Entropies are also computed by means of non-parametric kernel methods which are generally used to estimate the density function of empirical data. Recently entropic graphs are applied to estimate entropy of manifolds. These procedures generally involve numerous computations and also require reasonably moderate number of data points for the convergence of the algorithms and for reliable results. Hence different versions of entropy like approximate entropy and sample entropy have been introduced for typically short and noisy time series. These measure the extent to which given data did not arise from a random process.

ApEn is a set of measures of serial irregularity and closely related to the entropy measure,. ApEn grades a continuum that ranges from totally ordered to maximally irregular (completely random). ApEn attempts to distinguish data sets on the basis of regularity and not to construct an accurate model of the data. ApEn measures the logarithmic likelihood that runs of patterns that are close remain close on next incremental comparisons. The intuition motivating ApEn is that if joint probability measures that describe each of two systems are different, then their marginal distributions on a fixed partition are likely to be different. ApEn assigns a non-negative number to a sequence or time series, with a larger value corresponding to greater apparent serial randomness or irregularity and a smaller value corresponding to more instances of recognizable features in the data. Two input parameters – a block or run length m and a tolerance window r, are required to be specified to compute ApEn. Thus, ApEn of a time series computes the logarithmic frequency that runs of patterns that are within r% of the SD (standard deviation) of the time series for m contiguous observations, remain within the same tolerance width r for m+1 contiguous observations. Normalising r to the SD of the time series makes ApEn translation and scale invariant, in that ApEn remains unchanged under uniform process magnification.

Let the given time series be $u_1, u_2, \ldots, u_N$.

For any m s.t. $1 \leq m < N$, define in $\Re^m$ the following m-tuples

$x_{m,1} = (u_1, u_2, \ldots, u_m)$

$x_{m,2} = (u_2, u_3, \ldots, u_{m+1})$

……….

$x_{m,i} = (u_i, u_{i+1}, \ldots u_{i+m-1})$

……….

$x_{m,N-\overline{m-1}} = (u_{N-\overline{m-1}}, u_{1+N-\overline{m-1}}, \ldots, u_N)$

Define $d(x_{m,i}, x_{m,j}) = \max |u_{i+k} - u_{j+k}|$ where k = 0,1,…,m-1

For r > 0, the r-neighbourhood of $x_{m,i}$ is $\{ x_{m,j} \in \Re^m / d(x_{m,i}, x_{m,j}) \leq r \}$

$\because$ $d(x_{m,i}, x_{m,i}) = 0 \;\; \forall$ i, the r-neighbourhood of any $x_{m,i}$ is never empty for any r, which is chosen generally as a % of the standard deviation of the data series $\{ u_i \}$.

Let $C_{m,i}(r) = \dfrac{\text{Number of } j \text{ s.t. } d(x_{m,i}, x_{m,j}) \leq r}{N - \overline{m-1}}$ = ratio of $x_{m,j}$'s in the r-neighbourhood of $x_{m,i}$

and $\Phi_m(r) = \dfrac{1}{N - \overline{m-1}} \displaystyle\sum_{i=1}^{N-\overline{m-1}} \log C_{m,i}(r)$

= average of the log of the ratios of $x_{m,j}$'s in the r-neighbourhood of any $x_{m,i}$

Then $\Phi_{m+1}(r) - \Phi_m(r) = \log \dfrac{\left[\prod_{i=1}^{N-m} C_{m+1,i}(r)\right]^{\frac{1}{N-m}}}{\left[\prod_{i=1}^{N-\overline{m-1}} C_{m,i}(r)\right]^{\frac{1}{N-\overline{m-1}}}}$ - - - - (1)

$$= \frac{\text{average of the log of the ratios of } (m+1) \text{ tuples in the r-neighbourhood of any } x_{m+1,i}}{\text{average of the log of the ratios of m-tuples in the r-neighbourhood of any } x_{m,i}}$$

The ratio in (1) is always ≤ 1 so that $-\infty < \Phi_{m+1}(r) - \Phi_m(r) \leq 0 \ \forall r \geq 0$ and m = 1,2,…,N.

Fixing m and r, ApEn = $Lt_{N \to \infty} \{\Phi_m(r) - \Phi_{m+1}(r)\}$

Given N data points, this formula is implemented by defining

ApEn(m,r,N) = $\Phi_m(r) - \Phi_{m+1}(r)$

Thus $0 \leq$ ApEn $< \infty$ with ApEn = 0 implying perfect regularity, since in such case $\Phi_m(r) = \Phi_{m+1}(r)$ i.e. the ratios of the m-tuples in close neighbourhoods remain the same as the ratios of (m+1)-tuples in close neighbourhoods. Small values of ApEn imply strong regularity or persistence in a sequence and large values of ApEn imply substantial fluctuation or irregularity. ApEn algorithm counts each sequence as matching itself, in order to avoid the occurrence of log 0 in the calculations. This leads to a bias which causes ApEn to lack two important properties

- ApEn is heavily dependent on the record length and is uniformly lower than expected for short records
- ApEn lacks relative consistency ie. if ApEn of a data set is higher than that of another, it should, but does not, remain higher for all conditions.

Hence a new statistic called sample entropy (SampEn) has been introduced to quantify irregularity in short and noisy time series (Joshua S.Richman and J.Randall Moorman, 2000). SampEn is a new family of statistics which is free of the bias caused by self-matching. SampEn is largely independent of record length and displays relative consistency under circumstances where ApEn does not. The name refers to the applicability to time series data sampled from a continuous process.

$\because x_{m+1,i}$ is not defined for i = $N - \overline{m-1}$, only the first (N – m) vectors of length m and all the (N –m) vectors of length m+1 are considered without self-matches in the calculation of SampEn.

Let $B_{m,i}(r) = \dfrac{\text{Number of } j \neq i \text{ s.t. } d(x_{m,i}, x_{m,j}) \leq r}{N - \overline{m+1}}$ where j = 1,2,…,N –m

and $B_m(r) = \dfrac{1}{N-m} \sum_{i=1}^{N-m} B_{m,i}(r)$

Similarly, let $B_{m+1,i}(r) = \dfrac{\text{Number of } j \neq i \text{ s.t. } d(x_{m+1,i}, x_{m+1,j}) \leq r}{N - \overline{m+1}}$ where j = 1,2,…,N –m

and $B_{m+1}(r) = \dfrac{1}{N-m} \sum_{i=1}^{N-m} B_{m+1,i}(r)$

Then SampEn(m,r) = $Lt_{N \to \infty} \log \left[\dfrac{B_{m+1}(r)}{B_m(r)} \right]$ which is estimated by the statistic

$$\text{SampEn}(m,r,N) = -\log\left[\frac{B_{m+1}(r)}{B_m(r)}\right]$$

There are two major differences between SampEn and ApEn statistics:

- SampEn does not count self-matches, which is justified on the ground that entropy being a measure of the rate of information production, comparing data with themselves is meaningless
- SampEn does not use a template-wise approach when estimating conditional probabilities

Since sample entropy addresses the drawbacks of approximate entropy, sample entropy of the time series of trade price, trade time and trade quantity of a scrip over a period may be used to discern serial irregularity and to study manipulation in the price of the scrip (Dr Y.V.Reddy and A.Sebastin, 2006).

6. PARAMETERS FOR SAMPLE ENTROPY ESTIMATION

6.1 Selection of values for parameters : SampEn(m,r) is precisely the negative natural logarithm of the conditional probability that a data set, having repeated itself within a tolerance r% for m points, will also repeat itself for m+1 points, without allowing self-matches. SampEn displays the property of relative consistency i.e. if SampEn of a data set is higher than that of another data set, for a set of values of the parameters m and r, it remains higher for any other values of the parameters also. However, for the purpose of comparing SampEn of the same variable over different periods of time, choosing appropriate values for the parameters m and r may be critical. Although no guidelines exist for optimising their values, generally values between 0.1 and 0.25 for r and values of 1 or 2 for m are used for data sets with length ranging from 100 to 5000. Informed selection of values for the parameters m and r is to be preferred to unguided use of the parameters based on unquestioned acceptance of the idea that differences in entropy estimates are always the result of differences in irregularity of the data. Optimal selection of the parameters is an unexplored area of paramount importance.

For picking the value of m, some authors have suggested the use of auto-regression (AR) models (Douglas E.Lake et al, 2002). The motivation for this approach is that if a data set is an AR process of order x, then $m \geq x$. To estimate m for a data set, AR model of various orders is fit to the data and the order corresponding to the minimum value of Schwarz Bayesian Criterion (SBC) or Aiken Information Criterion (AIC) is considered to be the order x of the process. In this article, it is proposed that the information theoretic concept of mutual information be used to estimate appropriate value for the parameter m.

6.2 Mutual information : The mutual information I(X;Y) between two random variables X and Y with a joint probability mass function p(x,y) and marginal mass functions p(x) and p(y), is defined as the relative entropy between the joint distribution p(x,y) and the product distribution p(x) p(y).

ie $I(X;Y) = D(p(x,y) \,\|\, p(x)\, p(y)) = \sum_x \sum_y p(x,y) \log \{p(x,y) / p(x)\, p(y)\}$

It may be noted that $I(X;Y) \geq 0$

$= 0$ iff X and Y are independent.

Also, I(X;Y) = H(X) – H(X / Y) = H(Y) – H(Y / X) where H denotes the entropy.
i.e. mutual information is the reduction in the uncertainty of X due to the knowledge of Y and vice versa. Due to symmetry, X says as much about Y as Y says about X.
Also, I(X;Y) = H(X) + H(Y) – H(X,Y) and I(X;X) = H(X).
Thus the mutual information of a random variable with itself is the entropy of the random variable. That is why, entropy is referred to as self-information.

6.3 Mutual information of a time series : The mutual information I(m) between a time series $\{u_1, u_2, \ldots, u_N\}$ and itself with a delay of m viz. $\{u_{m+1}, u_{m+2}, \ldots, u_N\}$ measures the information carried over by the delayed time series from the original time series. If I(m) is small or around 0, then the two time series are essentially independent and if I(m) is very large, then the delayed series is related to the original series. If the delay m is too short, then the delayed series is similar to the original series and when the data are plotted, most of the observations will lie near the line $u_{m+i} = u_i$ and I(m) will tend to be large. If the delay m is too long, then the data are independent and no information can be gained from the plot and I(m) will tend to be small.

6.4 Template size m : It may be noted that the computation of SampEn of a time series involves construction of templates of size m from the scalar observations forming the time series and counting the number of such templates in the neighbourhood (i.e. within a distance of r) of each such template. A good choice for m is such that contiguous templates of size m constructed from the time series are not within the neighbourhood of one another. Such a choice is provided by the value of m corresponding to which the mutual information of the time series with delay m viz. I(m) is small and consequently the contiguous templates are independent to a large extent. As m is increased, I(m) decreases and may rise again and hence the first minimum of I(m) may be considered to choose the value of m. It may also be noted that in the construction of multidimensional phase portrait from a scalar time series, the time delay T that produces the first local minimum of the mutual information of the time series has been suggested to be used (Andrew M.Fraser and Harry L.Swinney, 1986). Since mutual information measures the general dependence between two variables or between two time series of the same variable with time delay, it provides a better criterion for the choice of m than the autocorrelation function which measures only linear dependence.

6.5 Tolerance limit r : If A is the number of templates of size m which match within a tolerance level of r and B is the number of templates out of A which matches for template size m+1also, then B / A estimates the conditional probability P of match of template size m+1 given that there is a match of template size m and SampEn is – log(P). We know that for any differentiable function f of a random variable X, the standard deviation $\sigma_{f(X)}$ is approximated by | f '(X) | σ_X . Hence we have $\sigma_{SampEn} = \sigma_P / P$ and thus the standard error of SampEn is the relative error of P.

r is to be chosen in such a way that it is neither so stringent that the number of matches is too near 0 (low confidence) nor so relaxed that P is too near 1 (low discrimination). r may be selected so as to minimise the quantity max $[\frac{\sigma_P}{P}, \frac{\sigma_P}{-P\log(P)}]$ which is the maximum of the relative errors of the estimate of P and and SampEn. This efficiency metric favours estimates with low variance and thus reflects the efficiency of the entropy estimate. This criterion also represents a trade-off between accuracy and discrimination capability as it simultaneously penalises P near 0 and near 1. Given a value of m based on the first minimum of the mutual information of the stock price time series, an optimal value of r can be selected to minimise the efficiency metric.

7. CASE STUDY

The scrip of the company M/s Morepen Hotels Ltd., which has been reported to be subject to price manipulation in the course of trading on the National Stock Exchange of India Limited (NSEIL) on various days during the period September 2000 – March 2001 (www.sebi.com) was chosen for the study. The prices of all the trades executed in the scrip on the NSEIL were taken for the various trading days during this period. The differences in the prices of successive trades were taken as time series, for the various trading days since daily rolling settlement is followed in NSEIL. Trade data were available for 16 trading days in September 2000, 15 trading days in October 2000, 14 trading days in November 2000, 20 trading days in December 2000, 22 trading days in January 2001, 20 trading days in February 2001 and 21 trading days in March 2001and thus a total of 128 time series of price differences of successive trades on a day formed the data set. Of these, 50 time series have less than 50 data points, 70 have data points in the range 50 – 100 and 8 have data points in the range 100 – 200.

For deciding the template size m in the computation of SampEn for each time series, the mutual information of each time series for the various trading days was calculated with time lag ranging from 1 to 20. The values are presented in tables I to IV. It may be observed that the first minimum of mutual information generally occurred for the time lag between 2 and 5 and hence SampEn may be calculated for template size m = 2, 3, 4 or 5. For time series with a few hundreds of data points, the optimum value of r has been observed to lie between 0.15 and 0.20 if the template size m is assigned a value between 2 and 5.

Accordingly, SampEn of the time series consisting of the differences in successive trade prices of the scrip of M/s Morepen Hotels Ltd. was computed for m = 2, 3, 4, 5 and r = 0.15, 0.16, 0.17, 0.18, 0.19, 0.20 These SampEn values for the various trading days during the period September 2000 – March 2001 are given in tables V to XI respectively. It may be observed that SampEn is very low on days 2, 3, 4, 8, 11 and 12 in September 2000, on days 11 and 12 October 2000, on days 6, 18, 19 and 21 in January 2001, on days 4, 6, 7, 8, 9, 10, 12,13, 14, 15, 16, 17, 18 and 20 in February 2001 and on days 1, 2, 3, 4, 6, 7, 8, 9, 13, 14, 16, 18 and 19 in March 2001, for all values of m and r. Specifically, SampEn for all these days is utmost 0.250 for m = 5 and r = 0.20*SD. Also, SampEn was less than 0.1 on a few days implying high level of regularity in the data pertaining to these days. The above mentioned days in September 2000 – March 2001, in respect of which SampEn is very low, are days of potential manipulation in the price of the scrip of M/s Morepen Hotels Ltd. Further, it appears that manipulation has been rampant in the months of February and March 2001 since sample entropy has remained at very low level continuously for many days. The order related data for the scrip, pertaining to these days may be analysed further to observe the trading patterns of the participants and discern price manipulation attempt by any participant.

8. CONCLUSION

Entropic analysis is a novel area as for as the Indian stock market is concerned and there is almost a vacuum in research efforts in the application of entropic analysis in the Indian stock market. This paper applies entropic analysis to study price manipulation in the Indian stock market and sample entropy is found to be suited for this study. SampEn values for the trade price data related to the scrip of M/s Morepen Hotels Ltd., for various trading days in the period during which it was reported to be subject to price manipulation, are found to support such reporting. The values of the parameters required in the computation of SampEn - the template size m and the tolerance limit r – are not to be assigned arbitrarily but m may be chosen on the basis of minimum mutual entropy of the trade price time series so as to enhance the independence of the templates to a large extent and r may be chosen on the basis of minimum relative error of sample entropy so as to reduce the variance of the entropy estimate to a large extent. This empirical analysis is to be done for many other scrips in order that entropic analysis is considered as an effective tool to study stock market manipulation. Further, entropic analysis of order related data (if available) will ensure more efficiency in the study of price manipulation attempts in the stock market.

REFERENCES

1. Gilad Bavly and Abraham Neyman, "Online concealed correlation by boundedly rational players", DP 336, 2003, www.ratio.huji.ac.il/neyman/publications
2. David Nawrocki, "Entropy, bifurcation and dynamic market disequilibrium", The Financial Review, May 1984
3. John Conover , "NtropiX", 1994, www.johncon.com
4. David T.Marantette, "The entropy danger", 1998, www.goldstock.com
5. Wolfgang Kispert, "Implicit distributions in stock markets – estimation with a maximum entropy procedure", www.lrz-muenchen.de/projekte/hlr-projects/1997-1999
6. Esfandiar Maasoumi and Je Racine, "Entropy and predictability of stock market returns", UCSD working paper, 2000
7. Steve Pincus and Rudolf E.Kalman, "Irregularity, volatility, risk and financial market time series", Proceedings of the National Academy of Sciences 2004
8. Jing Chen, "Information theory and market behaviour" , University of Northern British Columbia working paper, 2005
9. Joshua S.Richman and J.Randall Moorman, "Physiological time-series analysis using approximate entropy and sample entropy", American Journal of Physiology, 2000
10. Y.V.Reddy and A.Sebastin, "Measuring stock price manipulation using entropy analysis: a conceptual framework", The ICFAI Journal of Applied Finance, Vol. 12, No. 5, 2006
11. Douglas E. Lake, Joshua S.Richman, M.Pamela Griffin and J.Randall Moorman, "Sample entropy analysis of neonatal heart rate variability", American Journal of Physiology, 283, 2002
12. Andrew M.Fraser and Harry L.Swinney, "Independent coordinates for strange attractors from mutual information", Physical Review A, Vol. 33, No. 2, 1986

Table I – Mutual information for the trade price time series - September 2000

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16
0	5	6	5	6	4	5	5	5	4	2	4	4	4	3	4	0
1	2.438	2.063	2.5	3.531	1.25	1.563	1.438	4	0.75	0	1.125	1.125	1.375	1	1.125	0
2	1.25	2.094	1.625	3	0.75	0.938	1.563	3.313	1.125	2	0.75	0.75	1.25	1	1	0
3	1.875	1.219	1.688	2.438	1	1.438	1.938	2.188	1.125	0	1	1	1.25	1	1	0
4	1.313	2.031	1.813	2.531	0.5	1.375	1.625	1.813	1	2	1	1	0.5	1	1	0
5	1.313	1.656	1.438	2	1	1.438	2	1.813	1	2	0.875	0.875	0.5	1	1	0
6	1.125	1.656	1.688	1.656	1	1.25	1.438	1.75	1.125	0	0.875	0.875	1	1	1	0
7	1.375	1.875	1.125	2	1	1	1.5	1.188	1.375	2	1.625	1.625	1.75	1	1	0
8	1.625	1.75	1.875	2.219	1	0.875	1.313	1.25	1.625	0	1.125	1.125	1.75	1	0.75	0
9	1.5	2.125	1.688	1.594	1	1.5	1.438	1.313	1.125	2	1.25	1.25	1.75	0.5	1	0
10	1.813	1.531	1.625	1.375	1.5	1.313	1.438	1.5	1.25	0	1	1	1.75	1	0.75	0
11	1.938	1.906	1.5	1.719	0.5	1.438	1.438	2.875	1.125	0	0.5	0.5	1.75	0.5	1	0
12	1.563	1.844	1.75	1.656	1.375	1	1.563	1.938	1	0	0.875	0.875	1.375	1	0.875	0
13	1.625	2.531	1.688	1.938	0.5	1.125	1.313	1.813	1.625	2	0.875	0.875	1.75	1	0.875	0
14	1.938	1.75	1.313	2.063	1.125	1.188	1.438	1.688	1.5	2	0.5	0.5	1.5	1	1	0
15	1.563	2.125	1.875	1.625	1.25	1.313	1.063	1.5	1.375	0	1.5	1.5	1.75	1	1	0
16	1.625	1.5	1.438	1.656	1.25	1.688	1.875	1.438	1	0	1.375	1.375	1.25	1	1	0
17	1.75	1.688	1.625	1.844	1	1.313	2	1.375	0.875	2	1.375	1.375	1.5	1	1	0
18	2.313	1.906	1.25	2.063	1.5	1.375	1.438	1.625	1	0	1.25	1.25	1.5	1	1	0
19	2	1.875	1.438	1.875	1	1.5	1.875	1.375	0.5	2	0.875	0.875	1.25	1	1.375	0
20	2.438	1.938	1.5	1.531	0.75	1.375	1.75	1.5	1	0	0.875	0.875	1.5	0.5	0.5	0

Table II – Mutual information for the trade price time series - October 2000

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15
0	4	1	4	3	3	3	1	0	4	4	3	4	5	4	4
1	1.25	1	1	1	1	1	1	0	1.625	1.625	1	1.25	1.3125	1.5	2
2	1.25	1	1.75	1	1	1	1	0	0.75	0.875	1	0.75	1.375	1.25	0.875
3	0.5	1	1.625	1	1	1.5	1	0	1	1.125	1	0.5	1.125	1	0.75
4	1.375	1	1	1	0.5	1	1	0	1	1.25	1	0.75	1	1.625	1
5	2.5	1	1.5	1	3	0.5	1	0	0.5	1.625	1	1.125	1.1875	1.25	0.5
6	1.625	1	1.125	1	0.5	1	1	0	0.5	1.125	1	0.75	1.1875	1.875	1
7	1	1	1.25	1	1	1	1	0	1	1	1	1.25	0.8125	1.25	0.75
8	1.25	1	1.375	1.5	1	1	1	0	0.75	1	1	0.5	1.125	1	1.375
9	0.875	1	1.5	1	1	1	1	0	1.25	1.125	1	1	1.125	1	0.75
10	1.125	1	1	1	0.5	0.5	1	0	0.75	1.25	1	1.125	0.875	1.75	1
11	1.5	1	1.75	0.5	1	1	1	0	1.125	1	1	1	0.8125	1.25	1
12	1	1	1.25	1	1	1	1	0	1	1.625	1	1	1.125	1	0.75
13	1.25	1	1.125	1	1	1	1	0	1	1.5	1	1	1.375	1	1
14	1.5	1	1	1	1	1	1	0	0.75	1.25	1	0.75	1	1.625	2
15	1.75	1	0.75	1	1	1	1	0	0.5	1.25	1	1.375	1.125	1.375	1.125
16	1.25	1	0.75	0.5	1	1	1	0	1.25	0.75	0.5	0.875	1.125	0.75	1.125
17	1.375	1	1	0.5	1	1	1	0	1.125	0.75	1	1	1.3125	1	1.25
18	1.25	1	1.125	1	1	1	1	0	1	0.75	1	0.75	0.8125	1.25	1
19	1	1	1.25	1	0.5	0.5	1	0	1	0.875	0.5	1.25	1.125	0.875	1
20	1	1	1.75	1	1	1	1	0	1.375	0.75	0.5	1.25	1.0625	1.125	1.625

Table III – Mutual information for the trade price time series - November 2000

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13
0	1	4	4	4	2	2	1	0	1	1	3	3	2
1	1	1.375	1.375	1.5	0	0	1	0	1	1	1	2	0
2	1	0.75	1	1.25	2	2	1	0	1	1	1	1	2
3	1	0.5	1.5	1.125	0	2	1	0	1	1	1	1	0
4	1	1	1.375	1	0	0	1	0	1	1	1	1.5	0
5	1	1.375	1.5	0.75	0	0	1	0	1	1	0.5	1	2
6	1	0.5	1.25	1.375	0	2	1	0	1	1	1	1	0
7	1	0.75	1.375	0.75	2	2	1	0	1	1	1	1	2
8	1	1	1.375	1.125	0	2	1	0	1	1	1	1	0
9	1	1.125	1.375	1	2	0	1	0	1	1	1	1	0
10	1	0.875	0.75	1	0	0	1	0	1	1	0.5	1	0
11	1	0.5	1.375	1	0	0	1	0	1	1	1	1	2
12	1	1	1	1.125	2	2	1	0	1	1	1	1	0
13	1	1.375	1.375	1.625	0	2	1	0	1	1	1	0.5	0
14	1	0.75	1	0.5	0	2	1	0	1	1	0.5	1	0
15	1	1.5	0.75	1.75	0	2	1	0	1	1	1	2	0
16	1	2	1	1.25	0	2	1	0	1	1	1	1	0
17	1	1.25	0.75	1	2	2	1	0	1	1	1	1	0
18	1	1	1.25	1.125	0	2	1	0	1	1	1	0.5	0
19	1	1	1	0.75	0	0	1	0	1	1	1	1	0
20	1	1.62	1.25	1	2	0	1	0	1	1	1	1	2

Table IV – Mutual information for the trade price time series - December 2000

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19
0	3	3	4	4	3	2	2	4	1	4	3	3	2	1	3	3	4	3	5.000
1	1	1	1.125	0.5	1	0	0	1.25	1	1	0.5	0.5	0	1	1	1	1.625	0.5	2.875
2	1.5	0.5	1.25	2.125	1	0	2	1	1	0.5	1	0.5	0	1	1	1	1.5	1	1.750
3	0.5	1	0.75	1.125	1	0	2	1.375	1	1	0.5	1	0	1	0.5	1	1.125	1	1.063
4	0.5	0.5	2	1.25	1	2	0	0.75	1	1	1	1	0	1	1	1	1.125	1	1.625
5	1	1	1.75	2.125	1	2	0	1	1	0.875	1	1	2	1	1.5	1	1.25	1	1.938
6	1	1	1.375	1	1	2	2	1	1	1.125	0.5	1	2	1	1	1	1.75	1	1.875
7	0.5	1	1	1.5	0.5	2	2	1.625	1	1.125	1	1	2	1	1	1	0.875	0.5	1.750
8	1	1.5	0.75	1.25	1	2	0	0.5	1	1.5	1	1	2	1	1	1	1.125	1.5	1.563
9	1	0.5	0.75	1	1	2	0	1	1	1.375	1	1	2	1	1	1	1.625	0.5	1.375
10	1	1	0.75	1.5	1	2	0	0.875	1	0.75	1	1	2	1	1	1	1.125	1	1.813
11	1	1	1	1.25	1	2	2	0.75	1	1	1	1	0	1	0.5	1	0.75	1	1.813
12	1	1.5	0.5	1.125	1	0	2	1.25	1	1	1	0.5	0	1	1	1	0.5	1	1.625
13	0.5	1	1.125	1.125	0.5	0	0	0.5	1	1	1	1	0	1	1	0.5	1	1	1.438
14	1	1	1	1.875	1	2	0	1	1	1.125	1	1	0	1	1	1	0.75	1	1.750
15	1	1	0.75	1.875	0.5	2	0	1	1	0.5	1	1	0	1	1	1	0.75	0.5	1.688
16	0.5	1.5	1	1.375	0.5	2	0	1.125	1	1	1	1	0	1	0.5	0.5	1.125	0.5	1.500
17	1	0.5	1.625	1.375	1	2	2	0.5	1	1.125	0.5	1	0	1	1	1	1	0.5	1.375
18	1	1	1.5	2	1	2	2	0.75	1	1.75	1	1	2	1	1	1	1.5	0.5	1.375
19	1	1	1.75	1.5	1	2	0	1.25	1	1	1	0.5	2	1	1	1	0.875	1	1.375
20	1	1	1	1.75	1	2	0	1.125	1	1	1	1	2	1	1	1	0.5	1	1.625

Table V – SampEn values for September 2000

m, r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16
2, 0.15	0.28	0.23	0.21	0.25	0.44	0.56	0.29	0.17	0.40	1.10	0.22	0.22	0.54	0.22	0.27	0.38
2, 0.16	0.28	0.23	0.21	0.25	0.44	0.56	0.29	0.17	0.40	1.10	0.22	0.22	0.55	0.22	0.25	0.38
2, 0.17	0.28	0.23	0.21	0.25	0.44	0.56	0.29	0.16	0.40	1.10	0.23	0.23	0.55	0.22	0.25	0.38
2, 0.18	0.28	0.23	0.21	0.25	0.44	0.56	0.29	0.16	0.40	1.10	0.23	0.23	0.56	0.22	0.25	0.38
2, 0.19	0.28	0.23	0.21	0.25	0.44	0.56	0.29	0.15	0.52	0.63	0.22	0.22	0.56	0.22	0.25	0.38
2, 0.20	0.28	0.23	0.21	0.25	0.44	0.56	0.29	0.15	0.52	0.63	0.22	0.22	0.20	0.22	0.25	0.38
3, 0.15	0.26	0.23	0.24	0.28	0.41	0.50	0.19	0.23	0.34	1.10	0.24	0.24	0.39	0.22	0.32	0.22
3, 0.16	0.26	0.23	0.24	0.28	0.41	0.50	0.19	0.23	0.34	1.10	0.24	0.24	0.39	0.22	0.29	0.22
3, 0.17	0.26	0.23	0.24	0.28	0.41	0.50	0.19	0.23	0.34	1.10	0.25	0.25	0.39	0.22	0.29	0.22
3, 0.18	0.26	0.23	0.24	0.28	0.40	0.50	0.19	0.23	0.34	1.10	0.25	0.25	0.40	0.22	0.29	0.22
3, 0.19	0.26	0.23	0.24	0.28	0.41	0.50	0.19	0.21	0.35	0.69	0.25	0.25	0.40	0.22	0.29	0.22
3, 0.20	0.26	0.23	0.24	0.28	0.42	0.50	0.19	0.21	0.35	0.69	0.25	0.25	0.21	0.22	0.29	0.22
4, 0.15	0.29	0.26	0.22	0.22	0.50	0.63	0.21	0.26	0.38	6.04	0.13	0.13	0.31	0.25	0.38	0.25
4, 0.16	0.29	0.26	0.22	0.22	0.50	0.63	0.21	0.26	0.38	6.04	0.13	0.13	0.31	0.25	0.33	0.25
4, 0.17	0.29	0.26	0.22	0.22	0.50	0.63	0.21	0.26	0.38	6.04	0.13	0.13	0.31	0.25	0.33	0.25
4, 0.18	0.29	0.26	0.22	0.22	0.49	0.63	0.21	0.26	0.38	6.04	0.13	0.13	0.31	0.25	0.33	0.25
4, 0.19	0.29	0.26	0.22	0.22	0.49	0.63	0.21	0.24	0.37	0.29	0.13	0.13	0.31	0.25	0.33	0.25
4, 0.20	0.29	0.25	0.22	0.22	0.49	0.63	0.21	0.24	0.37	0.29	0.13	0.13	0.23	0.25	0.33	0.25
5, 0.15	0.44	0.25	0.25	0.20	0.42	0.66	0.24	0.23	0.47	6.04	0.14	0.14	0.38	0.29	0.46	0.29
5, 0.16	0.44	0.25	0.25	0.20	0.42	0.66	0.24	0.23	0.47	6.04	0.14	0.14	0.38	0.29	0.40	0.29
5, 0.17	0.44	0.25	0.25	0.20	0.42	0.66	0.24	0.23	0.47	6.04	0.14	0.14	0.38	0.29	0.40	0.29
5, 0.18	0.44	0.25	0.25	0.20	0.41	0.66	0.24	0.23	0.47	6.04	0.14	0.14	0.38	0.29	0.40	0.29
5, 0.19	0.44	0.25	0.25	0.20	0.41	0.66	0.24	0.21	0.45	0.41	0.15	0.15	0.38	0.29	0.40	0.29
5, 0.20	0.44	0.25	0.25	0.20	0.41	0.66	0.24	0.21	0.45	0.41	0.15	0.15	0.27	0.29	0.40	0.29

Table VI – SampEn values for October 2000

m, r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15
2, 0.15	0.45	5.72	0.76	1.05	0.27	0.82	0.57	0.18	0.75	0.71	0.12	0.14	0.43	1.01	0.47
2, 0.16	0.45	5.72	0.76	1.05	0.27	0.82	0.50	0.18	0.75	0.71	0.12	0.14	0.43	0.81	0.49
2, 0.17	0.45	5.72	0.76	1.10	0.25	0.78	0.50	0.18	0.75	0.67	0.11	0.13	0.42	0.81	0.49
2, 0.18	0.45	5.72	0.76	1.10	0.25	0.57	0.50	0.18	0.72	0.67	0.11	0.13	0.37	0.72	0.49
2, 0.19	0.45	5.72	0.76	1.13	0.24	0.57	0.50	0.17	0.72	0.67	0.11	0.13	0.34	0.72	0.50
2, 0.20	0.45	5.72	0.76	1.13	0.15	0.57	0.50	0.17	0.72	0.67	0.10	0.13	0.33	0.69	0.50
3, 0.15	0.36	5.72	0.29	1.25	0.30	1.45	0.35	0.19	0.78	0.74	0.12	0.16	0.46	1.39	0.45
3, 0.16	0.34	5.72	0.29	1.25	0.30	1.45	0.29	0.19	0.78	0.74	0.12	0.15	0.46	1.16	0.44
3, 0.17	0.34	5.72	0.29	1.25	0.29	1.30	0.29	0.19	0.78	0.83	0.11	0.14	0.43	1.16	0.44
3, 0.18	0.35	5.72	0.29	1.25	0.29	0.86	0.29	0.19	0.71	0.83	0.11	0.14	0.40	0.88	0.44
3, 0.19	0.35	5.72	0.29	0.69	0.27	0.86	0.29	0.19	0.71	0.83	0.11	0.14	0.37	0.88	0.44
3, 0.20	0.35	5.72	0.29	0.69	0.16	0.86	0.29	0.19	0.71	0.83	0.10	0.14	0.35	0.86	0.44
4, 0.15	0.21	5.72	0.34	6.23	0.35	6.55	0.41	0.21	0.99	0.40	0.13	0.16	0.41	1.95	0.37
4, 0.16	0.26	5.72	0.34	6.23	0.35	6.55	0.34	0.21	0.99	0.40	0.13	0.16	0.41	1.65	0.37
4, 0.17	0.26	5.72	0.34	6.23	0.33	2.71	0.34	0.21	0.99	0.38	0.12	0.15	0.35	1.65	0.37
4, 0.18	0.25	5.72	0.34	6.23	0.33	1.61	0.34	0.21	0.83	0.38	0.12	0.15	0.32	1.15	0.34
4, 0.19	0.25	5.72	0.34	0.92	0.33	1.61	0.34	0.21	0.83	0.38	0.12	0.15	0.28	1.15	0.36
4, 0.20	0.25	5.72	0.34	0.92	0.30	1.61	0.34	0.21	0.83	0.38	0.11	0.15	0.26	1.08	0.36
5, 0.15	0.21	5.72	0.41	6.23	0.42	6.55	0.13	0.31	1.18	0.46	0.14	0.18	0.37	7.55	0.46
5, 0.16	0.21	5.72	0.41	6.23	0.42	6.55	0.41	0.31	1.18	0.46	0.14	0.17	0.37	0.92	0.45
5, 0.17	0.21	5.72	0.41	6.23	0.39	6.55	0.41	0.31	1.18	0.45	0.12	0.16	0.32	0.92	0.45
5, 0.18	0.20	5.72	0.41	6.23	0.39	6.55	0.41	0.31	1.04	0.45	0.12	0.16	0.29	1.03	0.43
5, 0.19	0.20	5.72	0.41	0.00	0.39	6.55	0.41	0.26	1.04	0.45	0.12	0.16	0.26	1.03	0.43
5, 0.20	0.20	5.72	0.41	0.00	0.34	6.55	0.41	0.26	1.04	0.45	0.11	0.16	0.23	0.98	0.43

Table VII – SampEn values for November 2000

m, r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14
2, 0.15	0.88	1.03	1.21	0.96	0.83	1.18	0.49	0.82	1.39	5.35	1.30	1.61	1.50	6.04
2, 0.16	0.77	1.03	1.21	0.96	0.83	1.18	0.38	0.66	1.39	5.35	1.30	1.61	1.50	6.04
2, 0.17	0.58	1.03	1.21	0.84	0.75	1.39	0.34	0.66	1.50	2.20	1.25	1.01	1.67	6.04
2, 0.18	0.64	1.03	1.21	0.64	0.67	1.39	0.35	0.73	1.30	2.20	1.25	1.01	1.67	1.39
2, 0.19	0.69	1.03	1.21	0.55	0.67	1.39	0.32	0.54	1.39	1.30	1.39	1.01	1.57	1.39
2, 0.20	0.69	1.03	1.21	0.55	0.67	1.39	0.28	0.47	1.39	1.10	1.39	1.01	1.57	1.39
3, 0.15	0.92	0.73	1.83	0.77	1.54	5.84	0.55	0.79	5.72	5.35	1.10	6.48	6.63	6.04
3, 0.16	0.69	0.73	1.83	0.77	1.54	5.84	0.44	0.56	5.72	5.35	1.10	6.48	6.63	6.04
3, 0.17	0.81	0.73	1.87	0.68	1.28	5.84	0.39	0.56	5.72	5.35	1.39	1.39	1.10	6.04
3, 0.18	0.81	0.73	1.87	0.64	1.15	5.84	0.41	0.56	5.72	5.35	1.39	1.39	1.10	6.04
3, 0.19	0.81	0.73	1.87	0.54	1.15	5.84	0.41	0.54	5.72	1.10	1.39	1.39	1.61	6.04
3, 0.20	0.81	0.73	1.87	0.54	1.15	5.84	0.32	0.51	5.72	1.39	1.39	1.39	1.61	6.04
4, 0.15	0.69	1.03	7.14	1.00	5.84	5.84	0.64	0.92	5.72	5.35	5.61	6.48	6.63	6.04
4, 0.16	0.41	1.03	7.14	1.00	5.84	5.84	0.53	0.69	5.72	5.35	5.61	6.48	6.63	6.04
4, 0.17	0.69	1.03	7.14	0.77	5.84	5.84	0.53	0.69	5.72	5.35	5.61	6.48	6.63	6.04
4, 0.18	0.69	1.03	7.14	0.76	5.84	5.84	0.53	0.69	5.72	5.35	5.61	6.48	6.63	6.04
4, 0.19	0.69	1.03	7.14	0.61	5.84	5.84	0.54	0.69	5.72	5.35	5.61	6.48	6.63	6.04
4, 0.20	0.69	1.03	7.14	0.61	5.84	5.84	0.44	0.69	5.72	5.35	5.61	6.48	6.63	6.04
5, 0.15	5.61	1.61	7.14	0.85	5.84	5.84	0.51	5.48	5.72	5.35	5.61	6.48	6.63	6.04
5, 0.16	0.69	1.61	7.14	0.85	5.84	5.84	0.35	1.39	5.72	5.35	5.61	6.48	6.63	6.04
5, 0.17	0.69	1.61	7.14	0.62	5.84	5.84	0.29	1.39	5.72	5.35	5.61	6.48	6.63	6.04
5, 0.18	0.69	1.61	7.14	0.69	5.84	5.84	0.29	1.39	5.72	5.35	5.61	6.48	6.63	6.04
5, 0.19	0.69	1.61	7.14	0.75	5.84	5.84	0.34	0.85	5.72	5.35	5.61	6.48	6.63	6.04
5, 0.20	0.69	1.61	7.14	0.75	5.84	5.84	0.32	0.59	5.72	5.35	5.61	6.48	6.63	6.04

Table VIII – SampEn values for December 2000

m, r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19	Day20
2, 0.15	6.31	6.40	1.66	1.95	0.83	6.23	6.14	1.95	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	1.95	0.49	1.23	0.54
2, 0.16	6.31	6.40	1.39	1.95	0.83	6.23	6.14	1.95	6.90	5.72	6.90	6.40	6.48	6.04	5.72	1.50	1.95	0.49	1.23	0.54
2, 0.17	6.31	6.40	1.54	1.95	0.73	6.23	6.14	1.95	6.90	5.72	6.90	6.40	6.48	6.04	5.72	1.50	1.95	0.47	1.23	0.54
2, 0.18	6.31	6.40	1.54	1.95	0.73	6.23	6.14	2.30	6.90	5.72	6.90	6.40	6.48	6.04	5.72	1.54	1.95	0.47	1.23	0.54
2, 0.19	6.31	6.40	1.39	1.95	0.73	6.23	6.14	2.30	6.90	5.72	6.90	6.40	6.48	6.04	1.39	1.54	1.91	0.47	1.23	0.54
2, 0.20	6.31	6.40	1.39	1.95	0.73	6.23	6.14	2.30	6.90	5.72	6.90	6.40	6.48	6.04	1.39	1.61	1.91	0.51	1.23	0.54
3, 0.15	6.31	6.40	6.70	6.96	0.86	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.74	2.49	0.40
3, 0.16	6.31	6.40	6.70	6.96	0.86	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.74	2.49	0.40
3, 0.17	6.31	6.40	6.70	6.96	0.68	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.69	2.49	0.40
3, 0.18	6.31	6.40	6.70	6.96	0.68	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.69	2.49	0.40
3, 0.19	6.31	6.40	2.20	6.96	0.68	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.69	2.49	0.40
3, 0.20	6.31	6.40	2.20	6.96	0.68	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.68	2.49	0.40
4, 0.15	6.31	6.40	6.70	6.96	0.79	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.74	6.77	0.25
4, 0.16	6.31	6.40	6.70	6.96	0.79	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.74	6.77	0.25
4, 0.17	6.31	6.40	6.70	6.96	0.59	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.69	6.77	0.25
4, 0.18	6.31	6.40	6.70	6.96	0.59	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.69	6.77	0.25
4, 0.19	6.31	6.40	6.70	6.96	0.59	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.69	6.77	0.25
4, 0.20	6.31	6.40	6.70	6.96	0.59	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.76	6.77	0.25
5, 0.15	6.31	6.40	6.70	6.96	0.51	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.92	6.77	0.29
5, 0.16	6.31	6.40	6.70	6.96	0.51	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.92	6.77	0.29
5, 0.17	6.31	6.40	6.70	6.96	0.41	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.77	6.77	0.29
5, 0.18	6.31	6.40	6.70	6.96	0.41	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.77	6.77	0.29
5, 0.19	6.31	6.40	6.70	6.96	0.41	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.77	6.77	0.29
5, 0.20	6.31	6.40	6.70	6.96	0.41	6.23	6.14	6.04	6.90	5.72	6.90	6.40	6.48	6.04	5.72	6.31	6.63	0.85	6.77	0.29

Table IX – SampEn values for January 2001

m, r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19	Day20	Day21	Day22
2, 0.15	0.95	1.06	0.88	0.78	0.55	0.22	0.46	0.46	0.64	0.64	0.53	0.79	1.06	1.67	0.30	0.62	0.53	0.15	0.22	0.78	0.25	0.50
2, 0.16	0.95	1.06	0.85	0.57	0.55	0.22	0.46	0.46	0.64	0.64	0.53	0.79	1.06	1.67	0.30	0.62	0.53	0.15	0.22	0.78	0.25	0.50
2, 0.17	0.95	1.06	0.85	0.57	0.55	0.22	0.46	0.46	0.64	0.64	0.53	0.79	1.06	1.67	0.30	0.62	0.53	0.15	0.22	0.78	0.25	0.50
2, 0.18	0.95	1.06	0.85	0.57	0.55	0.16	0.33	0.46	0.64	0.64	0.53	0.37	1.06	1.67	0.30	0.62	0.53	0.15	0.22	0.58	0.25	0.35
2, 0.19	0.95	1.00	0.85	0.57	0.55	0.16	0.33	0.46	0.64	0.64	0.53	0.37	1.06	1.67	0.30	0.62	0.53	0.15	0.22	0.58	0.25	0.35
2, 0.20	0.95	1.00	0.85	0.57	0.55	0.16	0.33	0.46	0.64	0.64	0.53	0.37	1.06	1.05	0.30	0.62	0.53	0.15	0.22	0.58	0.25	0.35
3, 0.15	0.96	1.41	1.26	0.98	0.75	0.25	0.56	0.55	0.73	0.73	0.56	0.56	0.53	0.76	0.35	0.68	0.71	0.09	0.17	0.62	0.28	0.46
3, 0.16	0.96	1.41	1.19	0.69	0.75	0.25	0.56	0.55	0.73	0.73	0.56	0.56	0.53	0.76	0.35	0.68	0.71	0.09	0.17	0.62	0.28	0.46
3, 0.17	0.96	1.41	1.19	0.69	0.75	0.25	0.56	0.55	0.73	0.73	0.56	0.56	0.53	0.76	0.35	0.68	0.71	0.09	0.17	0.62	0.28	0.46
3, 0.18	0.96	1.41	1.19	0.69	0.75	0.17	0.39	0.55	0.73	0.73	0.56	0.32	0.53	0.76	0.35	0.68	0.71	0.09	0.17	0.38	0.28	0.30
3, 0.19	0.96	1.14	1.19	0.69	0.75	0.17	0.39	0.55	0.73	0.73	0.56	0.32	0.53	0.76	0.35	0.68	0.71	0.09	0.17	0.38	0.28	0.30
3, 0.20	0.96	1.14	1.19	0.69	0.75	0.17	0.39	0.55	0.73	0.73	0.56	0.32	0.53	0.78	0.35	0.68	0.71	0.09	0.17	0.38	0.28	0.30
4, 0.15	0.99	1.17	1.33	1.56	0.91	0.22	0.66	0.50	0.81	0.99	0.67	0.72	0.65	0.44	0.43	0.85	0.66	0.10	0.19	0.88	0.26	0.53
4, 0.16	0.99	1.17	1.17	1.00	0.91	0.22	0.66	0.50	0.81	0.99	0.67	0.72	0.65	0.44	0.43	0.85	0.66	0.10	0.19	0.88	0.26	0.53
4, 0.17	0.99	1.17	1.17	1.00	0.91	0.22	0.66	0.50	0.81	0.99	0.67	0.72	0.65	0.44	0.43	0.85	0.66	0.10	0.19	0.88	0.26	0.53
4, 0.18	0.99	1.17	1.17	1.00	0.91	0.19	0.44	0.50	0.81	0.99	0.67	0.25	0.65	0.44	0.43	0.85	0.66	0.10	0.19	0.46	0.26	0.30
4, 0.19	0.99	0.93	1.17	1.00	0.91	0.19	0.44	0.50	0.81	0.99	0.67	0.25	0.65	0.44	0.43	0.85	0.66	0.09	0.19	0.46	0.26	0.30
4, 0.20	0.99	0.93	1.17	1.00	0.91	0.19	0.44	0.50	0.81	0.99	0.67	0.25	0.65	0.62	0.43	0.85	0.66	0.09	0.19	0.46	0.26	0.30

Table X – SampEn values for February 2001

m, r	**Day1**	**Day2**	**Day3**	**Day4**	**Day5**	**Day6**	**Day7**	**Day8**	**Day9**	**Day10**	**Day11**	**Day12**	**Day13**	**Day14**	**Day15**	**Day16**	**Day17**	**Day18**	**Day19**	**Day20**
2, 0.15	0.52	0.43	0.31	0.20	0.29	0.22	0.24	0.15	0.17	0.22	0.33	0.19	0.21	0.19	0.16	0.17	0.17	0.19	0.39	0.20
2, 0.16	0.52	0.43	0.31	0.20	0.29	0.22	0.20	0.15	0.17	0.22	0.33	0.19	0.21	0.15	0.16	0.17	0.17	0.19	0.39	0.20
2, 0.17	0.52	0.43	0.25	0.20	0.29	0.14	0.20	0.15	0.17	0.22	0.33	0.19	0.21	0.15	0.16	0.17	0.17	0.19	0.39	0.20
2, 0.18	0.52	0.43	0.25	0.20	0.29	0.14	0.20	0.15	0.17	0.22	0.33	0.19	0.21	0.15	0.16	0.17	0.17	0.19	0.39	0.20
2, 0.19	0.52	0.43	0.25	0.20	0.29	0.14	0.20	0.15	0.17	0.22	0.33	0.19	0.21	0.15	0.16	0.17	0.17	0.19	0.33	0.20
2, 0.20	0.52	0.37	0.25	0.20	0.29	0.14	0.20	0.16	0.17	0.22	0.33	0.19	0.21	0.15	0.16	0.20	0.17	0.19	0.33	0.20
3, 0.15	0.70	0.28	0.26	0.22	0.31	0.25	0.13	0.08	0.19	0.24	0.24	0.21	0.20	0.21	0.13	0.09	0.14	0.21	0.38	0.22
3, 0.16	0.70	0.28	0.26	0.22	0.31	0.25	0.12	0.08	0.18	0.24	0.24	0.21	0.20	0.16	0.13	0.09	0.14	0.21	0.38	0.22
3, 0.17	0.70	0.28	0.19	0.22	0.31	0.15	0.12	0.08	0.18	0.24	0.24	0.21	0.20	0.16	0.13	0.10	0.14	0.20	0.38	0.22
3, 0.18	0.70	0.28	0.19	0.22	0.31	0.15	0.12	0.08	0.18	0.24	0.24	0.21	0.20	0.16	0.16	0.10	0.14	0.20	0.38	0.22
3, 0.19	0.70	0.28	0.19	0.22	0.31	0.15	0.12	0.08	0.18	0.24	0.24	0.21	0.20	0.16	0.16	0.10	0.14	0.20	0.30	0.22
3, 0.20	0.70	0.26	0.19	0.22	0.31	0.15	0.12	0.08	0.18	0.24	0.24	0.21	0.20	0.16	0.16	0.14	0.14	0.20	0.30	0.22
4, 0.15	0.58	0.27	0.36	0.17	0.31	0.26	0.18	0.00	0.20	0.24	0.16	0.28	0.22	0.20	0.14	0.09	0.15	0.23	0.41	0.18
4, 0.16	0.58	0.27	0.36	0.17	0.31	0.26	0.16	0.00	0.20	0.24	0.16	0.28	0.22	0.15	0.14	0.09	0.15	0.23	0.41	0.18
4, 0.17	0.58	0.27	0.26	0.17	0.31	0.14	0.16	0.00	0.20	0.24	0.16	0.28	0.22	0.15	0.14	0.09	0.15	0.23	0.41	0.18
4, 0.18	0.58	0.27	0.26	0.17	0.31	0.14	0.16	0.00	0.20	0.24	0.16	0.28	0.22	0.15	0.13	0.09	0.15	0.23	0.41	0.18
4, 0.19	0.58	0.27	0.26	0.17	0.31	0.14	0.16	0.00	0.20	0.24	0.16	0.28	0.22	0.15	0.13	0.09	0.15	0.23	0.31	0.18
4, 0.20	0.58	0.25	0.26	0.17	0.31	0.14	0.16	0.00	0.20	0.24	0.16	0.28	0.22	0.15	0.13	0.09	0.15	0.23	0.31	0.18

Table XI – SampEn values for March 2001

m, r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19	Day20	Day21
2, 0.15	0.25	0.28	0.19	0.15	0.30	0.16	0.15	0.26	0.29	0.28	0.22	0.33	0.20	0.14	0.37	0.16	0.22	0.18	0.18	0.28	0.23
2, 0.16	0.22	0.19	0.18	0.15	0.30	0.16	0.15	0.26	0.29	0.28	0.22	0.33	0.20	0.14	0.37	0.16	0.22	0.18	0.18	0.28	0.23
2, 0.17	0.22	0.19	0.18	0.15	0.30	0.16	0.12	0.26	0.29	0.28	0.22	0.33	0.20	0.14	0.37	0.16	0.22	0.12	0.16	0.28	0.23
2, 0.18	0.22	0.19	0.18	0.14	0.30	0.16	0.12	0.21	0.29	0.28	0.22	0.33	0.20	0.14	0.37	0.16	0.22	0.12	0.16	0.28	0.23
2, 0.19	0.22	0.19	0.18	0.14	0.30	0.16	0.12	0.21	0.29	0.28	0.22	0.33	0.20	0.14	0.37	0.16	0.22	0.12	0.16	0.28	0.23
2, 0.20	0.22	0.19	0.18	0.04	0.30	0.16	0.12	0.21	0.25	0.28	0.22	0.33	0.20	0.14	0.37	0.19	0.22	0.11	0.16	0.28	0.23
3, 0.15	0.28	0.24	0.20	0.17	0.28	0.17	0.16	0.25	0.16	0.32	0.25	0.34	0.19	0.18	0.32	0.17	0.25	0.16	0.20	0.25	0.26
3, 0.16	0.25	0.14	0.20	0.17	0.28	0.17	0.16	0.25	0.16	0.32	0.25	0.34	0.19	0.18	0.32	0.17	0.25	0.16	0.20	0.25	0.26
3, 0.17	0.25	0.14	0.20	0.17	0.28	0.17	0.12	0.25	0.16	0.32	0.25	0.34	0.19	0.18	0.32	0.17	0.25	0.12	0.17	0.25	0.26
3, 0.18	0.25	0.17	0.20	0.14	0.28	0.17	0.12	0.18	0.16	0.32	0.25	0.34	0.19	0.18	0.32	0.17	0.25	0.12	0.17	0.25	0.26
3, 0.19	0.25	0.17	0.20	0.14	0.28	0.17	0.12	0.18	0.16	0.32	0.25	0.34	0.19	0.18	0.32	0.17	0.25	0.12	0.17	0.25	0.26
3, 0.20	0.25	0.17	0.20	0.04	0.28	0.17	0.12	0.18	0.19	0.32	0.25	0.34	0.19	0.18	0.32	0.17	0.25	0.12	0.17	0.25	0.26
4, 0.15	0.21	0.22	0.23	0.18	0.42	0.22	0.18	0.28	0.14	0.33	0.28	0.26	0.17	0.20	0.29	0.19	0.29	0.18	0.22	0.22	0.28
4, 0.16	0.19	0.15	0.22	0.18	0.42	0.22	0.18	0.28	0.14	0.33	0.28	0.26	0.17	0.20	0.29	0.19	0.29	0.18	0.22	0.22	0.28
4, 0.17	0.19	0.15	0.22	0.18	0.42	0.22	0.13	0.28	0.14	0.33	0.28	0.26	0.17	0.20	0.29	0.19	0.28	0.13	0.19	0.22	0.28
4, 0.18	0.19	0.15	0.22	0.15	0.42	0.22	0.13	0.25	0.14	0.33	0.28	0.27	0.17	0.20	0.29	0.19	0.28	0.13	0.19	0.22	0.28
4, 0.19	0.19	0.15	0.22	0.15	0.42	0.22	0.13	0.25	0.14	0.33	0.28	0.27	0.17	0.20	0.29	0.19	0.28	0.13	0.19	0.22	0.28
4, 0.20	0.19	0.15	0.22	0.03	0.42	0.22	0.13	0.25	0.17	0.33	0.28	0.27	0.17	0.20	0.29	0.19	0.28	0.13	0.19	0.22	0.28