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Dr Y V Reddy 29/9/08
Research Guide

Prof. L. S. Chandrashekar Rao 29/9/08
Prof & Head
Dept. of Banking Technology
Pondicherry University
Pondicherry

29/9/08
Prof. B. Ramesh
Head & Dean
Dept. of Commerce
Goa University

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A.SEBASTIN

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DR.Y.V.REDDY

DEPARTMENT OF COMMERCE

GOA UNIVERSITY

GOA – 403 206

2007

DR. Y.V.REDDY
READER

DEPARTMENT OF COMMERCE
GOA UNIVERSITY
GOA – 403 206, INDIA

CERTIFICATE

This is to certify that the thesis "**FINANCIAL APPLICATIONS OF ENTROPY THEORY**" for the award of Ph.D degree in Commerce, is a bonafide record of research work done by **Mr. A.Sebastin** during the period of study under my supervision and that the thesis has not formed the basis for the award of any degree, diploma, associateship, fellowship or similar title to the candidate and also that the thesis represents independent work on the part of the candidate.

Date : 20- 11 - 2007

Place : Goa

DR. Y.V.REDDY

(SUPERVISOR)

DECLARATION

I do hereby declare that the thesis entitled "**FINANCIAL APPLICATIONS OF ENTROPY THEORY"** submitted to the Goa University, Goa for the award of the degree of Doctor of Philosophy is an original and independent research work done by me during 2004 – 07 under the supervision and guidance of **Dr. Y.V.Reddy**, Reader, Department of Commerce, Goa University, Goa and also that it has not formed the basis for the award of any degree, diploma, associateship, fellowship or similar title to any candidate of any University.

Date : 20 - 11 - 2007

Place : Goa

A.SEBASTIN

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ABBREVIATIONS USED

ApEn	Approximate Entropy
AQ	Average Quantity Traded
AR	Auto Regression
BSE	Bombay Stock Exchange
CP	Closing Price
EGARCH	Exponential Generalised Auto Regressive Conditional Heteroskedastic
HP	Highest Price
KL distance	Kullback – Leibler distance
KS entropy	Kolmogorov – Sinai entropy
LE	Lyapunov Exponent
LP	Lowest Price
LTP	Last Traded Price
MCX	Multi Commodity Exchange of India
NCDEX	National Commodity & Derivatives Exchange Ltd.
NIF	Net Information Flow
NDI	Normalised Directionality Index
NSEIL	National Stock Exchange of India Limited
PTP	Preceding Trade Price
RBI	Reserve Bank of India
REA	Relative Explanation Added
SampEn	Sample Entropy
SD	Standard Deviation
SEBI	Securities and Exchange Board of India
TQ	Total Quantity Traded

CHAPTER - I
INTRODUCTION

CHAPTER – I

INTRODUCTION

This chapter gives a brief introduction to the theory of entropy and hints the possible areas of financial studies, in which the entropic concept may be applied. A review of the existing literature on such areas and the importance of this study are explicated to justify this study. Then the exact objectives of the study and the methodology followed are spelt out. Further, this chapter mentions the limitations of this study and explains the arrangement of chapters in this thesis.

Evidence of non-linear dependence in financial time series has been reported very often in financial literature. Non-linear structure has been observed in the stock returns of various stock exchanges. Such observation may be likely due to the microstructure character of the stock market itself, the herding behaviour of market participants, the low frequency of information input in the market relative to the observed prices, varied abilities of the participants to process information, differential transaction costs of the participants, etc. Even simple non-linear relationships may yield extremely complex time paths so that the system appears to be random. If a signature of approximate non-linear determinism is found then the notions of phase space reconstruction, non-linear invariants, etc. may provide a convenient framework for time series analysis. This is so since non-linear time series methods which arise as extensions and generalizations of linear tools have been found to be insufficient and there are many references that indicate non-linear structure in financial time series which cannot be extracted with a Generalised Auto Regressive Conditional Heteroskedastic model. Hence financial markets may be treated as non-linear dynamical systems to characterise their intrinsic nature and various characteristic measures like entropy, Lyapunov exponent and correlation dimension may be used to study the markets. One of the reasons for the relevance of the characteristic measures is their invariance under smooth coordinate transformations of the phase space. The values of these measures for an approximately noise-free and sufficiently long time series remain the same irrespective of the details of the measurement process and of the phase space reconstruction.

(i) Entropy of a dynamical system is the amount of disorder in the system, as described in Thermodynamics and also is the amount of information needed to predict the next measurement with a certain precision, as described in Information Theory. Entropy does not measure the shape of the distribution of the realizations of a system but provides information about how the system fluctuates with time – in frequency space or phase space. The concept of embedding the one-dimensional signal in a phase space which is achieved by comparing the time series of realizations with itself but lagged by a specified time interval, is used to estimate the entropy of a system. In an irregular signal, the prediction of the next point using the knowledge of previous points is not easy and in a regular signal such prediction is more reliable. The number of previous (lagged) points required to make the prediction is the embedding dimension. Using these embeddings, various versions of entropy such as Shannon entropy and KS entropy are estimated.

(ii) Lyapunov exponent (LE) is the inverse of time scale and quantifies the rate by which two typically nearby trajectories converge or diverge in time. In a predominantly periodic system, this divergence will be very slow whereas in a chaotic system, this separation will be exponentially fast. LE is a properly averaged exponent of this increase and is characteristic of the system underlying the data and quantifies the strength of chaos. There are as many LEs for a dynamical system as there are phase space dimensions and generally the maximal LE is measured to study a dynamical system. The maximal LE of a dissipative system may be negative, indicating the existence of a stable fixed point and two trajectories approaching a fixed point also approach each other exponentially fast. If the maximal LE is zero, the system is marginally stable and settles down to a limit cycle and two trajectories can separate or approach each other only slower than exponentially. A predominantly deterministic system, perturbed by small scale random noise behaves like a diffusion process and the corresponding maximal LE is large and positive. LE is invariant under all smooth transformations of shifting, rescaling or otherwise processing of data since it describes long term behaviour.

(iii) The portrayal of a data set as a geometrical object in phase space as represented by the trajectories of the system, leads to the concept of dimension of the data set. Non-integer dimensions are assigned to geometrical objects which exhibit unusual kind of self-similarity (a part of an object when magnified resembling the object itself) and which show structure on all length scales. The trajectories of a dissipative (contraction of volume elements) dynamical system do not fill the phase space and are confined to lower dimensional sub-sets which possess a fractal structure i.e. which are self-similar in a non-trivial way. Generalised dimensions are a class of quantities to characterize the fractal nature of a data set. Hausdorff dimension is the most natural concept to characterise a fractal set, from mathematical point of view. Information dimension is more attractive for physical systems since it takes into account the relative visitation frequencies. Correlation dimension is useful for the characterization of measured data. Dimensions are invariant under smooth transformations and thus computable in time delay embedding spaces.

Of the commonly used non-linear invariants (i) entropy measures irregularity or complexity of the data (ii) Lyapunov exponent measures sensitive dependence on initial conditions and (iii) correlation dimension measures spatial correlation in the phase space. The last two are used to study the presence of chaotic structure in very large data sets and perform poorly with small samples. Entropy is used to study the presence of repetitive patterns or shifts in data structure and some versions of entropy like approximate entropy and sample entropy may be measured for very short and noisy time series also. Hence entropy may be well suited to analyse time series of stock prices or the values of other financial instruments.

The concept of entropy has been applied in financial economics by researchers for various purposes like describing financial market dis-equilibrium, devising a methodology for programmed trading of equities, prediction of stock market returns by detecting non-linear dependence within the returns series, assessment of subtle and potentially exploitable changes in the serial structure of a financial variable and explanation of many empirical evidences about market behaviour. However, there appears to be no research about the potential of entropy to study stock price manipulation and only a few research papers using entropy to study price discovery in securities market or transfer of information between different segments of financial market. In the present study, the suitability of the entropic concept and the different versions of entropy for such applications in the financial market are studied.

(a) For the purpose of our study, stock price manipulation means planned buying / selling of a security by a person or a group acting in concert for the purpose of creating a false appearance of transactions in a security, to cause or maintain an artificial increase or decrease in the value of the security and thus influencing other investors to buy or sell at disadvantageous prices, with the aim of gaining undue profits. Essentially, price manipulation may be defined as intentional interference with the free forces of supply of or demand for a security. For example, one may deflate the price of a security by placing small orders at significantly lower price as compared to the one at which it has been trading. This gives investors the impression that there is something wrong with the issuer of the security, so they sell, thereby pushing the prices further down. Another example of manipulation is to place simultaneous buy and sell orders through different brokers, that cancel each other but give the perception that there is increased interest in the security, because of the high volume.

(b) Between the equities and the derivatives segments of the securities market, the question as to where security's price is discovered may be resolved by identifying the segment which leads the other in terms of pricing the security by the participants. Price discovery thus means determination in a market segment of the security's price which is trailed in the other segment after a lag in time.

(c) The price movements in the stock market are supposed to influence or be influenced by the price movements in other financial markets like foreign exchange market and commodities market, due to economic and other reasons. Such causal interactions at price level between stock market and other markets are proposed to be analysed in this study.

LITERATURE REVIEW

(A) PRICE MANIPULATION IN STOCK MARKET

The recent interest in stock market microstructure in general and market manipulation in particular suggests that a review of the literature on the subject is an essential requirement. However, since the research involves both theoretical and empirical investigations, any attempt to survey market manipulation in its entirety would be doomed to failure. Hence an attempt is made to review published research papers on the subject, based on a study of books on the topic like Handbooks in Operations Research and Management Science and journals like Econometrica, Economic Letters, European Economic Review, Journal of Financial and Quantitative Analysis and Journal of Finance and also based on various Working Papers available in the internet and interaction with various scholars. It is observed that although the Indian stock market has witnessed price manipulation now and then, there has not been much literature on such instances.

A few articles have, interestingly, questioned the justification of the aspersions cast on price manipulation in stock markets and raised doubts on basic premises like whether stock price manipulation is bad and whether such manipulation is to be prohibited.

Fischel and Ross (1991)[1] argues that stock manipulation effected by actual trades, as distinguished from fictitious trades, should not be considered as illegal and bases the attack on both legal and normative grounds. On the legal front, it is argued that manipulation does not meet the legal definition of fraud and that even if the manipulator has a fraudulent intent his trades are real and thus the prosecution cannot allege any bad conduct that constitutes the actus reus of this offence. On the normative front, it is suggested that the cost of regulating manipulation exceeds the benefits because (a) actual trades hardly affect price (b) manipulation has a negative expected return and is therefore self-deterred and (c) in any case, market regulator / courts of law can hardly distinguish between manipulation and investment.

Omri Yadlin (1999)[2] argues that stock manipulation is not socially harmful, should not be treated as fraud and hence it is not clear if a ban on stock manipulation would be warranted.. The author has addressed each of the three potential objections - to the approach that informed manipulators, more than informed investors are conducive to market efficiency since uninformed traders would prefer trading with informed manipulators because unlike investors they do not try to disguise their information - viz. (a) informed traders should have no interest in manipulating the market (b) informed manipulators could achieve the same effect by releasing their information rather than by employing the expansive means of manipulation (c) there is no way to distinguish between informed and uninformed manipulators. The author has provided the results of an empirical study of the performance of manipulated shares traded on the Tel Aviv Stock Exchange, Israel.

Whatever be the conclusions of these papers, stock price manipulation has been barred by legal provisions and / or regulations in both the developed and the developing markets on the premise that such manipulations are against the interest of the market participants and weaken the market. Now, we consider the important publications on the subject in a chronological order.

Kyle Albert S. (1985)[3] has considered manipulation in which a single insider has unique access to a private observation of the ex-post liquidation value of a risky asset and the market makers set a price and trade the quantity which makes markets clear and their information consists of observations of the current and the past aggregate quantities (called the order flow) traded by the insider and noise traders combined. The conditions for equilibrium in sequential trading and continuous trading have been studied, with linear functions for the insider's trading strategy and the market makers' pricing rule.

Lawrence Glosten and Paul R.Milgrom (1985)[4] considers a price manipulation model, in which a specialist taking into account the fact that the traders may be informed, sets the prices using Bayes rule to update his ex ante probability regarding the value of the stock.

Easley David and Maureen O'Hara (1985)[5] reviews market microstructure and provides examples of strategic information based manipulation.

Easley David and Maureen O'Hara (1987)[6] considers an informed trader who strategically chooses between small market orders and large block trades, to manipulate stock prices.

Vila Jean Luc (1989)[7] has presented two examples of market manipulation as games in extensive form with asymmetric information and has derived the conditions for equilibrium, treating the gains and losses as payoffs associated to the various strategies of the players.

Fishman Michael, J. and K.Hagerty (1991)[8] propounds a model in which an uninformed trader takes advantage of the mandatory disclosure (or post-announcement) requirement for insiders as found in the Securities Exchange Act and the manipulator takes advantage of the market's inability to infer the information content of his disclosed trades. For example, although he has no information, he discloses his sale causing the stock price to drop because the market believes that he may be informed and then the manipulator buys his shares at the lower price. The authors have suggested two approaches to circumvent manipulation around disclosures – If disclosure is mandatory, then the `short-swing profit' rule, which currently requires only corporate insiders to give up profits from short term trading profits, should be applied to all insiders who face disclosure requirements. Alternatively, mandatory disclosure requirement may be removed since voluntary disclosure is generally not forthcoming.

Utpal Bhattacharya and Matthew Spiegel (1991)[9] examines the conditions that lead to a collapse of trade in a financial market. Based on a simple model constructed from the classical portfolio problem, it is concluded that if insider trading laws do not exist, the market may fail completely as a communication system and the uninformed may not have the confidence to trade with the insider at all.

Franklin Allen and Gary Gorton (1992)[10] has relaxed the assumption made by Glosten and Milgrom and by Albert S. Kyle – treating liquidity traders as equally to be buyers as sellers and also treating them as equally likely to be informed – and have shown that the asymmetry of price elasticity between buyers and sellers can create an opportunity for profitable price manipulation.

Robert A. Jarrow (1992)[11] has examined the conditions under which a large trader, whose trades affect prices, can profit without risk, by implementing certain trading strategies like market corner and short squeeze, without any proprietary or inside information on the intrinsic value of the asset. For a market corner, the shares which the speculator brings by some time t must exceed the total supply. For the speculator's position to exceed the total supply, short interest must be strictly positive i.e. some traders should have shorted the risky asset and effectively borrowed them from the speculator. A short squeeze occurs at time t when the speculator reduces his holdings by calling in the shorts i.e. by requiring to provide him with the delivery of all his outstanding shares. Although this process keeps his holdings greater than the total supply, the shorts, in order to return the borrowed shares, need to purchase them from him only, because of the corner and hence the speculator can arbitrarily determine the price. The speculator's paper wealth is defined to be the value of his portfolio position when relative prices are evaluated using his current holdings and real wealth is defined to be the value of the speculator's position when relative prices are evaluated as if his stock holdings were liquidated. The real wealth is strictly less than paper wealth iff the large trader's risky asset position is non-zero. A market manipulation trading strategy is defined to be any zero initial wealth self-financing trading strategy such that the real wealth of the trading strategy at liquidation is non-negative for sure and strictly positive with positive probability. Thus a market manipulation trading strategy has a positive probability of generating positive real wealth with no losses from a zero initial investment.

Franklin Allen and Douglas Gale (1992)[12] depicts a model in which an uninformed trader mimics an informed trader with positive information about the stock to raise the stock price and then sells his shares at a profit. The observation of the operation of trading pools during the great crash of 1929 i.e. a group of investors combining first to buy a stock, then to spread favourable rumours about the firm and finally to sell out at a profit, led to extensive provisions in the Securities Exchange Act of 1934 to eliminate manipulation. The kinds of manipulation that the Act effectively outlawed fall naturally into two categories – action based manipulation i.e. manipulation based on actions that change the actual or perceived value of the assets and information based manipulation i.e. manipulation based on releasing false information or spreading false rumours. The Act attempted to eradicate action based manipulation by, among other things, making it illegal for directors and officers to sell short of the securities of their own firm. To eliminate information based manipulation, firms were required to issue information to the public on a regular basis so that the spreading of rumours would be more difficult and it was made illegal for anybody to attempt to raise or depress stock prices by making statements which they knew to be false. However, there is a third category of manipulation that is much more difficult to be eradicated viz. trade based manipulation which occurs when a trader attempts to manipulate a stock simply by buying and then selling without taking any publicly observable actions to alter the value of the firm or releasing false information to change the price.

Craig W. Holden and Avanidhar Subrahmanyam (1992)[13] considers a multi-period auction model in which multiple informed traders optimally exploit their long lived informational advantage. The basic finding is that in a unique linear equilibrium, informed traders trade very aggressively and cause nearly all of their common private information to be incorporated into prices almost immediately. Thus they cause the depth of the market to become extremely large almost immediately, provided the number of auctions is reasonably large. Hence it is shown that a market with multiple informed traders approximates a strong form efficient market quite accurately at almost all times. In the Kyle's model, a single privately informed trader with long-lived information optimally exploits his monopoly power over time and trades in a gradual manner so that his information is incorporated into prices at a slow, almost linear rate and when auctions are held continuously, the depth of the market is constant over time. The contrast in results between the case of a monopolistic informed trader and that of multiple informed traders is driven by aggressive competition among these traders. In the game in which private information lasts only one period with a linear pricing rule, the unique Nash equilibrium is an equilibrium in which imperfect competitors acting non-cooperatively choose larger quantities that a monopolist (or collusive agents) would choose. In the multi-period game with a linear pricing rule, the unique linear equilibrium consists of imperfect competitors trading aggressively in each period, in a manner analogous to their behaviour in a single period Nash equilibrium. This competition among informed traders causes prices to be more informationally efficient and alleviates information based manipulation. The model could be applied to explain intra-day phenomena such as the temporal variation in the adverse selection component of the bid – ask spread (measured by the adverse price impact of trades). For example, if long-lived information arrives during non-trading hours, then the model suggests that informed traders will concentrate their trading at the opening of the market and therefore adverse selection problem will be most severe at the beginning of the day.

Kerry Back (1992)[14] formalises and extends the continuous time version of the Kyle model. In the Kyle model, uniqueness of equilibrium has been established only within the linear class and for elliptical distributions and in contrast to the no expected trade theorem (which states that conditional on the total order, the market makers' expectation of the informed order is always zero in equilibrium), the expected informed order is proportional to the total order in equilibrium. The main result of the article is that there is a unique equilibrium in which the pricing rule of market makers is a strictly monotone function of the cumulative order and satisfies a certain finite variance condition.

Mark Bagnoli and Naveen Khanna (1992)[15] uses a standard signaling model in which the manager of the firm possesses better information than the market and chooses an observable action by the firm such as issuing securities, repurchasing shares, announcing special dividends, going public or making a takeover attempt. The manager is permitted to voluntarily trade in the firm's stock after the competitive market makers and noise traders have observed the action. The manager will trade only when he expects to profit from doing so, causing a market maker to sell (buy) more shares when the manager believes that their value exceeds the offer price (is less than the bid price).

Benabou, R. and G.Laroque (1992)[16] shows that many types of insiders have both the ability and the incentives to manipulate public information and asset prices through strategically distorted announcements or forecasts. There are three kinds of informed agents whose announcements influence prices - first is the journalist who writes a financial column and can trade directly or through namesakes; second is the guru who issues forecasts or newsletters but is also in the business of trading for his own account or some investment firm and third is the corporate executive who owns or trades stock in his company and by the very nature of his job, periodically makes prospective reports to stockholders and financial analysts.

Gerard, B. and V. Nanda (1993)[17] provides a model in which strategic informed traders short sell a firm's stock just prior to a seasoned equity offering in order to cause downward price pressures on the stock and then the manipulators will more than cover their positions by purchasing stocks in the offering at a reduced price.

Chatterjea Arkadev, Cherian Joseph A. and Jarrow Robert A. (1993)[18] reviews the purposes for which a corporate manipulates its shares strategically viz. to maximise its share price and to prevent its shares from being manipulated by others.

Steve Thel (1994)[19] has offered three reasons for why manipulation is a form of fraud - (a) rational informed traders have no interest in affecting the market price and would always try to buy at the lowest price available and sell for the highest (b) market participants should be able to look at reported prices as a reflection of transactions between players who trade stock for investment purposes i.e. buy at the lowest price possible and sell at the highest (c) bids placed for the purpose of raising (or depressing) the price of a stock, by buying (or selling) above (or below) the lowest (or highest) price possible mislead these price takers.

Cherian Joseph A. and Jarrow Robert A. (1995)[20] has classified market manipulation trading strategies as follows. (a) *Information based manipulation* - The prices of securities are manipulated by trading strategically based on inside information or after spreading false rumours. (b) *Trade based manipulation* - The prices of securities are manipulated by buying or selling stocks without taking any actions or possessing any special information. (c) *Action based manipulation* - The prices of securities are manipulated by actions that change the actual or perceived value of the stock price. The distinctions among the 3 different categories of manipulation are not always obvious but are nonetheless useful.

Mark Bagnoli and Barton L.Lipman (1996)[21] presents a model in which a bid may be made in order to profit from the takeover announcement effect. A large trader announces a takeover bid to manipulate the target corporate's shares and initiates a bidding by taking a substantial position in the stock, thereby causing an appreciation in share price as the market cannot identify if the bid is serious. The manipulator then sells his holdings at a profit and drops the bid. The effect depends crucially on the ex ante probability that the target is considered by a potential bidder. This may be referred to as the level of takeover activity and viewed as a measure of the number of agents who have both the capital to mount a takeover bid and the credibility to have the bid taken seriously relative to the number of targets.

Kose John and Ranga Narayanan (1997)[22] studies the impact of the trade disclosure rule on the dynamic trading behaviour of corporate insiders and shows that the disclosure rule creates incentives for an informed insider to manipulate the stock market by sometimes trading in the wrong direction (i.e. buying when there is bad news or selling when there is good news about a firm). Insiders are defined by the Securities and Exchange Act 1934, as officers, directors and beneficial owners of more than 10% of any class of equity securities. Rule 10b-5 of the Act made insider trading and other schemes intended to defraud in connection with the purchase and sale of securities illegal. Section 16(a) of the

Act, called the trade disclosure rule, requires the insiders of a firm to report periodically any equity transactions they conduct to the regulator. Section 16(b), known as the short swing profit rule, requires insiders to return to the firm any profits made from a round trip transaction in the firm's stock (a buy – sell or a sell – buy) within a six month period. Section 16(c) of the Act prohibits insiders from short selling their firm's stock.

Gerald T. Garvey, Simon Grant and Stephen P.King (1998)[23] considers a model which highlights the potential value of indexing an executive's compensation to remove the influence of short-term stock price movements, but shows why this value may be illusory. The possibility of the manager having private information about the firm's prospects is allowed and the case where the manager can simply announce her information to the market is considered. It is shown that indexation is impossible in this case because the manager will 'talk down' her firm – manipulate the short term share price and so artificially raise perceptions of her long-term value added. The manager will inform the truth in equilibrium, but only because her incentive contract will effectively ignore short-term stock price information.

Cherian Joseph A. and Kuriyan Vikram J. (1998)[24] investigates the possibility of information-less market manipulation by way of large trading volumes and in the presence of an intermediary akin to the market makers of U.S. capital markets and presents a model with positive feedback traders (who submit trades in the direction of current price movements) in which the price process responds to the entire order flow processed by the market maker, in consistence with a number of models of equilibrium market microstructure, as opposed to just the manipulator's trades.

Archishman Chakraborty and Bilge Yilmaz (1999)[25] considers a model of strategic trading by an insider called the dynamic trader who may have long lived private information about the expected future returns of the asset being traded or may be uninformed. Further, the market makers or price-setters also do not know if the insider has traded at all i.e. if the insider exists. There are a number of other traders in the market, called followers who have superior information when compared to the market makers in that they know if the insider has traded, although they do not know if the insider has any information and what the nature of his information is. Due to this informational advantage over the market makers, the followers will find it profitable to mimic the trades of the insider.

Archishman Chakraborty and Bilge Yilmaz (1999)[26] shows that in Kyle type of models with one insider trading repeatedly, if the number of periods is large enough, then the equilibrium will involve a non-linear manipulative trading strategy of the insider since, unlike in Kyle's model, the market faces uncertainty about the existence of the insider and noise trading is bounded. Due to bounded noise trading, some of his trades will be revealed in the long run and if he is trading non-manipulatively, this will also reveal his information and reduce his profits. This leads the insider to manipulate to try and signal that he is not trading on any information, provided there is uncertainty about his existence in the market place.

Fabrice Rousseau (1999)[27] considers a two-period model and the market is organised as a dealership market where the dealer or market maker sets the prices before the traders' order submissions. There exist a non-myopic trader with private information of the future asset value (informed trader) and many myopic liquidity traders. The quantity submitted by the liquidity traders is exogenously fixed and the market maker when facing a trader does not know the trader's identity. This paper determines the market conditions leading to the use of the bluffing strategy (establishing a trend or a bubble with some trades and then trading against this trend) in equilibrium.

Rajesh K.Aggarwal and Guojun Wu (2003)[28] examines various forms of stock market manipulation and their implications for stock market efficiency. Using a unique data set, it has been proved that more illiquid stocks are more likely to be manipulated and manipulation increases stock volatility and also shown that stock prices rise throughout the manipulation period and then fall in the post-manipulation period. Further, prices and liquidity are higher when the manipulator sells than when the manipulator buys. In addition, at the time the manipulator sells, prices are higher when liquidity is greater, consistent with returns to manipulation being higher when there are more information seekers in the market. Also, at the time the manipulator sells, prices are higher when volatility is greater, consistent with returns to manipulation being higher when there is greater dispersion in the market's estimate of the value of the stock. These results suggest that stock price manipulation may have important impacts on market efficiency.

Fang Cai (2003)[29] uses a detailed audit trail transactions dataset to investigate whether market makers in the treasury bond futures market of Chicago Board of Trade, who might have had superior knowledge of customer order flow, exploited such informational advantage in their trading and profited from the weakness of Long Term Capital Management when it had faced binding margin constraints. The term "front running" refers to a situation in which a trader, knowing that an order is about to come in, trades in the same direction before the anticipated order is executed. The front runner plans to unwind her position afterwards and hopes to profit through the price impact of the expected order. While front running by a trader against his own customers violates the rules of the Commodity Futures Trading Commission, front running based on signals observable in the trading pit about other incoming customer orders is legal.

Asim Ijaz Khwaja and Atif Mian (2003)[30] analyses a unique data set containing all daily trades of each broker in every stock trading on the Karachi Stock Exchange, the main stock exchange in Pakistan. The high level of dis-aggregation in the data has provided compelling evidence to isolate a particular price manipulation mechanism through which brokers cheat the naïve outside investor – when prices are low, colluding brokers trade amongst themselves to artificially raise prices and attract naïve positive feed-back traders; once prices have risen, the former exit leaving the latter to suffer the ensuing price fall. It is found that the principal brokers, who trade primarily on their own or for a few investors in a given stock, earn significantly higher returns than those who act as intermediaries in that stock. The difference in returns is both statistically and economically highly significant and the annualised return on trades done by the principal brokers in a stock is 4% to 8% higher.

Thus, most of the publications portray stock price manipulation in market maker model of the American stock market. Further, almost all the papers analyse the conditions for equilibrium of the market with price manipulation as a characteristic. Stock price manipulation has been studied under various situations like continuous auction, insider trading, asymmetric information, corners, short squeezes, imperfect competition, financial signaling, equity offerings, takeover bids, 'talking down' the firm, no information, nested information, bluffing and front running. A seminal article, Vila Jean Luc (1989) uses game theoretic model to study market manipulation. Although manipulators of the stock market use special strategies, like the players in a game, not many papers have used game theoretic concepts to study market manipulation. In spite of the vast literature on the subject, there is still 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.

(B) PRICE DISCOVERY IN SECURITIES MARKET

Examination of price discovery and hedging efficiency of futures market is as old as the futures market itself. Starting from the late 1970's, there has been a lot of research on the price discovery efficiency of commodity futures market, currency futures market and equity futures market in various developed and developing economies and hence there has been a large number of research articles on the subject. In view of the same, a review of such publications in respect of the Indian markets is in order.

Thiripalraju et al (1999)[31] studies price transmission from futures to spot market for the Indian pepper and castor markets, using Garbade - Silber model with a dataset from 1991 to 1996 and concludes that the futures market plays an important role in price discovery. Singh (2001)[32] investigates the price discovery efficiency of commodity futures market in India and finds strong lead lag relationship between the futures and the spot prices. Thomas and Karande (2002)[33] analyses price discovery between spot and futures contracts in India's castor seed markets at Ahmedabad and Mumbai, using Garbade

Silber model with daily data for the period May 1985 to December 1999. It is found that in the Mumbai market, futures market prices dominate spot market prices in all contracts except one, whereas in the Ahmedabad market neither the futures market nor the spot market dominates in price discovery.

Sahadevan (2002)[34] evaluates the efficiency of Indian agricultural commodities futures markets in price discovery and finds that the futures markets are not efficient since the futures prices are not an unbiased predictor of the future ready rates and that the futures exchanges fail to provide an efficient hedge against the risk emerging from the volatile prices of many farm products on which they carry on futures trading.

Vipul (2005)[35] has observed that futures contracts are under-priced which may result into misleading information regarding the prospective moves in the cash market, which in turn may damage the interest of the traders. It has also been observed that due to existence of co-integration, both the markets may be in dis-equilibrium in the short-run but such deviations are corrected through arbitrage process.

Praveen D.G. and Sudhakar A. (2006)[36] highlights how the commodity futures market influences the spot market and facilitates better price discovery, in India. It has been found that the spot and / or futures market dominates the price discovery, but it appears that a better price discovery occurs when there is a mature futures market for the commodity. Using Granger causality test on the Indian stock and commodity markets, a comparison is drawn for price discovery between the grown stock market and the growing commodity market.

Kapil and Balwinder (January 2006)[37] investigates the hypothesis that the market for futures contracts on Nifty equity index of National Stock Exchange of India Limited

(NSEIL) effectively serves the price discovery function in the underlying spot market. Johansen's co-integration, Vector error correction model and Generalized impulse response analysis are applied to test the hypothesis on daily data from NSEIL. Bilateral causality is observed between Nifty index and Nifty futures. The evidence supports the hypothesis, suggesting that the futures market in India is a useful price discovery vehicle.

Kakati and Kakati (2006)[38] examines price dynamics between spot and futures prices and also informational content of the basis (whether information revealed by the basis has a signaling role in determining the direction of change in spot and futures prices), using daily prices of futures contracts on Nifty index, CNX IT index and ten individual stocks traded on National Stock Exchange of India Limited. No evidence has been found to assert that futures prices lead spot prices on a day-to-day basis. It appears that information is mostly aggregated in the spot market and then transmitted to the futures market. For longer lag periods, bi-directional causality with moderate feedback has been noticed. It is found that the basis reveals the direction of changes in futures prices and to a much less extent, that of spot prices.

Sah and Kumar (2006)[39] observes that futures contracts on the equity index Nifty significantly leads the price movement in cash market of National Stock Exchange of India Limited (NSEIL), which may play key role in the risk transfer process from cash market to futures market.

Kapil and Balwinder (December 2006)[40] investigates the price discovery and hedging efficiency of the futures contracts on the equity index Nifty and some individual stocks traded on NSEIL for the period November 2001 to June 2006, using Vector Auto-Regression and finds significant evidence that futures market leads cash market, which implies that futures market is an efficient price discovery vehicle. Further, hedge ratio has been estimated using EGARCH (1,1) model.

M.T.Raju and Kiran Karande (2003)[41], applying error correction model to daily closing values of the equity index Nifty in the cash market and the futures contract on Nifty, in National Stock Exchange of India (NSEIL) over the period June 2000 – October 2002, concludes that information gets reflected first in the derivatives market segment.

Thus, many of the publications pertain to the commodities markets in India and analysis has been made using Garbade – Silber model or error correction method, in almost all the articles. Both the approaches involve construction of simultaneous linear equations relating the price levels in the spot and the futures markets and thus study only linear relationships between the two markets whereas financial time series are known to have non-linear characteristics also.

(C) INTERACTIONS BETWEEN STOCK AND OTHER MARKETS

The study about co-movement of the general price level in the stock market and the exchange rate of the currency of a country has gained considerable interest among financial economists since the mid-1990's and there has been many publications on the topic after the financial crisis of the east Asian countries during 1997 – 98. Some important articles on the interactions between stock and forex markets of various economies are given below.

Golaka C.Nath and G.P.Samanta (2003)[42] has used Granger causality test in Vector Auto Regression framework and Geweke's feedback measures on daily data of the exchange rate of Indian Rupee vis-à-vis USA Dollar and Nifty, the stock price index of NSE (National Stock Exchange of India) for the period from April 1993 to March 2003 and found that Granger causality test did not point much impressive causal relationship between returns in the two markets though there was evidence of strong causal relationship in some specific financial years, whereas Geweke's feedback measures detected strong bi-directional and contemporaneous causal relationship between returns in these markets.

Huzaimi Hussain and Venus Khim-Sen Liew (2004)[43] has used Granger causality test, Sim causality test and Geweke causality test on daily data of Kuala Lumpur Stock Exchange Composite Index and Stock Exchange of Thailand Index and exchange rates of Malaysian Ringitt and Thai Baht vis-à-vis US dollar for the period July 1997 – August 1998 and found that

- there was uni-directional causality from exchange rate to stock prices in Thailand
- there was feed-back relationship between exchange rate and stock prices in Malaysia
- the fall in Thailand currency had been transmitted to Malaysian currency via the close ties between the stock markets of the two countries, during the 1997 currency crisis.

Rizwan Tahir and Ahmed Abdul Ghani (2004)[44] has used Granger causality test on monthly data of stock price index of Bahrain stock market and exchange rates of Bahraini Dinar vis-à-vis Great Britain Pound, Deutsche Mark and Japanese Yen (since Bahraini Dinar is pegged to US dollar) and found no relationship between stock prices and exchange rate vis-à-vis Deutsche Mark and also uni-directional causality from stock prices and exchange rate vis-à-vis Great Britain Pound and Japanese Yen.

Victor Murinde and Sunil Poshakwale (2004)[45] has used a bi-variate vector autoregressive model on daily data of stock price indices and nominal exchange rates for Hungary, Czech Republic and Poland for the pre-Euro period January 1995 – December 1998 and the Euro period January 1999 – December 2003 and found

- during the pre-Euro period, that stock prices uni-directionally Granger caused exchange rate in Hungary and that mutually reinforcing interactions between exchange rates and stock prices existed in the Czech Republic and Poland
- during the Euro period, that exchange rates uni-directionally Granger caused stock prices in all the three nations

Naeem Muhammad and Abdul Rasheed (2004)[46] has used Granger causality test on monthly data of stock price indices and exchange rates for 4 Asian nations viz. Pakistan, India, Bangladesh and Sri Lanka and found no evidence of short run association between these variables in any of the 4 nations but found bi-directional long run relationship in Bangladesh and Sri Lanka.

Daniel Stavarek (2004)[47] has used vector error correction modeling and standard Granger causality test on monthly data of effective exchange rates and standard national indices of Morgan Stanley Capital International, pertaining to USA and eight European Union member countries and found predominantly uni-directional causality from stock prices to exchange rates in countries with developed capital and foreign exchange markets (old European Union member countries and USA), which was stronger than in the new European Union member countries.

Tahir M.F. and Wong Wing Keung (2006) [48] has used Granger causality test on monthly data of exchange rate of Pakistan Rupee vis-à-vis USA dollar and the main and sectoral indices of Karachi Stock Exchange and found evidence in favour of portfolio balance model i.e. uni-directional causation of stock prices to exchange rate.

W.N.W.Azman-Saini, M.S.Habibullah, Siong Hook Law and A.M.Dayang-Afizzah (2006) [49] has used Granger non-causality test, proposed by Toda and Yamamoto (1995), on daily data of Kuala Lumpur Stock Exchange Composite Index and exchange rate of Malaysian Ringitt vis-à-vis USA dollar for the period January 1993 – August 1998 and found that both stock and forex markets were not efficient since there was feed-back relationship during the pre-crisis period and that there was uni-directional causality from exchange rate to stock prices during the crisis period.

Benjamin M.Tabak (2006) [50] has used Granger causality test and impulse response functions on daily data of Sao Paulo Stock Exchange Index and the exchange rate of Brazilian Real vis-à-vis US dollar and found evidence supporting the portfolio balance approach after devaluation of the domestic currency, however using non-linear causality test it has been found that changes in exchange rate cause stock price changes.

Hooi Hooi Lean, Paresh Narayan and Russell Smyth (2006) [51] has used Granger causality test in a panel data framework on weekly data of stock price indices and nominal exchange rates for 8 Asian nations and found no evidence of a long run equilibrium relationship between the exchange rate and the stock prices.

Sangeeta Chakravarty (2006) [52] has used Granger non-causality test proposed by Toda and Yamamoto (1995), on monthly data of 5 macro-economic variables pertaining to

India and stock price index of Bombay Stock Exchange for the period from April 1991 to December 2005 and found no causal relation between stock prices and exchange rate. Paresh Kumar Narayan (2007)[53] has used several variants of EGARCH model on daily data of exchange rate of Indian Rupee vis-à-vis USA Dollar and stock price index of BSE (Bombay Stock Exchange) for the period January 1992 to September 2006 and found that over the entire period depreciation had reduced mean returns and an appreciation of the rupee during 2002 – 2006 had increased mean returns and reduced volatility.

Thus, most of the publications have used Granger causality analysis which studies only linear relationships between any two variables.

Apparently, not many studies have analysed the dynamical relationship between the stock and the commodities markets in India. V.Shanmugam and D.G.Prasad (2007)[54] has analysed 2 years data of crude oil prices in the Multi-Commodity Exchange of India (MCX) and the 30 stock index Sensex of Bombay Stock Exchange (BSE), India using regression analysis and found that an increase in crude oil price has led to a fall in the Sensex. In this article, it has also been reported that the equity prices of a few base metal companies and the associated metal futures prices in MCX are highly correlated.

IMPORTANCE OF THE STUDY

(a) The Indian stock market has undergone a sea change over the last ten years. The rapid expansion of electronic trading, the almost complete dematerialisation of securities, the

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IMPORTANCE OF THE STUDY

(a) The Indian stock market has undergone a sea change over the last ten years. The rapid expansion of electronic trading, the almost complete dematerialisation of securities, the smooth shift to rolling settlements, the implementation of a tighter settlement cycle (aimed at T + 1 settlement) and the formation of settlement guarantee fund have tilted the market system in favour of investors. The challenge now towards systemic improvement is to clamp down on price manipulation and trading based on inside information.

Securities and Exchange Board of India (SEBI), the market regulator has framed code of conduct for stock brokers vide SEBI (Stock brokers and sub-brokers) Regulations 1992 which stipulates, inter alia, that a stock broker shall not indulge in manipulative, fraudulent or deceptive transactions or schemes or spread rumours with a view to distort market equilibrium or make personal gains. SEBI has also put in place regulations like SEBI (Prohibition of insider trading) Regulations 1992, SEBI (Substantial acquisition of shares and takeovers) Regulations 1997and SEBI (Prohibition of fraudulent and unfair trade practices relating to securities market) Regulations 2003, to prevent manipulation of the stock market. Further, stock exchanges have framed rules prescribing strict disciplinary action against brokers who are found to have indulged in market manipulation and price rigging. Therefore there is an imminent need for effective tools to filter potential manipulation cases. In this context, testing the suitability of entropy in this area will serve a great purpose towards ensuring market integrity.

(b) Identification of causal relationships between the equities and the derivatives segments of the stock market furthers the understanding of the market's internal dynamics and has a lot of implications, for all the participants of the market. In case causal relationship exists between the two market segments, unexpected changes in equities and derivatives prices will be more correlated. This will improve risk transfer function of derivatives market and reduce arbitrage opportunities and further, the direction of causality serves as a guide to choose the dynamic relationship model between equities and futures prices. In case there is no causal relationship between the two markets, hedging results in non-trivial risk exposure to hedgers, however market players may diversify their portfolios across markets. Existing studies using linear models, have generally observed that price innovations appear first in the derivatives market and are then transmitted to the equities market. Hence analysis of such relationship using non-linear measures like entropy is expected to enhance our understanding of the price dynamics in the two segments.

(c) Interactions between the stock and the forex markets of a country have many implications for not only the domestic participants of the markets but also foreign investors. If exchange rate leads stock prices, then crisis in stock market can be prevented by controlling the exchange rate. Moreover, developing nations may exploit such interaction to attract foreign portfolio investment in their nations. If stock prices lead exchange rate, then policy makers can focus on domestic economic policies to stabilise the stock market. If there is feedback in both the directions, then investors may predict the behaviour of one market using information on the other market. If the markets are not related, investors may reduce risk exposure by diversifying their portfolios across the markets. Existing studies using linear models have arrived at mixed results such as stock market leading forex market or the other way and also, no relationship between the two markets. Non-linear analysis of the lead – lag relationship between the two markets in

India is likely to throw more light which may facilitate decision making regarding the policy requirements in order to attract more foreign investment for sustaining the growth of the Indian economy.

Interactions between the stock and the commodities markets of a country have many implications for not only the participants of the markets but also for the policy makers and the producers of the commodities and, in the case of developing nations, for the economy as a whole. If price discovery in commodities derivatives market is caused by the stock market, agricultural policy may be designed using such causal relationship. Similarly, pro-active steps may be taken to face any shortages or gluts in a commodity which are revealed in futures market in advance. Absence of relationship may be used to diversify investment portfolios across markets. There are not many studies regarding the relationship between the stock and the commodities markets of India and the existing studies have used only linear methods to analyse the relationship. Hence the dynamics of information transfer between the stock and the commodities markets in India may be studied using entropy, which captures non-linear dynamic relationship also, in order to facilitate better understanding of the relationship between these markets.

OBJECTIVES

The objectives of the study are as follows.

(A) To verify the suitability of entropy as a tool for studying price manipulation in the Indian stock market

(B) To study price discovery mechanism between the equities and the derivatives segments of the Indian securities market using the non-linear invariant entropy

(C) To analyse interactions between the stock market and other markets like foreign exchange market and commodities derivatives market of India, using entropy.

METHODOLOGY

(A) PRICE MANIPULATION IN INDIAN STOCK MARKET

For the study of manipulation in stock prices, generally, variation in the price quoted for purchase or sale of a security by the market participants, from the mean price levels is considered. For investigating into potential manipulation cases, stock exchanges maintain surveillance systems which monitor trading activities of the participants in the various securities and throw alerts based on intra-day price movements and abnormal trade quantities. For this purpose, the following measures of variation are used generally.

(a) Price variation in a security = $\dfrac{(LTP \sim CP)*100}{CP}$

where LTP = last trade price of the security

CP = previous closing price defined as the weighted average price of all the trades in the security during the last ½ hour of the previous trading day.

(b) High-low variation in a security = $\dfrac{(HP \sim LP)*100}{CP}$

where HP = highest price at which the security is traded during a day

LP = lowest price at which the security is traded during a day

CP = previous closing price of the security

(c) Consecutive trade price variation in a security = $\dfrac{(LTP \sim PTP) * 100}{PTP}$

where LTP = last traded price of the security

PTP = price of the trade immediately preceding the last trade

(d) Quantity variation in a security = $\dfrac{(TQ \sim AQ) * 100}{AQ}$

where TQ = total traded quantity in the security during a day

AQ = average traded quantity in the security during the last n days

It may be noted that although a trading pattern which crosses the limits stipulated for such variations may be identified on-line, there may be many manipulative trading patterns well within the stipulated limits which will go undetected. Further, these measures of variation identify only linear relationships. Hence advanced techniques are required to detect complex manipulative strategies involving non-linear relationships also. In this context, the non-linear invariant of entropy appears to be a suitable tool to study manipulation of stock prices since entropy is concerned about the irregularity or disorder in a system.

The matter may be approached also through the recent developments in game theory. It has been already observed that Vila Jean Luc (1989) has used game theoretic concepts to study the equilibrium of a stock market subject to price manipulation. Further, Ronald B.Shelton (1997)[55] has portrayed the stock market as a game and studied about pay-offs resulting from the strategies chosen by the players, based on the risks involved in the strategies. Before examining as to how the concepts applied in studying games may be used in the analysis of stock price manipulation, let us assess the stock market as a game.

There is a finite set of players in a game. Every player has a set of strategies and a real valued payoff function depending on the strategies chosen by the players. A game may be a one-stage game, a finitely repeated game or an infinitely repeated game. If the players know all past actions of all the players and the outcomes of all the past actions, then the game is said to be of perfect information. The action space of a player consists of his pure strategies. The more complex entity that chooses among the pure strategies at random in various proportions is called a mixed strategy. It is assumed that when a player uses mixed strategies, he is interested in his average return and does not care about his maximum possible gain or loss. The justification for this is the basic premise of utility theory, which states that one should evaluate a payoff by its utility to the player rather than its numerical monetary value.

The stock market may be considered as a finitely repeated game with many players. A stock exchange maintains an electronic order book that receives all orders placed by the market participants (players) for buying / selling securities. The orders may be placed at various prices for various quantities of any security. These orders result into trades as per pre-specified matching algorithms. Every player has pure strategies in the form of placing a buy order or sell order for a quantity of a security at market price or limit price, as considered justifiable by the player. Further, mixed strategies like placing successive orders quoting a range of prices / quantities and placing both buy and sell orders, may be used by the players. As long as the players place their orders spontaneously based on their information, near equilibrium prices will prevail depending on demand and supply factors apart from the fundamental features of the securities.

However, a player or a group of players may choose strategies which are correlated and may result in creating artificial demand / supply thereby leading to skewed prices. For the players to generate the correlation, the game may have to pass through many stages. Those opponents with so less information as not to observe such correlation, will find the skewed prices much to their disadvantage in terms of utility value of their payoff. The strategies are so distributed as to conceal the correlation from the weak opponents. For example, a group of players may place orders for buying and selling small quantities of a security successively at monotonically increasing prices although there is no natural demand / supply in respect of the security and thus create an artificially high price for the security. Those who do not have perfect information so as to recognise the correlation in the strategies will be lured to choose buy strategy, in successive stages at skewed prices disadvantageous to them. After the group of players sell all their store of the security in a few stages, there will not be any supply of the security and then the weak players against whom concealment of correlation was orchestrated, will be laden with large quantities of the security for which there will not be any demand in the market.

The presence of online correlation in the strategies of a few players of a game, which is concealed from the other players, has been studied by a few researchers, in the context of laboratory games. A path-breaking article, Gilad Bavly and Abraham Neyman (2003)[56] presents the feasibility of online correlation in the strategies adopted by a group of players in a repeated game, which is concealed from a player with less information. It has been shown that the best response of a player to the concealed and correlated actions of his opponents is not guaranteed to yield an expected payoff as large as his individually rational payoff. Further, the notion of strategic concealment is defined using information theoretic terminology and the conditions for the existence of such concealment have been stated in terms of entropy of the strategies adopted by the players. It may be noted that entropy is defined for the probability mass or density function of a random variable and that a mixed strategy being a probability distribution on the set of all pure strategies available to a player, entropy of the mixed strategies of the players in a game is defined naturally.

However, these studies have not covered the presence of online correlation in the trading strategies of the players in a stock market game. Those who are involved in price manipulation in the stock market may act in collusion with a few other players or may act in seclusion. They distribute their trading strategies in the successive stages in such a way that they appear random to the other players. However a concealed correlation is orchestrated in the distribution of the successive strategies. The entropy of such a distribution will be different from that of the distributions which do not have such correlation built-in by the players. Hence the concept of entropy is a prospective technique to study potential manipulation in stock prices.

Thus considering the stock market either as a non-linear dynamical system or as a game, we find entropy as an appropriate method to identify possible manipulation in stock prices. In the electronic stock trading system, as market participants place orders for buying or selling a security at different prices and for various quantities, trades are effected by matching these orders according to price – time priority. A security's price is expected to change from time to time based on the fundamental factors of the security, its past history and the demand for the security. 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 security change with time, a participant assigns values to the variables – price, time and quantity - with some probabilities, while placing orders. Hence order price, time and quantity in respect of a security may be construed as random variables with probability distributions.

Since the computation of entropy of a random variable requires its probability mass function, we may compute the entropy of the random variables of order price, order time and order quantity in respect of a security for every participant, if only we can fit a probability distribution for each of these variables. For any security, the only publicly available information are trade price, trade time and trade quantity, for all trades on any day and without the identity of the participants who are parties to the trades. Hence fitting probability mass or density function for the order placement strategies adopted by each of the participants is not possible. However, considering trade price, trade time and trade quantity, for all trades in a security on any day as variables, we have time series of these variables for any trading day. Different versions of entropy like sample entropy, are available to compute the entropy of such time series and we may compute the sample entropy of these time series for successive trading days. 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 security to security and from time to time, entropy also will vary from security to security, depending on the trading activity.

However, when a market participant repeatedly places orders for buying / selling a security according to some pattern in the price or time or quantity, with a motive of manipulating the price of the security, the probability distributions of these variables undergo changes which will get reflected in the corresponding entropy values. Further, 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 may lead to potential evidence of price manipulation by a participant. Of course, regularity of such nature may occur by chance rarely. However, repeated drops in the entropy values of the variables of a security in a span of a few trading days point to likely manipulation in the price of the security.

In this study, 3 securities which were reported to have been subject to manipulation are considered, sample entropy of the time series of the prices of all trades in each security for every trading day during the period of manipulation is computed and the values are analysed to identify any indication of price manipulation.

(B) PRICE DISCOVERY IN INDIAN SECURITIES MARKET

The temporal relationship between the equities and the derivatives segments of the securities market in various countries has been studied by identifying lead – lag relationship between the value of a representative index of the equities market and the price of a corresponding index futures contract in the derivatives market. Various methods have been proposed for the analysis of the set of simultaneously recorded variables - stock index value and index futures price - over a period of time and it has been generally observed that price innovations appear first in the derivatives market and are then transmitted to the equities market. Early studies of such price discovery have generally used cross-correlation and cross-spectrum, with time delay in the observations pertaining to one market segment, in order to facilitate identification of the direction of information flow. Garbade and Silber model and Granger's causality model have been introduced subsequently and have been used in a number of studies examining the source of price discovery. These two approaches involve estimation of simultaneous linear equations in a pair of variables with time lags.

Since relationship between financial variables include non-linear characteristics also, it is required to estimate the information exchange between financial time series, using non-linear methodology. An information theoretic measure called transfer entropy which quantifies the exchange of information between two non-linear dynamical systems, has been introduced recently. This has been used by researchers for studying the relationship between the US and German stock markets and also for studying information flow among groups of stocks traded in New York Stock Exchange. In this study, price discovery in

Indian securities market is analysed using transfer entropy, with high frequency data. Two time series – value of 50 stock index of the equities market of the National Stock Exchange of India Limited viz. Nifty and price of the near month Nifty index futures contract traded in the derivatives market of the exchange – with minute-wise data over the period October 2005 – September 2006 are formed since day-wise data may not be meaningful in the context of fast communication and information dissemination technology available now-a-days. Transfer entropy is computed between the two series in both the directions – from equities market to derivatives market and from derivatives market to equities market – and the computed values are interpreted using the notions of net information flow, normalised directionality index and relative explanation added.

(C) INTERACTIONS BETWEEN STOCK AND OTHER MARKETS OF INDIA

(i) The interactions between the stock market and the foreign exchange market of developing and developed nations has been studied by identifying lead – lag relationship between the value of a representative index of the stock market and the exchange rate of the local currency vis-à-vis US dollar or the currency of a developed economy. Researchers have used various methods and mostly, the error correction model to study such relationship and arrived at mixed results such as stock market leading forex market or the other way and also, no relationship between the two markets. All these methods study only linear relationship and hence in this study, it is proposed to use transfer entropy to identify interaction, if any, between the stock market and the foreign exchange market of India.

The 50 stock index of the National Stock Exchange of India Limited viz. Nifty and the Reserve Bank of India (RBI) reference rate for the Indian Rupee vis-à-vis US Dollar are taken as representatives of the stock market and the forex market of India, for identifying causal relationship, if exists. The daily values of these two variables over the period from November 1995 to March 2007 are taken as two time series and transfer entropy between the two series is computed. Considering the important developments in the two markets, the period under study is divided into 3 sub-periods and transfer entropy is computed for each sub-period separately, to study the interactions between the two markets in view of the developments. Further, net information flow, normalised directionality index and relative explanation added are computed from the transfer entropy values, to gain more insight into the relationship between the two markets in India.

(ii) Linear regression has been used in existing studies to analyse the relationship between the stock and the commodity markets in India and hence it is proposed to use the non-linear measure of transfer entropy to identify causal relationship, if any, between the two markets in India. The 50 stock index of the National Stock Exchange of India Limited viz. Nifty, the near month futures contract on the Nifty index, the index of commodities spot prices NCDEXAGRI launched by the National Commodity & Derivatives Exchange Ltd. (NCDEX) and the index FUTEXAGRI constructed on the basis of online prices of the nearest month expiry futures contracts traded in NCDEX are taken as the representatives of the stock, the stock derivatives, the commodities spot and the commodities derivatives markets in India, for studying the relationship among these markets. The daily values of these variables over the period from June 2005 to September 2007 are taken as four time series. Transfer entropy is computed between these series, taken two at a time and the computed values are interpreted using net information flow, normalised directionality index and relative explanation added.

LIMITATIONS

The value of sample entropy depends on 2 parameters - the template size m and the tolerance limit r – they are not to be assigned arbitrarily but m is to be chosen on the basis of minimum mutual information of the trade price time series so as to enhance the independence of the templates to a large extent and r is to 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. The study of price manipulation in the stock market has been done using trade related data since order related data are not available publicly. It may be noted that all the orders placed by a potential manipulator may not result in trades and thus order related data will carry more information than trade related data. Hence entropic analysis of order related data (if available) will ensure more efficiency in filtering potential manipulation cases. Further, if there are too few trades on any day in a scrip i.e. if the time series pertaining to any day is too short, say, with less than 25 trades, then sample entropy may not be defined for that day.

It may be noted that in the study of causal relationship, entropic analysis does not provide a model revealing the relationship between the variables under study but estimates a value for the same. Further, the value of transfer entropy, as such does not convey much information and deduced measures like net information flow, directionality index and real taken two at a time and the computed values are interpreted using net information flow, normalised directionality index and relative explanation added.

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It may be noted that in the study of causal relationship, entropic analysis does not provide a model revealing the relationship between the variables under study but estimates a value for the same. Further, the value of transfer entropy, as such does not convey much information and deduced measures like net information flow, directionality index and real explanation added are required to interpret the results. Moreover, in the computation of transfer entropy, determination of the appropriate partition of the data series and the block length of the transferee time series, has to be done with utmost care. $T_{Y \to X}$ (k,l) is a non-increasing function of the block length k of the series X, since inclusion of more number of past observations in the variable X is likely to result in reduction of flow of information from Y in the estimation of the next value of X. The parameter k is to be chosen as large as possible in order to find an invariant value for $T_{Y \to X}$, however due to the finite size of real time series, it is required to find a reasonable compromise between unwanted finite sample effects and a high value for k. Further, a very small value of k may lead to misinterpretation of information contained in past observations of actually both series as an information flow from Y to X and hence k may be chosen as large as possible. A good choice for k is such that contiguous templates of size k constructed from the time series are not within the neighbourhood of one another. Such a choice is provided by the value of k corresponding to which the mutual information of the time series with delay k viz. I(k) is small and consequently the contiguous templates are independent to a large extent. As k is increased, I(k) decreases and may rise again and hence the first minimum of I(k) may be considered to choose the value of k.

CHAPTERISATION

The thesis is divided into six chapters.

- The INTRODUCTION chapter portrays the backdrop in which this study is made and points out the relevant importance this study carries. This chapter also spells out the objectives of the study and reviews the existing literature on the subject. Further, this chapter includes a description of the methodology adopted in this study and the limitations of this study.

- The second chapter THEORETICAL FRAMEWORK OF ENTROPY explains the concept and the basics of entropy theory and also provides an account of the development of the theory.
- In the third chapter PRICE MANIPULATION IN INDIAN STOCK MARKET – CASE STUDIES, the suitability of sample entropy as a tool to filter potential manipulation cases is illustrated by way of 3 case studies.
- PRICE DISCOVERY IN INDIAN SECURITIES MARKET forms the fourth chapter in which lead – lag relationship between the equities and the derivatives segments of the Indian securities market is studied using transfer entropy.
- The fifth chapter INTERACTIONS BETWEEN STOCK AND OTHER MARKETS OF INDIA applies transfer entropy to study non-linear dynamical relationship between the stock market on the one side and the foreign exchange and the commodities markets on the other side.
- The concluding chapter SUMMARY OF FINDINGS AND SUGGESTIONS presents a brief summary of the findings of the study and a list of suggestions for policy making and also for the investing community. The scope for further research has been included in this chapter.

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CHAPTER - II

THEORETICAL FRAMEWORK OF ENTROPY

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THEORETICAL FRAMEWORK OF ENTROPY

This chapter deals with the historical background of entropy theory and its wide ranging applications. A few basic concepts and terminology in the study of entropy as used in information theory are included to facilitate easy understanding of the subject. In order to recognise the diverse nature of the entropic concept, some important versions of entropy have been explained. Then some seminal studies have been quoted, to appreciate the faculty of entropy for addressing various issues in the field of financial economics.

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 as well as 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. Boltzmann's approach is backwards to the microscopic origins of uncertainty in a probability measure whereas Shannon's view is ahead, taking the probability measure as given and generating a random signal as per the probability measure. The introduction of metric entropy and extension of classification theory of measure-preserving transformations, by Kolmogorov in the 1950's, led to significant advances.

BASIC CONCEPTS OF ENTROPY

A few basic concepts of entropy as per the Shannon's approach, which are widely used in information theory, are given below, in order to have an understanding of entropy theory.

ENTROPY OF A RANDOM VARIABLE

Let X be a random variable with p(x) as the probability mass function. Then the Shannon's entropy of X is defined as $H(X) = H(p) = -\sum_{x} p(x) \log p(x)$

$= E [\log \{1/ p(x)\}]$ 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.

JOINT ENTROPY

The joint entropy of a pair of random variables X and Y with a joint probability mass function p(x,y) is defined as $H(X,Y) = -\sum_{x}\sum_{y} p(x,y) \log p(x,y) = -E[\log p(x,y)]$

CONDITIONAL ENTROPY

The conditional entropy of a random variable Y given another variable X is defined as $H(Y / X) = \sum_{x} p(x)\ H(Y / X = x) = -E[\log p(Y / X)$.

Then we get the chain rule $H(X,Y) = H(X) + H(Y / X) = H(Y) + H(X / Y)$

and more generally, $H(X_1,X_2,\ldots,X_n) = \sum_{i=1}^{n} H(X_i / (X_1,X_2,\ldots,X_{i-1})$

It follows that $H(X_1,X_2,\ldots,X_n) \leq \sum_{i=1}^{n} H(X_i)$ with equality if and only if X_i are independent. Conditioning reduces entropy i.e. $H(X / Y) \leq H(X)$ with equality if and only if X and Y are independent. Also, $H((X,Y) / Z) = H(X / Z) + H(Y / (X,Z))$.

RELATIVE ENTROPY

The relative entropy or cross entropy or the Kullback – Leibler (KL) distance between two probability functions p(x) and q(x) is $D(p \| q) = \sum_{x} p(x) \log \{p(x) / q(x)\} = E[\log \{p(x) / q(x)\}]$. It may be noted that $D(p \| q) \geq 0$

$= 0$ if $p = q$.

However, $D(p \| q) \neq D(q \| p)$ in general. Since relative entropy is not symmetric and does not satisfy the triangle property, it is not a true distance between distributions.

MUTUAL INFORMATION

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

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

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

$= 0$ if X and Y are independent.

Also, $I(X;Y) = H(X) - H(X / Y) = H(Y) - H(Y / X)$

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.

CONDITIONAL MUTUAL INFORMATION

The conditional mutual information of random variables X and Y given Z is

$I((X;Y) / Z) = H(X / Z) - H(X / (Y,Z)) = E[\log\{p((X,Y) / Z) / p(X / Z)\, p(Y / Z)\}]$

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

$= 0$ if X and Y are conditionally independent given Z.

Then we get the chain rule for mutual information $I((X_1,X_2,\ldots,X_n);Y) = \sum_{i=1}^{n} I(X_i;Y / (X_1,X_2,\ldots,X_{i-1}))$

MAXIMUM ENTROPY

The uniform distribution over any range $\aleph$ has the probability density function

$u(x) = 1 / |\aleph| \; \forall x \in \aleph$ where $|\aleph|$ is the number of elements in $\aleph$.

The uniform distribution is the maximum entropy distribution.

For any distribution p(x), $0 \le D(p \| u) = \log |\aleph| - H(X)$ and hence $H(X) \le \log |\aleph|$

ENTROPY RATE

The entropy rate of a stochastic process $\{X_i\}$, i = 1,2,...,n is defined as

$$H(\aleph) = Lt_{n\to\infty} \frac{1}{n} H(X_1,X_2,\ldots,X_n) \text{ if the limit exists}$$

i.e. it is the rate at which the entropy of the sequence grows with n.

For example, if X_i are independent and identically distributed random variables, then

$$H(\aleph) = Lt_{n\to\infty} \frac{1}{n} H(X_1,X_2,\ldots,X_n) = Lt_{n\to\infty} \frac{1}{n} \sum_{i=1}^{n} X_i = Lt_{n\to\infty} \frac{1}{n} n\, H(X_1) = H(X_1)$$

If X_i are not identically distributed but are random, then all the $H(X_i)$'s need not be equal and the limit need not exist. Entropy rate may also be defined as $H'(\aleph) = Lt_{n\to\infty} H(X_n / X_1,X_2,\ldots,X_{n-1})$ if the limit exists.

$H(\aleph)$ is the per symbol entropy of the n random variables whereas $H'(\aleph)$ is the conditional entropy of the last variable given the past.

For a stationary stochastic process, H(ℵ) and H'(ℵ) exist and are equal.

DIFFERENT VERSIONS OF ENTROPY

The main contributions towards the applications of the entropic concept in the information theory came from Shannon, Renyi and Kolmogorov. Accordingly different versions of entropy have been introduced, apart from the Shannon's definition. Important versions of entropy are given below, in order to appreciate the potential of the entropic concept.

DIFFERENTIAL ENTROPY

The Shannon version of entropy defined in respect of a continuous random variable is called differential entropy. For a continuous variable X with probability density function f(x), the differential entropy is defined as $h(X) = - \int_{-\infty}^{\infty} f(x) * \ln f(x)\, dx$

The differential entropy satisfies the properties $h(X + c) = h(X)$ and $h(cX) = h(X) + \ln |c|$, where c is a constant.

KOLMOROGOROV – SINAI ENTROPY

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 only and this kind of uncertainty about the future is measured by Kolmogorov – Sinai (KS) entropy.

The joint entropy of a stochastic process $\{X_1, X_2, \ldots, X_n\}$ is defined as

$$H_n = - \sum_{x_1} \ldots \sum_{x_n} p(x_1, \ldots, x_n) \log p(x_1, \ldots, x_n)$$

where $p(x_1, \ldots, x_n)$ is the joint probability for the n random variables $X_1, X_2, \ldots, X_n$.

The state of a system at a certain instant X_n is partially determined by its history X_1, $X_2, \ldots, X_{n-1}$, however each new state carries a certain amount of new information. If the phase space of a system with d degrees of freedom is partitioned into hypercubes of content $\in^d$ and the state of the system is measured at intervals of time τ, then the mean rate of information creation in the system is given by $H_{KS} = Lt_{\tau \to 0} Lt_{\in \to 0} Lt_{n \to \infty} (H_{n+1} - H_n)$

The limit, if exists, is called the KS entropy (also known as metric entropy). Entropies of only finite order n may be computed numerically. As n becomes large w.r.t. the length of a given time series, the entropy H_n is underestimated and decays towards zero. So KS entropy for time series of finite length cannot be estimated with reasonable precision.

RENYI ENTROPY

Renyi entropy characterises the amount of information which is needed in order to specify the value of an observable with a certain precision when we know the probability density function of the observable. If the range of a random variable X is partitioned into disjoint boxes ρ_j of side length $\leq \in$ and $\mu(x)$ is the measure of X, then

$p_j = \int_{\rho_j} d\mu(x)$ denotes the fraction of the measure contained in the j^{th} box. Given such a partitioning, the order-q Renyi entropy of X is defined as $H_q(\in) = \frac{1}{1-q} \ln \sum_j p_j^q$

For q = 1, the Renyi entropy becomes $H_1(\in) = - \sum_j p_j * \ln p_j$ which is the Shannon entropy.

It may be noted that the various concepts and versions of entropy are concerned about not only linear but also non-linear characteristics in dynamical systems and hence may be useful to study the dynamics in financial markets, which are observed to have displayed non-linear relationship. In the Indian context, Sunil S. Poshakwale (2002)[1] has examined the random walk hypothesis using daily data on individual stocks traded in Bombay Stock Exchange (BSE) and an equally weighted portfolio and found statistical evidence to reject the random walk hypothesis and also to suggest that daily returns earned by individual stocks show significant non-linear dependence and persistent volatility effects. Further, Saket Sathe (2005)[2] has found using serial correlation, mutual information, correlation dimension and method of close returns, that daily returns of various stock indices of National Stock Exchange of India Limited (NSE) display small amounts of linear and significant amounts of non-linear dependence. Hence non-linear dynamics in general and the entropy theory in particular, may be quite useful in studying the microstructure of Indian stock markets and other markets which display non-linear dependence.

IMPORTANT STUDIES USING ENTROPY IN FINANCIAL ECONOMICS

As already seen, the theory of entropy has been applied in a wide range of subjects and specifically, used to explain various concepts in the field of financial economics. A few important studies are mentioned below, in order to illustrate the pervasiveness of entropy throughout the entire gamut of financial economics.

(1) David Nawrocki (1984)[3] has described an application of entropy theory to financial market disequilibrium.

(2) John Conover (1994)[4] has applied entropy theory in devising a methodology for programmed trading of equities.

(3) David T.Marantette (1998)[5] has found the analysis of entropy tops and bottoms as an addition to the buy and sell points of cyclic analysis.

(4) Marco Frittelli (2000)[6] has studied the characterization of the density of the minimal entropy martingale measure, which suggests that the equivalence between the maximization of expected exponential utility and the minimization of the relative entropy.

(5) Esfandiar Maasoumi and Jeff Racine (2002)[7] has examined the predictability of stock market returns by employing a new metric entropy measure which is capable of detecting non-linear dependence within the returns series.

(6) Wolfgang Kispert[8] has used the prices of stock options to find a probability measure for the underlying stock and has derived that the probability vector with maximal entropy seems to be theoretically more justified than others.

(7) Debasis Bagchi (2003)[9] has studied the behaviour of Indian public sector banks with respect to their capital adequacy ratio dynamics, by decomposing the financial statements, using entropy based measures and found that such measures can explain banks' policy decisions on liabilities and assts reorganisation.

(8) Steve Pincus and Rudolf E.Kalman (2004)[10] has demonstrated the utility of approximate entropy to assess subtle and potentially exploitable changes in serial structure of a financial variable.

(9) Jing Chen (2005)[11] has shown that most empirical evidences about market behaviour may be explained by a new information theory generalised from Shannon's entropy theory of information.

(10) Andreia Dionisio, Rui Menezes and Diana A. Mendes (2005)[12] has presented the advantages of entropy over variance as a measure of uncertainty and also shown the good performance of entropy in comparison with systematic risk and specific risk with respect to diversification effect in portfolio management.

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CHAPTER - III

PRICE MANIPULATION IN INDIAN STOCK MARKET

CHAPTER III

PRICE MANIPULATION IN INDIAN STOCK MARKET

This chapter elucidates the advantages of entropy over the measures of variation in the study of stock price manipulation. The formulae based on identification of repetitive patterns, which are used for the estimation of two versions of entropy viz. approximate entropy (ApEn) and sample entropy (SampEn), are explained to illustrate that ApEn and SampEn are much aligned to the analysis of patterns, a key feature of price manipulation in stock markets. Then the selection of values for the parameters in the computation of SampEn of a time series is taken up. To substantiate the theoretic findings, case studies involving three scrips which were reported to have been subject to price manipulation, are presented in this chapter.

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 for pricing 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 model, 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 seen already, entropy which measures the rate of information production in a dynamical system, is a potential tool for the purpose.

ENTROPY Vs VARIANCE

Stock market analysts normally study shifts in mean levels and in variation (in various notations) to understand the state of the stock 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 with the magnitude of asset price fluctuations or variation, 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 a security's 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 security, 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. Approximate entropy (ApEn), introduced by Steve Pincus and Burton H.

Singer (1998)[1] as a family of statistics closely related to the entropy measure, proves to be an appropriate tool to grade the extent of irregularity.

Entropy is a measure of disparity of the probability mass function of a distribution from the uniform distribution whereas variance measures the average distance of the various realizations from the mean of a distribution. According to Ebrahimi, Maasoumi and Soofi (1999)[2], both these measures reflect concentration, however unlike variance which measures concentration only around the mean, entropy measures diffuseness of the density irrespective of the location of concentration. They also show, using a Legendre series expansion, that entropy depends on many parameters of a distribution and may be related to high order moments of a distribution. Therefore entropy could offer a closer characterization of the probability mass function since it uses more information about the distribution than that used by variance and hence is more general than the traditional methods based on variance. McCauley J. (2003)[3] propounds that entropy represents the disorder and uncertainty of a stock market or a particular stock since entropy has the ability to capture the complexity of the systems, without requiring rigid assumptions which could bias the results. While volatility is an estimate of the variation of a security'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.

APPROXIMATE ENTROPY

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. The calculation of Shannon entropy requires the probability density (mass) function of the random variable which denotes the time series. However, Kolmogorov - Sinai (KS) entropy may be a useful parameter to characterise system dynamics. Though KS entropy measures the mean rate of creation of information, it cannot be estimated with reasonable precision for real world time series of finite length. Hence ApEn (approximate entropy), a set of measures of serial irregularity, has been introduced for typically short noisy time series. 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. Precisely, 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.

ApEn ESTIMATION

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

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

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

....

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

....

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

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

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 $\{ u_i \}$.

$$\text{Let } C_{m,i}(r) = \frac{\text{Number of j s.t. } d(x_{m,i}, x_{m,j}) \leq r}{N - \overline{m-1}}$$

$= \text{ratio of } x_{m,j}\text{'s in the r-neighbourhood of } x_{m,i}$

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....

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$\because$ $d(x_{m,i}, x_{m,i}) = 0 \ \forall$ 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 $\{ u_i \}$.

$$\text{Let } C_{m,i}(r) = \frac{\text{Number of j s.t. } d(x_{m,i}, x_{m,j}) \leq r}{N - \overline{m - 1}}$$

$$= \text{ratio of } x_{m,j}\text{'s in the r-neighbourhood of } x_{m,i}$$

Define $C_m(r) = \dfrac{1}{\overline{\overline{N-m-1}}} \sum_{i=1}^{\overline{\overline{N-m-1}}} C_{m,i}(r)$

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

(If $Lt_{r\to 0} Lt_{N\to\infty} \dfrac{\log C_m(r)}{\log r}$ exists for sufficiently large m, it is the correlation dimension and is denoted as β_m).

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

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

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

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

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

$\therefore 0 \leq$ ApEn $< \infty$ with ApEn = 0 implying perfect regularity.

Small values of ApEn imply strong regularity or persistence in a sequence and large values of ApEn imply substantial fluctuation or irregularity.

For finite N, the largest possible value of ApEn is $-\Phi_{m+1}(r) \leq -\log(N-m)^{-1}$

$\therefore 0 \le$ ApEn(m,r,N) $\le$ log(N-m)

It has been observed that, for m = 2 and N = 1000, choices of r ranging from 0.1 to 0.2 times the standard deviation of the data series $\{u_i\}$ would produce reasonable statistical validity of ApEn(m,r,N).

For small values of r, one achieves poor estimates of the size of the r-neighbourhoods and for large values of r, much detailed information is lost.

DRAWBACKS OF ApEn

It may be noted that 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 i.e. if ApEn of a data set is higher than that of another, it should, but does not, remain higher for all conditions.

Let $A_{m,i}$ (r) = Number of j $\neq$ i s. t. d($x_{m,i}$,$x_{m,j}$) $\le$ r

The ApEn algorithm, then assigns to each template $x_{m,i}$, a biased conditional probability of $\frac{A_{m+1,i}(r)+1}{A_{m,i}(r)+1}$ which will be always > the unbiased probability of $\frac{A_{m+1,i}(r)}{A_{m,i}(r)}$. The largest deviation occurs when a large number of templates $x_{m,i}$ have $A_{m,i}$ (r) = $A_{m+1,i}$ (r) = 0, since a conditional probability of 1 is assigned to these templates (corresponding to perfect order). The difference between the biased and the unbiased conditional probabilities assigned to individual templates makes the calculations sensitive to record length in a way that depends on the conditional probability. As $N \rightarrow \infty$, $A_{m,i}(r)$ and $A_{m+1,i}(r)$ will be generally large, making the biased and the unbiased probabilities asymptotically equivalent. Hence the bias is evident only for finite data sets and the expected value of ApEn(m,r,N) is less than the parameter ApEn(m,r). This bias cannot be eliminated by simply removing self-matches, unless $C_{m,i}(r) > 0 \ \forall i$. One way of reducing the bias is to redefine $A_{m+1,i}(r) = \in_1$ when $A_{m+1,i}(r) = 0$ and $A_{m,i}(r) = \in_2$ when $A_{m,i}(r) = 0$ where $\in_1$ and $\in_2$ are infinitesimal, however this is arbitrary. Hence another family of statistics called sample entropy has been introduced by Joshua Richman S., and J. Randall Moorman (2000)[4] to overcome these drawbacks.

SAMPLE ENTROPY

SampEn (sample entropy) 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. 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

SampEn ESTIMATION

$\because x_{m+1,i}$ 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 $\text{SampEn}(m,r) = \text{Lt}_{N\to\infty} \log \left[\dfrac{B_{m+1}(r)}{B_m(r)}\right]$ which is estimated by the statistic

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

STATISTICAL SIGNIFICANCE OF THE SampEn VALUE

SampEn is not defined unless template and forward matches occur and is not necessarily reliable for small numbers of matches. For fixed m and r, it is assumed that the sample conditional probability follows t distribution with B(m,r) -1 degrees of freedom, where

$$B(m,r) = \frac{(N-m)(N-\overline{m+1})}{2} B_m(r).$$

Then the 95% confidence interval for the "true" average conditional probability of the process is given by $\frac{SD \times t_{0.975}}{\sqrt{B(m,r)}}$ where SD is the sample standard deviation and $t_{0.975}$ is the upper 2.5th percentile of a t distribution with B(m,r) -1 degrees of freedom. Large confidence interval indicates that there are insufficient data to estimate the conditional probability with confidence for that choice of m and r. For small values of N and r, the confidence interval may extend to a probability of > 1 or < 0 and hence no value of SampEn(m,r,N) can be assigned with confidence.

SampEn Vs ApEn

$\frac{(N-m)(N-\overline{m+1})}{2}$ $B_m(r)$ = B(m,r) is the total number of template matches of length m.

Similarly $\frac{(N-m)(N-\overline{m+1})}{2}$ $B_{m+1}(r)$ = B(m+1,r) is the total number of forward matches of length m+1. The conditional probability that two sequences within a tolerance of r for m points remain within r at the next point is given by

$\frac{B(m+1,r)}{B(m,r)} = \frac{B_{m+1}(r)}{B_m(r)}$. Hence SampEn(m,r,N) = - log [$\frac{B(m+1,r)}{B(m,r)}$].

In contrast to ApEn(m,r,N) which calculates probabilities in a template-wise fashion, SampEn(m,r,N) calculates the negative logarithm of a probability associated with the time series as a whole. SampEn(m,r,N) is defined except when B(m,r) = 0 which implies that no regularity has been detected or when B(m+1,r) = 0 which corresponds to a conditional probability of 0 and an infinite value of SampEn(m,r,N). The lowest non-zero conditional probability as per this algorithm is $\frac{2}{(N-m)(N-m+1)}$ and therefore the upper bound of SampEn(m,r,N) is given by

- log [$\frac{2}{(N-m)(N-m+1)}$] = log [$\frac{(N-m)(N-m+1)}{2}$] which is almost double the upper bound of ApEn(m,r,N) viz. log (N- m).

Since sample entropy addresses the drawbacks of approximate entropy and has a wider range of values than approximate entropy, sample entropy of the time series of trade price, trade time and trade quantity of a security over a period may be used to discern serial irregularity and to study manipulation in the price of a security.

PARAMETERS FOR SampEn ESTIMATION

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 may be critical. Although no guidelines exist for optimising their values, generally values between 0.1 and 0.25 for r and values of 2 to 5 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. 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 or Akaike Information Criterion is considered to be the order x of the process. In this study, it is proposed that the information theoretic concept of mutual information be used to estimate appropriate value for the parameter m.

As already seen, 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 $I(X;Y) = D(p(x,y) \parallel p(x)\, p(y)) = \sum_{x} \sum_{y} p(x,y) \log \{p(x,y) / p(x)\, p(y)\}$

$$= H(X) - H(X / Y) = H(Y) - H(Y / X) = H(X) + H(Y) - H(X,Y)$$

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.

TEMPLATE SIZE

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 Andrew M. Fraser and Harry L. Swinney (1986)[5] has suggested 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 may be used.

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.

TOLERANCE LIMIT

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 the standard deviation $\sigma_{f(X)}$ of a differentiable function f of a random variable 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). Douglas E. Lake, Joshua S.Richman, M.Pamela Griffin and J.Randall Moorman (2002)[6] ha suggested that 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.

CASE STUDIES

The scrips Lupin Laboratories Ltd., Morepen Hotels Ltd. and Surya Rooshni Ltd. which have been reported to be subject to price manipulation on various days during the periods October 1999 – January 2000, September 2000 – March 2001 and April 2000 - October 2000 respectively, by the Securities Exchange Board of India[7], are chosen for the study. The prices of all the trades executed in the scrips on the National Stock Exchange of India Limited are taken for the various trading days during these periods. The differences in the prices of successive trades are taken as time series, for the various trading days during such periods, for each scrip. By taking such first differences, stationary character of the time series may be assumed so that meaningful analysis may be made. Further, a manipulator is always interested in price differences in order to gain as much as possible and hence places successive orders with artificial prices carrying a manipulative intent.

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 is calculated with time lag ranging from 1 to 10 and the lags at which the first minimum of mutual information occurred are taken as values for m. For time series with a few hundreds of data points, the optimum value of the tolerance window r has been observed to lie between 0.15 and 0.20

The SampEn of the time series consisting of the differences in successive trade prices of the securities for the various trading days during the periods chosen, for such values of m and r are computed and tabulated.

LUPIN LABORATORIES LTD.

The differences in the prices of successive trades in the scrip Lupin Laboratories Ltd. are taken as time series, for the various trading days during the period October 1999 - January 2000. Thus data are taken in respect of 20 trading days in October 1999, 21 trading days in November 1999, 21 trading days in December 1999 and 7 trading days in January 2000, making a total of 69 time series. Of these, 4 time series have data points less than 100 in number, 7 series have 100 - 500 data points each, 18 series have 500 - 1000 data points each and 40 series have more than 1000 data points each. The summary statistics of a sample time series (of the price differences of the first trading day in October 1999) are given below.

Minimum	-2.90000
1st Quartile	-0.10000
Mean	-0.00378
Median	0.00000
3rd Quartile	0.10000
Maximum	3.40000
Number of data points	1587
Standard Deviation	0.61897
Skewness	0.18456
Kurtosis	3.63352

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 during the period October 1999 - January 2000 is calculated with time lag ranging from 1 to 20. The values are presented in tables 1.1 to 1.4. It may be observed that the first minimum of mutual information generally occurred for the time lag between 2 and 4 and in some cases 5. Hence SampEn may be calculated for template size m = 2, 3, 4 or 5 and 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 these time series is 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 in October 1999, November 1999, December 1999 and January 2000 are given in tables 1.5 to 1.8 respectively. It is observed that SampEn is very low on days 4, 5, 6, 7, 8, 9, 10 and 13 in October 1999, on days 5, 17 and 19 in November 1999, on days 15, 16 and 18 in December 1999 and on days 1 and 7 in January 2000, for all values of m and r. Specifically, SampEn for all these 16 days is utmost 0.20 for m = 5 and r = 0.20*SD. Also, SampEn is 0 on days 6, 7 and 13 in October 1999 and on day 17 in November 1999 implying maximum regularity in the data pertaining to these days. The fact that all the trades on each of these days were executed at the same price lends credence to the maximum possible regularity in the time series and hence the least possible value of SampEn for each of these days. The above mentioned 16 days in October 1999 – January 2000, in respect of which SampEn is very low, are days of potential manipulation in the price of the scrip of Lupin Laboratories Ltd.

MOREPEN HOTELS LTD.

The differences in the prices of successive trades in the scrip Morepen Hotels Ltd. are taken as time series, for the various trading days during the period September 2000 – March 2001. Thus data are taken in respect of 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, 21 trading days in March 2001, making a total of 128 time series. Of these, 50 have data points less than 50 in number, 70 have 50 - 100 data points each and 8 have 100 - 200 data points each. The summary statistics of a sample time series (of the price differences of the first trading day in September 2000) are given below.

Minimum	-1.80000
1st Quartile	0.00000
Mean	0.05476
Median	0.00000
3rd Quartile	0.00000
Maximum	2.20000
Number of data points	63
Standard Deviation	0.44988
Skewness	0.80746
Kurtosis	12.65075

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 during the period September 2000 – December 2000 is calculated with time lag ranging from 1 to 20. The values are presented in tables 1.9 to 1.12. 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.

Accordingly, SampEn of the time series consisting of the differences in successive trade prices of the scrip of M/s Morepen Hotels Ltd. is 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 1.13 to 1.19 respectively. It is 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 is 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 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 during these months.

SURYA ROOSHNI LTD.

The differences in the prices of successive trades in the scrip Surya Rooshni Ltd. are taken as time series, for the various trading days during the period April 2000 - October

2000. Thus data are taken in respect of 17 trading days in April 2000, 20 trading days in May 2000, 21 trading days in June 2001, 20 trading days in July 2000, 17 trading days in August 2000, 18 trading days in September 2000 and 14 trading days in October 2000, making a total of 127 time series. Of these, 123 time series have data points less than 50 in number and 4 series have 50 - 100 data points each. The summary statistics of a sample time series (of the price differences of the first trading day in April 2000) are given below.

Minimum	-0.50000
1st Quartile	0.00000
Mean	0.11875
Median	0.02500
3rd Quartile	0.11250
Maximum	1.00000
Number of data points	25
Standard Deviation	0.29848
Skewness	1.40949
Kurtosis	3.45045

For deciding the template size m in the computation of SampEn for each time series, the mutual information of each time series for various trading days during the period April 2000 - September 2000 is calculated with time lag ranging from 1 to 10 and the values are presented in tables 1.20 and 1.21. It may be observed that the first minimum of mutual information occurred for the time lag between 2 and 4 in almost all the cases and hence SampEn may be calculated for template size $m = 2, 3$ or 4.

Accordingly, SampEn of the time series consisting of the differences in successive trade prices of the scrip of M/s Surya Rooshni Ltd. is computed for $m = 2, 3, 4$ 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 April 2000 - October 2000 are given in tables 1.22 to 1.28. It is observed that SampEn is very low on days 2, 5, 8 and 10 in April 2000; on days 8,12, 13, 14, 17, 18 and 21 in June 2000; on days 2 and 3 in July 2000; on days 5 and 14 in August 2000; on days 4, 7, 12 and 13 in September 2000 and on days 2, 7, 8, 11, 12 and 13 in October 2000, for all values of m and r. Specifically, SampEn for all these days is utmost 0.85 for m = 4 and r = 0.20*SD. The above mentioned days in April 2000 - October 2000, in respect of which SampEn is very low, are days of potential manipulation in the price of the scrip of Surya Rooshni Ltd. Further, it appears that manipulation has been rampant in the months of June and October 2000 since sample entropy has remained at very low level continually for many days during these months.

CONCLUSION

SampEn values for the trade price data related to the scrips of Lupin Laboratories Ltd., Morepen Hotels Ltd. and Surya Rooshni Ltd. for various trading days in the periods during which the scrips were reported to have been subject to price manipulation, are found to support such reporting. Thus sample entropy is found to be suited to study price manipulation in the stock market.

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Table 3.1 – Lupin Laboratories Ltd. – Mutual information - October 1999

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19
1	2.0352	1.7617	1.9492	3.0469	0.875	4	7	3.2969	2.5000	4.4688	2.7275	2.1230	4.5117	2.7910	1.9180	1.8926	1.7695	2.0488	2.0586
2	1.7148	1.6660	1.7402	3.0781	1.25	4	7	3.2852	2.6719	4.1484	2.4424	2.0234	3.3223	2.6777	1.4883	1.5762	1.4414	1.8340	1.8047
3	1.7441	1.6426	1.6426	2.9531	1	4	7	3.1094	2.4453	4.1172	2.2969	2.0059	3.1934	2.6074	1.5820	1.6113	1.5742	1.7402	1.6641
4	1.6582	1.5137	1.9375	3.0078	1	4	7	3.2461	2.5703	4.0469	2.2451	2.0078	3.0781	2.6074	1.4453	1.5605	1.6133	1.6563	1.7129
5	1.7500	1.7109	1.7773	2.9063	1	4	7	2.5508	2.4844	4.2031	2.2959	1.7695	3.0625	2.6309	1.5352	1.6172	1.4141	1.6641	1.7031
6	1.7285	1.5840	1.7266	2.8906	0.875	4	7	2.9180	2.4297	4.3359	2.3340	1.8047	2.9414	2.5547	1.4414	1.5840	1.6797	1.6543	1.7090
7	1.6836	1.6055	1.7559	3.1328	1.25	4	7	2.9883	2.4844	4.4492	2.3828	1.8945	2.9434	2.5703	1.4141	1.4629	1.5977	1.6465	1.7227
8	1.7090	1.6133	1.6387	3.0313	0.75	4	7	2.9922	2.5703	4.4141	2.0664	1.9297	2.8145	2.5996	1.5938	1.5195	1.6289	1.6816	1.5977
9	1.7324	1.6367	1.7402	3.0469	0.75	4	7	2.9883	2.5859	4.4766	2.2012	1.9492	2.9473	2.5430	1.6094	1.4844	1.5352	1.7305	1.6426
10	1.6211	1.7227	1.7207	3.0547	1	4	7	2.8125	2.4844	4.3750	2.2891	1.9512	2.8711	2.5313	1.6211	1.6035	1.5898	1.5801	1.5703
11	1.6406	1.6504	1.8613	2.9844	1	4	7	2.8242	2.3359	4.1641	2.1982	2.0117	2.9336	2.5488	1.4531	1.5625	1.5156	1.5996	1.5820
12	1.7090	1.6426	1.5898	2.9453	1.25	4	7	2.6797	2.6406	4.4219	2.3477	1.9492	3.0254	2.4473	1.5938	1.7031	1.7031	1.7051	1.6367
13	1.6074	1.5039	1.6523	2.9141	0.875	4	7	2.6406	2.5547	4.4141	2.0801	1.9199	3.0664	2.5820	1.7031	1.5859	1.4844	1.5840	1.6523
14	1.7949	1.6602	1.7441	3.1641	0.875	4	7	3.2773	2.3906	4.4844	2.1289	1.8027	3.0742	2.4551	1.4336	1.6348	1.3789	1.5898	1.5195
15	1.7129	1.5625	1.6895	3.0859	1	4	7	2.6875	2.2578	4.3750	2.3506	1.8145	3.1582	2.5391	1.5859	1.5391	1.6250	1.5605	1.5957
16	1.6270	1.6758	1.6797	3.2109	1	4	7	3.0859	2.4297	4.4766	1.9561	1.7656	3.1641	2.5078	1.4766	1.4746	1.5391	1.5918	1.5684
17	1.7012	1.5586	1.5664	3.1953	1	4	7	2.8633	2.6250	4.4727	2.1729	1.8457	3.0762	2.5078	1.5469	1.6035	1.4609	1.6504	1.6504
18	1.7852	1.5898	1.7852	3.3828	1	4	7	2.8320	2.4688	4.4766	2.1992	1.7344	3.1543	2.4980	1.5469	1.6387	1.4727	1.6309	1.5078
19	1.7070	1.5781	1.7383	3.3750	1	4	7	2.7500	2.6094	4.4844	2.3047	1.7539	3.1289	2.4902	1.6328	1.6133	1.6211	1.6699	1.5801
20	1.7070	1.5195	1.6895	3.4219	1	4	7	2.8711	2.5156	4.4844	2.0830	1.9395	3.0645	2.4063	1.4219	1.5176	1.5039	1.6250	1.4844

Table 3.2 – Lupin Laboratories Ltd. – Mutual information - November 1999

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19	Day20
1	1.7305	2.0410	2.1289	1.8320	2.6387	1.8086	2.2246	2.0371	2.8848	1.9688	2.1406	1.7422	2.9248	1.9414	1.8516	2.1250	1.8281	2.6406	2.8906	2.0313
2	1.5586	1.8066	1.7715	1.6328	2.2949	1.5195	1.8672	1.9629	2.5107	1.5254	1.9375	1.7070	2.6816	1.6777	1.5859	2.0391	1.6836	2.3691	2.6953	1.8203
3	1.5820	1.8359	1.8906	1.5273	2.3066	1.6406	1.5820	2.0586	2.4033	1.4844	1.9297	1.6641	2.6836	1.7031	1.6875	1.9766	1.8027	2.3242	3.0820	1.7969
4	1.6445	1.7988	1.7813	1.6992	2.0391	1.4805	1.7715	1.9082	2.3369	1.4180	1.7676	1.5449	2.5703	1.6758	1.5000	1.8555	1.7617	2.1602	2.9199	1.6895
5	1.4883	1.7617	1.7305	1.5234	2.1758	1.5469	1.7617	1.7285	2.2236	1.6133	1.8535	1.6172	2.5635	1.6406	1.5000	1.9375	1.7559	2.2656	2.7324	1.6582
6	1.4531	1.8340	1.6719	1.4805	2.1191	1.4961	1.8730	1.8926	2.4355	1.5566	1.6484	1.6426	2.6270	1.6523	1.4766	2.0332	1.6758	2.2051	2.7930	1.7676
7	1.5039	1.7813	1.7266	1.4922	2.0391	1.5313	1.8457	1.8379	2.4463	1.5254	1.7539	1.5996	2.5566	1.6387	1.5039	1.9375	1.7461	2.2852	2.4922	1.6641
8	1.4961	1.6836	1.7031	1.5703	2.3086	1.3516	1.8828	1.8691	2.3457	1.5664	1.7188	1.5332	2.6035	1.6777	1.5391	1.6777	1.7129	2.1152	2.6133	1.6699
9	1.4922	1.7695	1.8301	1.5664	2.2090	1.4688	1.9063	2.0215	2.4326	1.5020	1.7129	1.6250	2.5156	1.5938	1.4961	1.7988	1.7363	2.1719	2.9023	1.7266
10	1.6484	1.6836	1.7617	1.6953	2.2930	1.4688	1.7480	1.8770	2.4473	1.6074	1.7480	1.5840	2.5273	1.6660	1.5273	1.9512	1.7871	2.1328	2.8633	1.6816
11	1.4609	1.6699	1.7695	1.5586	1.9824	1.4297	1.6641	1.8535	2.4170	1.5410	1.7559	1.6563	2.5371	1.5371	1.6641	1.9160	1.7695	2.2656	2.6523	1.6563
12	1.5664	1.7441	1.7813	1.6680	2.1914	1.6094	1.7793	1.8164	2.3623	1.6094	1.7988	1.6250	2.5088	1.4375	1.4766	1.8145	1.6543	2.1113	2.5918	1.7207
13	1.5664	1.6055	1.6895	1.6367	2.0078	1.4141	1.7637	1.7754	2.0195	1.4961	1.6875	1.5703	2.4365	1.5156	1.3711	1.8594	1.8066	2.1045	2.3809	1.7422
14	1.4297	1.6973	1.6895	1.6094	1.9648	1.4922	1.6875	1.9805	2.0908	1.6484	1.6797	1.6074	2.4141	1.5684	1.4805	1.9316	1.7363	1.9727	2.4004	1.7402
15	1.5508	1.7168	1.7773	1.6250	2.3262	1.4453	1.8105	1.9590	2.3027	1.3984	1.6172	1.5879	2.3789	1.6055	1.5820	1.7988	1.6055	2.0742	2.4727	1.7285
16	1.5000	1.7734	1.6914	1.7656	2.1992	1.3867	1.8223	1.9316	2.3164	1.5059	1.7637	1.6816	2.4648	1.5020	1.5078	1.8438	1.6074	2.0889	2.8438	1.7734
17	1.4219	1.6074	1.7227	1.5430	2.1484	1.5469	1.8223	1.8535	2.2100	1.4844	1.7637	1.5566	2.4160	1.5449	1.6914	1.8613	1.7676	2.2422	2.8750	1.5977
18	1.4531	1.6191	1.7070	1.5938	2.3301	1.5352	1.7012	1.9355	2.2510	1.5215	1.8008	1.5430	2.3867	1.5723	1.4570	1.6895	1.7129	2.1621	2.8145	1.7852
19	1.6602	1.6641	1.6465	1.6211	2.1465	1.5430	1.8008	1.9805	2.1875	1.4902	1.7578	1.5762	2.3105	1.6016	1.4688	1.8594	1.7910	2.1904	2.6270	1.8223
20	1.5391	1.7480	1.6426	1.4219	2.0566	1.5352	1.6113	1.8887	2.0684	1.5469	1.8574	1.5039	2.4033	1.5605	1.3945	1.9668	1.7988	2.2666	2.6738	1.7227

Table 3.3 – Lupin Laboratories Ltd. – Mutual information - December 1999

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19	Day20
1	2.2266	1.9922	2.2480	2.7285	2.3320	2.4766	2.0352	2.3438	1.9102	2.2305	1.9492	2.1992	2.8887	4.5020	4.4688	2.9688	4.2148	2.0645	3.0117	1.7344
2	2.0273	1.6172	1.9219	2.4258	2.1387	1.8672	1.8203	1.8984	1.8320	1.6367	1.6680	1.9258	2.4863	4.2578	4.2813	2.8125	3.5508	1.8652	2.5703	2.0547
3	1.8789	1.4766	1.9609	2.3945	2.1699	1.9043	1.6680	1.8281	1.8320	1.5430	1.8008	2.0469	2.4229	4.1348	4.1563	2.7578	2.9531	1.7148	2.3066	1.8203
4	1.7891	1.4883	1.9863	2.2461	2.2656	1.9805	1.8672	1.8164	1.6992	1.9922	1.8008	2.0117	2.3887	4.3965	4.3750	2.7285	2.9531	1.8672	2.3027	1.8828
5	1.8555	1.5859	1.8398	2.3848	1.8145	1.9688	1.7500	1.8789	1.7461	1.8789	1.6953	1.9473	2.2764	4.2324	2.7813	2.7422	2.7227	1.8633	2.1621	1.9453
6	1.9473	1.7305	1.7793	2.3984	2.1230	1.8516	1.7617	1.6367	1.7695	1.8516	1.7031	1.9219	2.1348	4.3848	2.8125	2.6387	2.7461	1.9277	2.0859	1.6797
7	1.8789	1.4570	1.9570	2.1836	1.7617	1.8574	1.8438	1.7461	1.8125	1.6992	1.5078	1.9902	2.1016	4.2910	2.6563	2.7012	2.6602	1.8848	2.1953	1.5938
8	1.7754	1.5547	1.8301	2.3477	1.8809	1.8203	1.7305	1.7305	1.5703	1.6055	1.5273	1.7695	2.2207	4.1680	2.6563	2.5059	2.8984	1.7441	1.8594	1.8047
9	1.8301	1.6328	1.8652	2.1719	1.8203	1.8262	1.6563	1.7422	1.7031	1.6406	1.7656	1.6660	2.0508	4.1367	2.7813	2.5801	2.7266	1.6406	2.2051	1.7188
10	1.7031	1.5703	1.9180	2.3789	1.8340	1.8945	1.7227	1.5195	1.6563	1.5469	1.6016	1.8457	2.2529	4.2695	2.6250	2.7578	2.8750	1.7578	2.1445	1.8672
11	1.9492	1.6328	1.8125	2.2461	1.8438	1.7773	1.6289	1.6914	1.7188	1.7109	1.5039	1.9512	2.1787	4.0859	2.5938	2.7500	2.9727	1.7402	2.1895	1.6641
12	1.8047	1.7070	1.9609	2.3672	1.9102	1.7949	1.6289	1.7383	1.6875	1.4922	1.6133	1.8672	2.0791	4.1465	2.5000	2.5195	3.1289	1.7910	2.1543	1.4375
13	1.8594	1.5820	1.8145	2.2695	1.9785	1.8359	1.6680	1.6367	1.5781	1.6172	1.4609	1.8066	2.2021	4.0449	2.5000	2.5723	2.4961	1.7246	2.3086	1.7344
14	1.8477	1.5117	2.0039	2.3340	1.9766	1.8789	1.6094	1.6016	1.7227	1.8438	1.4570	1.8848	2.1729	4.1172	2.4375	2.5723	2.7852	1.7715	2.0859	1.7422
15	1.8770	1.6172	1.8613	2.3125	1.8301	1.9707	1.6328	1.7109	1.6992	1.6484	1.6094	1.8164	1.9932	4.0430	2.1875	2.6563	2.6484	1.7344	2.2285	1.7500
16	1.9043	1.5625	2.0137	2.5098	1.9961	2.0059	1.7109	1.7656	1.8945	1.7031	1.5430	1.8223	2.3271	4.0371	2.7813	2.6484	2.7891	1.6367	2.0547	1.7422
17	1.8008	1.6563	1.9375	2.3633	1.9063	1.8906	1.7070	1.7148	1.8359	1.6602	1.6836	1.7754	2.2979	4.1816	3.1875	2.6094	2.8203	1.7305	1.8574	1.8203
18	1.9199	1.5586	2.0313	2.3359	1.8828	1.8945	1.9219	1.6523	1.7656	1.7188	1.6719	1.9453	2.0977	4.1016	3.0938	2.7305	2.6875	1.6875	2.1387	1.7656
19	1.8379	1.5430	1.8809	2.2246	1.8691	1.7480	1.6367	1.7109	1.7500	1.9063	1.7383	1.8359	2.2090	3.8203	3.0938	2.8125	2.5664	1.6504	2.1523	1.6563
20	1.9434	1.6133	1.8086	2.2891	2.0430	1.7207	1.6484	1.8477	1.6172	1.7305	1.3672	1.9180	2.1660	4.0508	3.0313	2.6680	2.6289	1.7930	2.1895	1.5391

Table 3.4 – Lupin Laboratories Ltd. – Mutual information - January 2000

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7
1	2.4688	2.2988	2.2109	2.043	1.9219	1.6172	2
2	2.8203	2.1035	1.8398	1.9375	1.7539	1.4219	2.1797
3	2.8672	1.9219	2.0625	1.6602	1.75	1.3359	1.8672
4	2.2891	1.8418	1.9805	1.6992	1.5742	1.4922	1.8203
5	2.0469	1.8262	1.8438	1.7109	1.7969	1.3672	1.9219
6	2.0313	1.9375	1.7148	1.6836	1.6641	1.4375	1.6797
7	2.0625	2.0059	1.9414	1.793	1.7344	1.5703	1.9297
8	2.2031	1.7754	2.0273	1.6875	1.5664	1.3125	1.875
9	2.1641	1.9922	2.0273	1.7773	1.6484	1.2109	1.9375
10	2.3438	1.9258	1.8789	1.6953	1.6055	1.3906	1.8828
11	2.2031	1.9121	1.7578	1.7969	1.6602	1.3672	1.9453
12	2.0938	1.9316	1.9492	1.5977	1.6133	1.3203	1.8906
13	2.1484	1.7988	1.8867	1.6367	1.6445	1.4922	1.8125
14	2.2188	1.7461	1.9961	1.5625	1.6367	1.3359	1.8984
15	2.4219	1.7227	1.9258	1.6953	1.7344	1.3438	1.7422
16	2.3516	1.9316	1.8945	1.5586	1.6836	1.4688	1.8203
17	1.9453	1.9043	1.8125	1.6523	1.5078	1.5313	1.875
18	2.2656	1.8965	1.8125	1.7422	1.5391	1.3516	1.9219
19	2.0078	1.9902	1.9883	1.6445	1.5703	1.3203	1.7109
20	1.7344	1.7715	1.8242	1.6133	1.5625	1.2891	1.8047

Table 3.5 – Lupin Laboratories Ltd. – Sample entropy - October 1999

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	1.031	1.184	0.961	0.132	0.05	0	0	0.391	0.22	0.239	0.644	0.905	0	0.482	0.551	0.672	0.957	1.007	0.935	0.958
2, 0.16	1.031	1.025	0.961	0.132	0.05	0	0	0.391	0.22	0.241	0.644	0.905	0	0.482	0.551	0.672	0.957	1.007	0.835	0.958
2, 0.17	0.94	1.025	0.961	0.132	0.05	0	0	0.391	0.22	0.241	0.644	0.838	0	0.482	0.551	0.672	0.957	1.007	0.835	0.958
2, 0.18	0.94	1.025	0.961	0.132	0.05	0	0	0.371	0.221	0.241	0.63	0.838	0	0.482	0.551	0.672	0.957	1.007	0.835	0.918
2, 0.19	0.94	1.025	0.961	0.132	0.05	0	0	0.371	0.221	0.241	0.63	0.838	0	0.492	0.551	0.672	0.957	1.007	0.835	0.918
2, 0.20	0.94	1.025	0.961	0.132	0.05	0	0	0.371	0.222	0.24	0.63	0.838	0	0.492	0.517	0.627	0.906	0.937	0.835	0.918
3, 0.15	0.993	1.006	0.887	0.098	0.051	0	0	0.276	0.15	0.176	0.541	0.843	0	0.352	0.431	0.61	0.977	0.947	0.752	0.903
3, 0.16	0.993	0.9	0.887	0.098	0.051	0	0	0.276	0.15	0.179	0.541	0.843	0	0.352	0.431	0.61	0.977	0.947	0.663	0.903
3, 0.17	0.855	0.9	0.887	0.098	0.051	0	0	0.276	0.15	0.179	0.541	0.775	0	0.352	0.431	0.61	0.977	0.947	0.663	0.903
3, 0.18	0.855	0.9	0.887	0.098	0.051	0	0	0.273	0.15	0.179	0.534	0.775	0	0.352	0.431	0.61	0.977	0.947	0.663	0.842
3, 0.19	0.855	0.9	0.887	0.098	0.051	0	0	0.273	0.15	0.179	0.534	0.775	0	0.362	0.431	0.61	0.977	0.947	0.663	0.842
3, 0.20	0.855	0.9	0.887	0.099	0.051	0	0	0.273	0.151	0.184	0.534	0.775	0	0.362	0.406	0.57	0.912	0.888	0.663	0.842
4, 0.15	0.828	0.719	0.871	0.077	0.053	0	0	0.236	0.063	0.16	0.462	0.673	0	0.288	0.298	0.602	0.984	0.9	0.679	0.696
4, 0.16	0.828	0.738	0.871	0.077	0.053	0	0	0.236	0.063	0.159	0.462	0.673	0	0.288	0.298	0.602	0.984	0.9	0.589	0.696
4, 0.17	0.746	0.738	0.871	0.077	0.053	0	0	0.236	0.063	0.159	0.462	0.632	0	0.288	0.298	0.602	0.984	0.9	0.589	0.696
4, 0.18	0.746	0.738	0.871	0.077	0.053	0	0	0.245	0.063	0.159	0.449	0.632	0	0.288	0.298	0.602	0.984	0.9	0.589	0.652
4, 0.19	0.746	0.738	0.871	0.077	0.053	0	0	0.245	0.063	0.159	0.449	0.632	0	0.295	0.298	0.602	0.984	0.9	0.589	0.652
4, 0.20	0.746	0.738	0.871	0.078	0.053	0	0	0.245	0.063	0.164	0.449	0.632	0	0.295	0.299	0.562	0.904	0.895	0.589	0.652
5, 0.15	0.668	0.633	0.874	0.062	0.054	0	0	0.178	0.048	0.124	0.419	0.587	0	0.236	0.235	0.506	0.914	0.935	0.609	0.495
5, 0.16	0.668	0.745	0.874	0.062	0.054	0	0	0.178	0.048	0.123	0.419	0.587	0	0.236	0.235	.0.506	0.914	0.935	0.461	0.495
5, 0.17	0.617	0.745	0.874	0.062	0.054	0	0	0.178	0.048	0.123	0.419	0.567	0	0.236	0.235	0.506	0.914	0.935	0.461	0.495
5, 0.18	0.617	0.745	0.874	0.062	0.054	0	0	0.192	0.048	0.123	0.404	0.567	0	0.236	0.235	0.506	0.914	0.935	0.461	0.482
5, 0.19	0.617	0.745	0.874	0.062	0.054	0	0	0.192	0.048	0.123	0.404	0.567	0	0.245	0.235	0.506	0.914	0.935	0.461	0.482
5, 0.20	0.617	0.745	0.874	0.063	0.054	0	0	0.192	0.048	0.123	0.404	0.567	0	0.245	0.229	0.461	0.837	0.866	0.461	0.482

Table 3.6 – Lupin Laboratories Ltd. – Sample entropy - November 1999

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	0.785	0.677	0.95	1.021	0.368	1.089	0.957	0.863	0.744	1.055	0.893	0.901	0.574	1.235	1.139	0.662	0	0.824	0.371	0.723
2, 0.16	0.785	0.677	0.95	1.021	0.368	1.089	0.957	0.863	0.744	1.055	0.893	0.901	0.574	1.235	1.139	0.662	0	0.824	0.371	0.723
2, 0.17	0.785	0.677	0.95	0.913	0.368	1.089	0.957	0.863	0.744	1	0.849	0.901	0.574	1.045	0.968	0.662	0	0.824	0.371	0.723
2, 0.18	0.786	0.677	0.95	0.913	0.368	1.089	0.957	0.863	0.744	1	0.849	0.901	0.574	1.045	0.968	0.662	0	0.824	0.371	0.723
2, 0.19	0.786	0.658	0.901	0.913	0.367	1.089	0.893	0.863	0.744	1	0.849	0.901	0.546	1.045	0.968	0.662	0	0.824	0.371	0.676
2, 0.20	0.786	0.658	0.901	0.913	0.367	1.019	0.893	0.863	0.744	1	0.849	0.901	0.546	1.045	0.968	0.622	0	0.824	0.371	0.676
3, 0.15	0.639	0.544	0.817	1.009	0.257	1.026	0.938	0.731	0.665	1.064	0.755	0.821	0.433	1.224	1.043	0.612	0	0.75	0.326	0.704
3, 0.16	0.639	0.544	0.817	1.009	0.257	1.026	0.938	0.731	0.665	1.064	0.755	0.821	0.433	1.224	1.043	0.612	0	0.75	0.326	0.704
3, 0.17	0.639	0.544	0.817	0.857	0.257	1.026	0.938	0.731	0.665	1.024	0.739	0.821	0.433	1.044	0.927	0.612	0	0.75	0.326	0.704
3, 0.18	0.639	0.544	0.817	0.857	0.257	1.026	0.938	0.731	0.665	1.024	0.739	0.821	0.433	1.044	0.927	0.612	0	0.75	0.326	0.704
3, 0.19	0.639	0.538	0.757	0.857	0.26	1.026	0.873	0.731	0.665	1.024	0.739	0.821	0.463	1.044	0.927	0.612	0	0.75	0.326	0.664
3, 0.20	0.639	0.538	0.757	0.857	0.26	0.976	0.873	0.731	0.665	1.024	0.739	0.821	0.463	1.044	0.927	0.589	0	0.75	0.326	0.664
4, 0.15	0.54	0.42	0.669	1.005	0.194	0.909	0.812	0.61	0.552	1.031	0.612	0.835	0.338	0.971	0.889	0.549	0	0.643	0.255	0.665
4, 0.16	0.54	0.42	0.669	1.005	0.194	0.909	0.812	0.61	0.552	1.031	0.612	0.835	0.338	0.971	0.889	0.549	0	0.643	0.255	0.665
4, 0.17	0.54	0.42	0.669	0.817	0.194	0.909	0.812	0.61	0.552	1.012	0.592	0.835	0.338	0.908	0.852	0.549	0	0.643	0.255	0.665
4, 0.18	0.528	0.42	0.669	0.817	0.194	0.909	0.812	0.61	0.552	1.012	0.592	0.835	0.338	0.908	0.852	0.549	0	0.643	0.255	0.665
4, 0.19	0.528	0.425	0.64	0.817	0.189	0.909	0.776	0.61	0.552	1.012	0.592	0.835	0.388	0.908	0.852	0.549	0	0.643	0.255	0.62
4, 0.20	0.528	0.425	0.64	0.817	0.189	0.868	0.776	0.61	0.552	1.012	0.592	0.835	0.388	0.908	0.852	0.537	0	0.643	0.255	0.62
5, 0.15	0.436	0.347	0.686	1.094	0.177	0.92	0.757	0.555	0.495	1.025	0.493	0.726	0.266	0.794	0.892	0.506	0	0.622	0.201	0.636
5, 0.16	0.436	0.347	0.686	1.094	0.177	0.92	0.757	0.555	0.495	1.025	0.493	0.726	0.266	0.794	0.892	0.506	0	0.622	0.201	0.636
5, 0.17	0.436	0.347	0.686	0.833	0.177	0.92	0.757	0.555	0.495	1.061	0.506	0.726	0.266	0.864	0.833	0.506	0	0.622	0.201	0.636
5, 0.18	0.461	0.347	0.686	0.833	0.177	0.92	0.757	0.555	0.495	1.061	0.506	0.726	0.266	0.864	0.833	0.506	0	0.622	0.201	0.636
5, 0.19	0.461	0.366	0.623	0.833	0.172	0.92	0.741	0.555	0.495	1.061	0.506	0.726	0.31	0.864	0.833	0.506	0	0.622	0.201	0.606
5, 0.20	0.461	0.366	0.623	0.833	0.172	0.899	0.741	0.555	0.495	1.061	0.506	0.726	0.31	0.864	0.833	0.487	0	0.622	0.201	0.606

Table 3.7 – Lupin Laboratories Ltd. – Sample entropy - December 1999

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	0.87	0.992	0.763	0.576	0.962	0.864	0.857	0.91	0.815	0.775	1.085	0.641	0.805	0.821	0.183	0.038	0.508	0.457	0.872	0.651	0.671
2, 0.16	0.87	0.992	0.763	0.576	0.962	0.864	0.855	0.91	0.766	0.775	1.049	0.641	0.805	0.804	0.175	0.038	0.508	0.457	0.872	0.645	0.671
2, 0.17	0.87	0.992	0.763	0.526	0.962	0.864	0.855	0.834	0.766	0.735	1.049	0.641	0.805	0.804	0.175	0.038	0.508	0.452	0.817	0.645	0.671
2, 0.18	0.87	0.992	0.763	0.526	0.962	0.864	0.855	0.834	0.766	0.735	1.049	0.641	0.806	0.804	0.175	0.038	0.508	0.452	0.817	0.645	0.653
2, 0.19	0.814	0.915	0.763	0.526	0.909	0.852	0.855	0.834	0.766	0.735	1.042	0.641	0.806	0.804	0.175	0.038	0.508	0.452	0.817	0.645	0.653
2, 0.20	0.814	0.915	0.763	0.526	0.909	0.852	0.855	0.834	0.716	0.735	1.042	0.624	0.806	0.787	0.175	0.038	0.508	0.453	0.805	0.622	0.653
3, 0.15	0.816	0.994	0.715	0.477	0.904	0.76	0.79	0.655	0.835	0.691	1.096	0.534	0.718	0.749	0.123	0.039	0.39	0.334	0.952	0.558	0.628
3, 0.16	0.816	0.994	0.715	0.477	0.904	0.76	0.8	0.655	0.774	0.691	1.077	0.534	0.718	0.736	0.118	0.039	0.39	0.334	0.952	0.555	0.628
3, 0.17	0.816	0.994	0.715	0.453	0.904	0.76	0.8	0.616	0.774	0.652	1.077	0.534	0.718	0.736	0.118	0.039	0.39	0.329	0.886	0.555	0.628
3, 0.18	0.816	0.994	0.715	0.453	0.904	0.76	0.8	0.616	0.774	0.652	1.077	0.534	0.716	0.736	0.118	0.039	0.39	0.329	0.886	0.555	0.632
3, 0.19	0.748	0.889	0.715	0.453	0.844	0.755	0.8	0.616	0.774	0.652	1.067	0.534	0.716	0.736	0.118	0.039	0.39	0.329	0.886	0.555	0.632
3, 0.20	0.748	0.889	0.715	0.453	0.844	0.755	0.8	0.616	0.718	0.652	1.067	0.513	0.716	0.726	0.118	0.039	0.39	0.33	0.875	0.541	0.632
4, 0.15	0.793	1.002	0.665	0.393	0.772	0.704	0.696	0.67	0.725	0.604	0.998	0.503	0.692	0.679	0.109	0.04	0.352	0.192	0.922	0.517	0.516
4, 0.16	0.793	1.002	0.665	0.393	0.772	0.704	0.722	0.67	0.686	0.604	0.956	0.503	0.692	0.665	0.106	0.04	0.352	0.192	0.922	0.497	0.516
4, 0.17	0.793	1.002	0.665	0.392	0.772	0.704	0.722	0.598	0.686	0.556	0.956	0.503	0.692	0.665	0.106	0.04	0.352	0.189	0.872	0.497	0.516
4, 0.18	0.793	1.002	0.665	0.392	0.772	0.704	0.722	0.598	0.686	0.556	0.956	0.503	0.69	0.665	0.106	0.04	0.353	0.189	0.872	0.497	0.537
4, 0.19	0.746	0.905	0.665	0.392	0.764	0.689	0.722	0.598	0.686	0.556	0.946	0.503	0.69	0.665	0.106	0.04	0.353	0.189	0.872	0.497	0.537
4, 0.20	0.746	0.905	0.665	0.392	0.764	0.689	0.722	0.598	0.667	0.556	0.946	0.485	0.69	0.659	0.106	0.04	0.353	0.191	0.861	0.488	0.537
5, 0.15	0.749	1.129	0.611	0.358	0.716	0.628	0.674	0.632	0.776	0.658	0.82	0.462	0.644	0.634	0.098	0.02	0.271	0.141	0.81	0.434	0.486
5, 0.16	0.749	1.129	0.611	0.358	0.716	0.628	0.692	0.632	0.768	0.658	0.775	0.462	0.644	0.611	0.096	0.02	0.271	0.141	0.81	0.419	0.486
5, 0.17	0.749	1.129	0.611	0.355	0.716	0.628	0.692	0.581	0.768	0.611	0.775	0.462	0.644	0.611	0.096	0.02	0.271	0.138	0.802	0.419	0.486
5, 0.18	0.749	1.129	0.611	0.355	0.716	0.628	0.692	0.581	0.768	0.611	0.775	0.462	0.633	0.611	0.096	0.02	0.272	0.138	0.802	0.419	0.499
5, 0.19	0.696	1.033	0.611	0.355	0.746	0.601	0.692	0.581	0.768	0.611	0.768	0.462	0.633	0.611	0.096	0.02	0.272	0.138	0.802	0.419	0.499
5, 0.20	0.696	1.033	0.611	0.355	0.746	0.601	0.692	0.581	0.757	0.611	0.768	0.477	0.633	0.615	0.096	0.02	0.272	0.14	0.79	0.419	0.499

Table 3.8 – Lupin Laboratories Ltd. – Sample entropy - January 2000

m, r	Day1	Day2	Day3	Day4	Day5	Day6	Day7
2, 0.15	0.339	0.835	0.787	1.031	0.733	1.065	0.376
2, 0.16	0.339	0.835	0.787	1.031	0.733	1.065	0.376
2, 0.17	0.316	0.779	0.781	0.979	0.733	0.99	0.376
2, 0.18	0.316	0.779	0.781	0.979	0.721	0.99	0.374
2, 0.19	0.316	0.779	0.781	0.979	0.721	0.981	0.374
2, 0.20	0.315	0.77	0.773	0.963	0.721	0.965	0.374
3, 0.15	0.267	0.839	0.705	1.166	0.646	0.972	0.31
3, 0.16	0.267	0.839	0.705	1.166	0.646	0.972	0.31
3, 0.17	0.256	0.793	0.698	1.096	0.646	0.903	0.31
3, 0.18	0.256	0.793	0.698	1.096	0.637	0.903	0.316
3, 0.19	0.256	0.793	0.698	1.096	0.637	0.893	0.316
3, 0.20	0.255	0.778	0.69	1.072	0.637	0.889	0.316
4, 0.15	0.228	0.733	0.656	1.182	0.575	0.992	0.272
4, 0.16	0.228	0.733	0.656	1.182	0.575	0.992	0.272
4, 0.17	0.218	0.713	0.647	1.111	0.575	0.935	0.272
4, 0.18	0.218	0.713	0.647	1.111	0.566	0.935	0.272
4, 0.19	0.218	0.713	0.647	1.111	0.566	0.93	0.272
4, 0.20	0.218	0.694	0.636	1.108	0.566	0.926	0.272
5, 0.15	0.206	0.736	0.688	1.027	0.423	1.085	0.203
5, 0.16	0.206	0.736	0.688	1.027	0.423	1.085	0.203
5, 0.17	0.187	0.683	0.675	0.91	0.423	0.98	0.203
5, 0.18	0.187	0.683	0.675	0.91	0.43	0.98	0.205
5, 0.19	0.187	0.683	0.675	0.91	0.43	0.964	0.205
5, 0.20	0.187	0.698	0.66	0.922	0.43	0.951	0.205

Table 3.9 – Morepen Hotels Ltd. - Mutual information - 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 3.10 – Morepen Hotels Ltd. - Mutual information – 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 3.11 – Morepen Hotels Ltd. - Mutual information – 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	1.625	1.25	1	2	0	1	0	1	1	1	1	2

Table 3.12 – Morepen Hotels Ltd. - Mutual information – 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 3.13 – Morepen Hotels Ltd. – Sample entropy - 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 3.14 – Morepen Hotels Ltd. - Sample entropy – 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 3.15 – Morepen Hotels Ltd. - Sample entropy – 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 3.16 – Morepen Hotels Ltd. - Sample entropy – 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 3.17 – Morepen Hotels Ltd. - Sample entropy – 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 3.18 – Morepen Hotels Ltd. - Sample entropy – 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 3.19 – Morepen Hotels Ltd. - Sample entropy – 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

Table 3.20 – Surya Rooshni Ltd. - Mutual information – April to June 2000

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19	Day20
0	2	5	3	4	5	3	4	4	2	1	6	4	4	4	1	2	3	2	2	2
1	0	1.125	1	1	1.875	1	1	1.5	0	1	1.28125	1.5	0.75	1	1	0	1	0	2	2
2	0	2.8125	1	1.125	1.1875	1	0.5	0.5	2	1	1.53125	1.25	1.125	0.5	1	2	1	2	0	0
3	2	1.375	1	1.25	1.375	1	1.125	2	0	1	1.25	0.5	0.5	1	1	0	1	0	0	0
4	0	1.375	1.5	1.25	1.1875	0.5	1.375	1.875	0	1	1.5625	0.75	1	1.5	1	0	1	2	0	2
5	0	1.125	1	1.5	1,125	0.5	0.75	1	2	1	1.1875	0.75	0.875	1.25	1	0	1	2	0	2
6	0	1.1875	0.5	1.875	1.0625	1	1.125	0	0	1	1.46875	1.25	1	0.75	1	2	1	0	2	2
7	2	1.8125	1	0.875	1.0625	1	0.875	1.375	2	1	1	1	0.5	0.75	1	0	1	0	0	0
8	0	1.625	1	0.875	1.125	1	1.5	1.125	0	1	1.1875	1.5	0.5	2	1	0	0.5	0	0	0
9	0	1.25	1	1.25	1.4375	1	1	0.75	0	1	1.34375	1	0.5	1.125	1	2	1	0	0	2
10	0	1.5625	1	1.5	1.4375	0.5	1	1.25	0	1	1.0625	1	1.25	0.75	1	0	1	0	0	0
11	0	1.1875	1	1.25	1.5625	1	1	1.5	0	1	0.9375	0.875	1.125	1	1	2	1	0	0	2
12	0	1.3125	1	1	1.25	1	1	0.75	2	1	1.3125	0.75	1	0.5	1	2	1	2	2	2
13	0	1.25	1	1.25	1.375	1	0.75	1.375	2	1	1.65625	1.25	1	1.125	1	0	0.5	0	2	2
14	0	1.375	1	1.25	1.1875	1	1.125	1.25	0	1	1.28125	1.25	1.125	1.375	1	2	0.5	2	0	0
15	2	1.375	1	1.625	1.375	1	1.5	0.875	0	1	1.28125	1.125	1.25	0.5	1	0	1	0	2	0
16	0	1.5	1	1	1.375	0.5	1.375	1.125	2	1	1.4375	1	1.25	1	1	2	1	0	0	0
17	0	1.25	1	1	1	1	1	1	0	1	1.25	1	1.625	1	1	0	1	2	0	0
18	2	1.375	1	1.5	1.125	1	1	0.75	0	1	1.375	1.5	1	1	1	0	1	2	0	0
19	2	1.5625	1	0.875	1.5625	1	0.75	1	0	1	1.5625	1.25	1.375	1.5	1	2	0.5	0	0	2
20	0	1.6875	1	1.25	1.125	1	1.5	1	2	1	1.09375	0.875	1	1.125	1	2	1	0	0	0

Table 3.21 – Surya Rooshni Ltd. - Mutual information – July to October 2000

Delay	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18	Day19	Day20	Day21
0	3	0	0	3	1	2	1	2	2	3	4	6	4	3	2	3	3	2	4	2	3
1	1	0	0	1	1	0	1	0	2	1.5	0.75	1.40625	1	0.5	0	1	1	2	1	0	1
2	1	0	0	1	1	2	1	2	2	1	0.75	1.375	1	0.5	0	1	1	2	1.375	0	0.5
3	1	0	0	1.5	1	0	1	2	2	1	0.75	1.09375	0.5	0.5	2	1	1	0	1	0	1
4	0.5	0	0	1	1	2	1	0	0	1	2	1.3125	1.5	1	2	1	2	0	1.125	2	1
5	1	0	0	1	1	0	1	0	0	0.5	1.625	1.40625	1	1	2	0.5	1	2	1	0	1
6	1.5	0	0	1.5	1	0	1	0	0	1	1.25	1.03125	1	1	2	1	0.5	2	1.25	0	1
7	1	0	0	1	1	0	1	2	0	0.5	1	1.375	1	3	2	1	1	2	0.5	0	0.5
8	1	0	0	1	1	2	1	0	0	1.5	1	1.40625	0.5	1	0	1	1	0	1.375	2	0.5
9	1	0	0	0.5	1	0	1	2	2	0.5	1.375	1.125	1	1	0	1	1	0	1	0	1
10	1	0	0	1	1	0	1	0	0	0.5	1	1.125	0.75	1	0	1	1	0	1.75	0	0.5
11	1	0	0	1	1	0	1	2	0	1	1.625	1.34375	1	0.5	0	1	1	0	1.125	0	1
12	1	0	0	0.5	1	0	1	0	0	1	1.125	1.15625	1.625	1	0	1	1	0	0.875	0	1
13	1	0	0	1	1	2	1	0	2	1	0.75	1.03125	1	1	0	1	0.5	0	1.125	0	1
14	0.5	0	0	1	1	0	1	0	0	1	0.875	1.375	0.75	0.5	2	0.5	0.5	0	1	2	1
15	1.5	0	0	1	1	2	1	2	2	1	0.5	1.4375	0.75	1	2	1	1	0	1.5	2	1
16	0.5	0	0	1	1	0	1	0	2	1	1.25	1.0625	1.375	1	0	0.5	0.5	0	0.75	2	1
17	1	0	0	1	1	0	1	0	2	0.5	1.625	1.0625	1.125	1	0	0.5	1	2	1.5	0	1
18	0.5	0	0	1	1	0	1	0	2	1	1.25	1.25	1.25	0.5	0	1	0.5	2	0	2	1.5
19	1	0	0	1	1	2	1	0	2	0.5	0	1.25	1	0.5	0	1	0.5	2	0.5	0	1
20	1	0	0	1.5	1	0	1	0	2	1	1	1.3125	1.375	1	0	1	1	0	1.25	2	1

Table 3.22 – Surya Rooshni Ltd. – Sample entropy – April 2000

m,r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17
2,0.15	1.253	0.441	2.996	4.025	0.142	0.916	1.609	0.51	1.386	0.764	1.213	4.7	4.025	4.025	2.485	0.288	1.946
2,0.16	1.253	0.441	2.996	4.025	0.142	0.916	1.609	0.51	1.386	0.764	1.213	4.7	4.025	4.025	2.485	0.288	1.946
2,0.17	1.253	0.441	2.996	4.025	0.142	0.916	1.609	0.51	1.386	0.764	1.213	4.7	4.025	4.025	2.485	0.288	1.946
2,0.18	1.312	0.441	2.996	4.025	0.142	0.916	1.609	0.51	1.386	0.764	1.213	4.7	4.025	4.025	2.485	0.288	1.355
2,0.19	1.312	0.441	2.996	4.025	0.142	1.204	1.014	0.51	1.386	0.764	1.213	4.7	4.025	4.025	2.485	0.288	1.355
2,0.20	1.312	0.441	2.996	4.025	0.142	1.204	1.014	0.51	1.386	0.764	1.213	4.7	4.025	4.025	2.485	0.288	1.355
3,0.15	1.792	0.362	2.996	4.025	0	0.693	1.386	0.264	6.477	0.718	0.606	4.7	4.025	4.025	2.485	0	6.136
3,0.16	1.792	0.362	2.996	4.025	0	0.693	1.386	0.264	6.477	0.718	0.606	4.7	4.025	4.025	2.485	0	6.136
3,0.17	1.792	0.362	2.996	4.025	0	0.693	1.386	0.264	6.477	0.718	0.606	4.7	4.025	4.025	2.485	0	6.136
3,0.18	1.946	0.362	2.996	4.025	0	0.693	1.386	0.264	6.477	0.718	0.606	4.7	4.025	4.025	2.485	0	1.386
3,0.19	1.946	0.362	2.996	4.025	0	1.099	1.308	0.264	6.477	0.718	0.606	4.7	4.025	4.025	2.485	0	1.386
3,0.20	1.946	0.362	2.996	4.025	0	1.099	1.308	0.264	6.477	0.718	0.606	4.7	4.025	4.025	2.485	0	1.386
4,0.15	6.04	0.321	2.996	4.025	0	5.347	7.451	0.1	6.477	0.357	0.693	4.7	4.025	4.025	2.485	1.099	6.136
4,0.16	6.04	0.321	2.996	4.025	0	5.347	7.451	0.1	6.477	0.357	0.693	4.7	4.025	4.025	2.485	1.099	6.136
4,0.17	6.04	0.321	2.996	4.025	0	5.347	7.451	0.1	6.477	0.357	0.693	4.7	4.025	4.025	2.485	1.099	6.136
4,0.18	6.04	0.321	2.996	4.025	0	5.347	7.451	0.1	6.477	0.357	0.693	4.7	4.025	4.025	2.485	1.099	0.693
4,0.19	6.04	0.321	2.996	4.025	0	5.347	7.451	0.1	6.477	0.357	0.693	4.7	4.025	4.025	2.485	1.099	0.693
4,0.20	6.04	0.321	2.996	4.025	0	5.347	7.451	0.1	6.477	0.357	0.693	4.7	4.025	4.025	2.485	1.099	0.693

Table 3.23 – Surya Rooshni Ltd. – Sample entropy – May 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	5.84	1.79	0.56	5.20	1.23	5.20	4.88	4.28	3.74	1.20	3.40	4.03	0.17	6.96	1.23	5.84	2.49	4.88	4.28	1.61
2,0.16	5.84	1.54	0.56	5.20	1.23	5.20	4.88	4.28	3.74	1.61	3.40	4.03	0.17	6.96	1.23	5.84	2.49	4.88	4.28	1.61
2,0.17	0.72	1.54	0.56	5.20	1.23	5.20	4.88	4.28	3.74	1.61	3.40	4.03	0.17	6.96	1.23	5.84	2.49	4.88	4.28	1.61
2,0.18	0.72	1.54	0.56	5.20	1.23	5.20	4.88	4.28	3.74	1.61	3.40	4.03	0.17	6.96	1.23	5.84	2.49	4.88	4.28	1.61
2,0.19	0.72	1.54	0.56	5.20	1.23	5.20	4.88	4.28	3.74	1.61	1.10	4.03	0.17	6.96	1.23	5.84	2.49	4.88	4.28	1.61
2,0.20	0.72	1.54	0.56	5.20	1.23	5.20	4.88	4.28	3.74	1.61	1.10	4.03	0.17	6.96	1.23	5.84	2.49	0.69	4.28	1.61
3,0.15	5.84	5.20	0.69	5.20	1.32	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.19	6.96	1.34	5.84	2.49	4.88	4.28	6.14
3,0.16	5.84	5.20	0.69	5.20	1.32	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.19	6.96	1.34	5.84	2.49	4.88	4.28	6.14
3,0.17	0.65	5.20	0.69	5.20	1.32	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.19	6.96	1.34	5.84	2.49	4.88	4.28	6.14
3,0.18	0.65	5.20	0.69	5.20	1.32	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.19	6.96	1.34	5.84	2.49	4.88	4.28	6.14
3,0.19	0.65	5.20	0.69	5.20	1.32	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.19	6.96	1.34	5.84	2.49	4.88	4.28	6.14
3,0.20	0.65	5.20	0.69	5.20	1.32	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.19	6.96	1.34	5.84	2.49	1.10	4.28	6.14
4,0.15	5.84	5.20	1.10	5.20	1.22	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.21	6.96	7.08	5.84	2.49	4.88	4.28	6.14
4,0.16	5.84	5.20	1.10	5.20	1.22	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.21	6.96	7.08	5.84	2.49	4.88	4.28	6.14
4,0.17	0.61	5.20	1.10	5.20	1.22	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.21	6.96	7.08	5.84	2.49	4.88	4.28	6.14
4,0.18	0.61	5.20	1.10	5.20	1.22	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.21	6.96	7.08	5.84	2.49	4.88	4.28	6.14
4,0.19	0.61	5.20	1.10	5.20	1.22	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.21	6.96	7.08	5.84	2.49	4.88	4.28	6.14
4,0.20	0.61	5.20	1.10	5.20	1.22	5.20	4.88	4.28	3.74	5.05	3.40	4.03	0.21	6.96	7.08	5.84	2.49	4.88	4.28	6.14

Table 3.24 – Surya Rooshni Ltd. – Sample entropy – June 2000

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	1.10	0.69	6.84	6.14	3.40	1.95	1.20	0.51	5.05	4.28	1.79	0.69	0.69	0.67	5.20	1.10	0.69	5.20	4.88	0.69	1.79
2,0.16	1.10	0.69	6.84	1.39	3.40	1.95	1.20	0.51	5.05	4.28	1.79	0.69	0.69	0.67	5.20	1.10	0.69	5.20	4.88	0.69	1.79
2,0.17	1.10	0.69	6.84	1.39	3.40	1.95	0.66	0.51	5.05	4.28	1.79	0.69	0.69	0.67	5.20	1.10	0.69	5.20	4.88	0.69	1.79
2,0.18	1.10	0.69	6.84	1.39	3.40	1.95	0.66	0.51	5.05	4.28	1.79	0.69	0.69	0.67	5.20	1.10	0.69	1.79	4.88	0.69	1.79
2,0.19	1.10	0.69	6.84	1.39	3.40	1.95	0.66	0.51	5.05	4.28	1.79	0.69	0.69	0.67	5.20	1.10	0.69	1.79	4.88	0.69	1.79
2,0.20	1.10	0.69	6.84	1.39	3.40	1.95	0.66	0.51	5.05	4.28	1.79	0.69	0.69	0.67	5.20	1.10	0.69	1.79	4.88	0.69	1.79
3,0.15	5.05	5.20	6.84	6.14	3.40	6.04	1.10	0.69	5.05	4.28	1.79	0.69	0.69	0.49	5.20	5.05	0.69	5.20	4.88	0.69	1.79
3,0.16	5.05	5.20	6.84	1.39	3.40	6.04	1.10	0.69	5.05	4.28	1.79	0.69	0.69	0.49	5.20	5.05	0.69	5.20	4.88	0.69	1.79
3,0.17	5.05	5.20	6.84	1.39	3.40	6.04	1.03	0.69	5.05	4.28	1.79	0.69	0.69	0.49	5.20	5.05	0.69	5.20	4.88	0.69	1.79
3,0.18	5.05	5.20	6.84	1.39	3.40	6.04	1.03	0.69	5.05	4.28	1.79	0.69	0.69	0.49	5.20	5.05	0.69	5.20	4.88	0.69	1.79
3,0.19	5.05	5.20	6.84	1.39	3.40	6.04	1.03	0.69	5.05	4.28	1.79	0.69	0.69	0.49	5.20	5.05	0.69	5.20	4.88	0.69	1.79
3,0.20	5.05	5.20	6.84	1.39	3.40	6.04	1.03	0.69	5.05	4.28	1.79	0.69	0.69	0.49	5.20	5.05	0.69	5.20	4.88	0.69	1.79
4,0.15	5.05	5.20	6.84	6.14	3.40	6.04	4.88	1.10	5.05	4.28	1.79	0.69	0.69	0.61	5.20	5.05	0.69	5.20	4.88	0.69	1.79
4,0.16	5.05	5.20	6.84	6.14	3.40	6.04	4.88	1.10	5.05	4.28	1.79	0.69	0.69	0.61	5.20	5.05	0.69	5.20	4.88	0.69	1.79
4,0.17	5.05	5.20	6.84	6.14	3.40	6.04	1.61	1.10	5.05	4.28	1.79	0.69	0.69	0.61	5.20	5.05	0.69	5.20	4.88	0.69	1.79
4,0.18	5.05	5.20	6.84	6.14	3.40	6.04	1.61	1.10	5.05	4.28	1.79	0.69	0.69	0.61	5.20	5.05	0.69	5.20	4.88	0.69	1.79
4,0.19	5.05	5.20	6.84	6.14	3.40	6.04	1.61	1.10	5.05	4.28	1.79	0.69	0.69	0.61	5.20	5.05	0.69	5.20	4.88	0.69	1.79
4,0.20	5.05	5.20	6.84	6.14	3.40	6.04	1.61	1.10	5.05	4.28	1.79	0.69	0.69	0.61	5.20	5.05	0.69	5.20	4.88	0.69	1.79

Table 3.25 – Surya Rooshni Ltd. – Sample entropy – July 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	3.74	0.81	0.69	1.79	1.79	3.00	4.70	3.00	1.79	2.57	5.48	5.20	3.40	4.28	0.41	4.50	1.39	3.40	1.79	2.49
2,0.16	3.74	0.81	0.69	1.79	1.79	3.00	4.70	3.00	1.79	2.57	5.48	5.20	3.40	4.28	0.41	4.50	1.39	3.40	1.79	2.49
2,0.17	3.74	0.81	0.69	1.79	1.79	3.00	1.25	3.00	1.79	2.57	5.48	5.20	3.40	4.28	0.41	4.50	1.39	3.40	1.79	2.49
2,0.18	3.74	0.81	0.69	1.79	1.79	3.00	1.25	3.00	1.79	2.57	5.48	5.20	3.40	4.28	0.41	4.50	1.39	3.40	1.79	2.49
2,0.19	3.74	0.81	0.69	1.79	1.79	3.00	1.25	3.00	1.79	2.57	5.48	5.20	3.40	4.28	0.41	4.50	1.39	3.40	1.79	2.49
2,0.20	3.74	0.81	0.69	1.79	1.79	0.00	1.25	3.00	1.79	2.57	5.48	5.20	3.40	4.28	0.41	4.50	1.39	3.40	1.79	2.49
3,0.15	3.74	0.69	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	1.10	4.50	5.20	3.40	1.79	2.49
3,0.16	3.74	0.69	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	1.10	4.50	5.20	3.40	1.79	2.49
3,0.17	3.74	0.69	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	1.10	4.50	5.20	3.40	1.79	2.49
3,0.18	3.74	0.69	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	1.10	4.50	5.20	3.40	1.79	2.49
3,0.19	3.74	0.69	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	1.10	4.50	5.20	3.40	1.79	2.49
3,0.20	3.74	0.69	0.69	1.79	1.79	0.41	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	1.10	4.50	5.20	3.40	1.79	2.49
4,0.15	3.74	0.41	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	5.05	4.50	5.20	3.40	1.79	2.49
4,0.16	3.74	0.41	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	5.05	4.50	5.20	3.40	1.79	2.49
4,0.17	3.74	0.41	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	5.05	4.50	5.20	3.40	1.79	2.49
4,0.18	3.74	0.41	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	5.05	4.50	5.20	3.40	1.79	2.49
4,0.19	3.74	0.41	0.69	1.79	1.79	3.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	5.05	4.50	5.20	3.40	1.79	2.49
4,0.20	3.74	0.41	0.69	1.79	1.79	0.00	4.70	3.00	5.72	6.63	5.48	5.20	3.40	4.28	5.05	4.50	5.20	3.40	1.79	2.49

Table 3.26 – Surya Rooshni Ltd. – Sample entropy – August 2000

m,r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17
2,0.15	1.39	3.74	4.70	5.20	1.04	1.79	4.03	1.25	0.69	0.61	1.10	4.28	1.10	0.85	0.69	1.95	2.64
2,0.16	1.39	3.74	4.70	5.20	1.04	1.79	4.03	1.25	0.69	0.61	1.10	4.28	1.10	0.85	0.69	1.95	2.64
2,0.17	1.39	3.74	4.70	5.20	1.04	1.79	4.03	1.25	0.69	0.61	1.10	4.28	1.10	0.85	0.69	1.95	2.64
2,0.18	1.39	3.74	4.70	5.20	1.04	1.79	4.03	0.34	0.69	0.61	1.10	4.28	1.10	0.85	0.69	0.84	2.64
2,0.19	1.39	3.74	1.10	5.20	1.04	1.79	4.03	0.34	0.69	0.61	1.10	4.28	1.10	0.85	0.69	0.84	2.64
2,0.20	1.39	3.74	1.10	5.20	1.04	1.79	4.03	0.34	0.69	0.61	1.10	4.28	1.10	0.85	0.69	0.84	2.64
3,0.15	5.84	3.74	4.70	5.20	0.69	1.79	4.03	0.69	1.10	0.69	5.05	4.28	4.28	1.10	1.10	6.23	6.70
3,0.16	5.84	3.74	4.70	5.20	0.69	1.79	4.03	0.69	1.10	0.69	5.05	4.28	4.28	1.10	1.10	6.23	6.70
3,0.17	5.84	3.74	4.70	5.20	0.69	1.79	4.03	0.69	1.10	0.69	5.05	4.28	4.28	1.10	1.10	6.23	6.70
3,0.18	5.84	3.74	4.70	5.20	0.69	1.79	4.03	0.35	1.10	0.69	5.05	4.28	4.28	1.10	1.10	0.98	6.70
3,0.19	5.84	3.74	4.70	5.20	0.69	1.79	4.03	0.35	1.10	0.69	5.05	4.28	4.28	1.10	1.10	0.98	6.70
3,0.20	5.84	3.74	4.70	5.20	0.69	1.79	4.03	0.35	1.10	0.69	5.05	4.28	4.28	1.10	1.10	0.98	6.70
4,0.15	5.84	3.74	4.70	5.20	0.41	1.79	4.03	5.94	4.28	6.04	5.05	4.28	4.28	0.00	5.20	6.23	6.70
4,0.16	5.84	3.74	4.70	5.20	0.41	1.79	4.03	5.94	4.28	6.04	5.05	4.28	4.28	0.00	5.20	6.23	6.70
4,0.17	5.84	3.74	4.70	5.20	0.41	1.79	4.03	5.94	4.28	6.04	5.05	4.28	4.28	0.00	5.20	6.23	6.70
4,0.18	5.84	3.74	4.70	5.20	0.41	1.79	4.03	0.38	4.28	6.04	5.05	4.28	4.28	0.00	5.20	1.10	6.70
4,0.19	5.84	3.74	4.70	5.20	0.41	1.79	4.03	0.38	4.28	6.04	5.05	4.28	4.28	0.00	5.20	1.10	6.70
4,0.20	5.84	3.74	4.70	5.20	0.41	1.79	4.03	0.38	4.28	6.04	5.05	4.28	4.28	0.00	5.20	1.10	6.70

Table 3.27 – Surya Rooshni Ltd. – Sample entropy – September 2000

m,r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14	Day15	Day16	Day17	Day18
2,0.15	1.39	1.41	1.11	0.69	1.56	0.85	0.82	3.00	0.87	1.10	1.23	0.69	0.69	3.00	2.49	2.40	1.79	4.50
2,0.16	1.39	1.41	1.11	0.69	1.56	0.85	0.82	3.00	0.87	1.10	1.23	0.69	0.69	3.00	2.49	2.40	1.79	4.50
2,0.17	1.39	1.41	1.11	0.69	1.56	0.85	0.82	3.00	0.87	1.10	1.23	0.69	0.69	3.00	2.49	2.40	1.79	4.50
2,0.18	1.39	1.41	1.11	0.69	1.56	0.69	0.82	3.00	0.87	1.10	1.23	0.69	0.69	3.00	2.49	2.40	1.79	4.50
2,0.19	1.39	1.41	1.11	0.69	1.56	0.69	0.82	3.00	0.87	1.10	1.23	0.69	0.69	3.00	2.49	2.40	1.79	4.50
2,0.20	1.39	1.41	1.11	0.69	1.56	0.69	0.82	3.00	0.87	1.10	1.23	0.69	0.69	3.00	2.49	2.40	1.79	4.50
3,0.15	5.05	1.61	1.09	0.80	1.39	6.04	0.76	3.00	1.47	6.04	1.45	0.69	0.69	3.00	2.49	6.31	1.79	4.50
3,0.16	5.05	1.61	1.09	0.80	1.39	6.04	0.76	3.00	1.47	6.04	1.45	0.69	0.69	3.00	2.49	6.31	1.79	4.50
3,0.17	5.05	1.61	1.09	0.80	1.39	6.04	0.76	3.00	1.47	6.04	1.45	0.69	0.69	3.00	2.49	6.31	1.79	4.50
3,0.18	5.05	1.61	1.09	0.80	1.39	0.69	0.76	3.00	1.47	6.04	1.45	0.69	0.69	3.00	2.49	6.31	1.79	4.50
3,0.19	5.05	1.61	1.09	0.80	1.39	0.69	0.76	3.00	1.47	6.04	1.45	0.69	0.69	3.00	2.49	6.31	1.79	4.50
3,0.20	5.05	1.61	1.09	0.80	1.39	0.69	0.76	3.00	1.47	6.04	1.45	0.69	0.69	3.00	2.49	6.31	1.79	4.50
4,0.15	5.05	7.64	1.49	0.65	6.48	6.04	0.85	3.00	0.41	6.04	0.69	0.69	0.69	3.00	2.49	6.31	1.79	4.50
4,0.16	5.05	7.64	1.49	0.65	6.48	6.04	0.85	3.00	0.41	6.04	0.69	0.69	0.69	3.00	2.49	6.31	1.79	4.50
4,0.17	5.05	7.64	1.49	0.65	6.48	6.04	0.85	3.00	0.41	6.04	0.69	0.69	0.69	3.00	2.49	6.31	1.79	4.50
4,0.18	5.05	7.64	1.49	0.65	6.48	0.41	0.85	3.00	0.41	6.04	0.69	0.69	0.69	3.00	2.49	6.31	1.79	4.50
4,0.19	5.05	7.64	1.49	0.65	6.48	0.41	0.85	3.00	0.41	6.04	0.69	0.69	0.69	3.00	2.49	6.31	1.79	4.50
4,0.20	5.05	7.64	1.49	0.65	6.48	0.41	0.85	3.00	0.41	6.04	0.69	0.69	0.69	3.00	2.49	6.31	1.79	4.50

Table 3.28 – Surya Rooshni Ltd. – Sample entropy – October 2000

m,r	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10	Day11	Day12	Day13	Day14
2,0.15	2.485	0.693	4.025	1.792	5.05	3.401	0.894	0.693	1.253	2.996	0.693	0.693	0.693	3.401
2,0.16	2.485	0.693	4.025	1.792	5.05	3.401	0.894	0.693	1.253	2.996	0.693	0.693	0.693	3.401
2,0.17	2.485	0.693	4.025	1.792	5.05	3.401	0.894	0.693	1.012	2.996	0.693	0.693	0.693	3.401
2,0.18	2.485	0.693	4.025	1.792	5.05	3.401	0.894	0.693	1.012	2.996	0.693	0.693	0.693	3.401
2,0.19	2.485	0.693	4.025	1.792	5.05	3.401	0.894	0.693	1.012	2.996	0.693	0.693	0.693	3.401
2,0.20	2.485	0.693	4.025	1.792	5.05	3.401	0.894	0.693	1.012	2.996	0.693	0.693	0.693	3.401
3,0.15	2.485	0.693	4.025	1.792	5.05	3.401	0.405	0.693	5.204	2.996	0.693	0.693	0.693	3.401
3,0.16	2.485	0.693	4.025	1.792	5.05	3.401	0.405	0.693	5.204	2.996	0.693	0.693	0.693	3.401
3,0.17	2.485	0.693	4.025	1.792	5.05	3.401	0.405	0.693	1.386	2.996	0.693	0.693	0.693	3.401
3,0.18	2.485	0.693	4.025	1.792	5.05	3.401	0.405	0.693	1.386	2.996	0.693	0.693	0.693	3.401
3,0.19	2.485	0.693	4.025	1.792	5.05	3.401	0.405	0.693	1.386	2.996	0.693	0.693	0.693	3.401
3,0.20	2.485	0.693	4.025	1.792	5.05	3.401	0.405	0.693	1.386	2.996	0.693	0.693	0.693	3.401
4,0.15	2.485	0.693	4.025	1.792	5.05	3.401	0.182	0.693	5.204	2.996	0.693	0.693	0.693	3.401
4,0.16	2.485	0.693	4.025	1.792	5.05	3.401	0.182	0.693	5.204	2.996	0.693	0.693	0.693	3.401
4,0.17	2.485	0.693	4.025	1.792	5.05	3.401	0.182	0.693	5.204	2.996	0.693	0.693	0.693	3.401
4,0.18	2.485	0.693	4.025	1.792	5.05	3.401	0.182	0.693	5.204	2.996	0.693	0.693	0.693	3.401
4,0.19	2.485	0.693	4.025	1.792	5.05	3.401	0.182	0.693	5.204	2.996	0.693	0.693	0.693	3.401
4,0.20	2.485	0.693	4.025	1.792	5.05	3.401	0.182	0.693	5.204	2.996	0.693	0.693	0.693	3.401

CHAPTER - IV

PRICE DISCOVERY IN INDIAN SECURITIES MARKET

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PRICE DISCOVERY IN INDIAN SECURITIES MARKET

This chapter deals with the nature and the implications of relationship between the equities and the derivatives segments of the securities market and narrates the approaches followed by existing studies to analyse such relationship. The aptness of transfer entropy, among the various entropic measures, to quantify directional information is highlighted and the computational aspects of transfer entropy are explained. Then the data used for the analysis are presented and the results obtained are interpreted.

Interactions between different sub-systems of financial market are considered to be an important internal force of the market. Deciphering the role played by highly correlated product lines is an important question faced particularly in stock market. The identification and quantification of causal relationships between the equities and the derivatives segments of the stock market, by analysing the prices over time of an equities market index and a futures contract on the index, furthers the understanding of the market's internal dynamics and has a lot of implications, for all the participants of the market, including the following.

- Detection of causal structure between the equities and the derivatives markets may lead to simplification of the design of control strategies and reduction of the number of measurement channels by exploiting redundant information. Since an impulse in a market is reflected quickly in the other market, policy intervention becomes more effective in the desired direction within reasonable time horizon.

- In case causal relationship exists between the two markets, unexpected changes in equities and futures prices will be more correlated. This will enhance substitutability of futures for position in equities market and will improve risk transfer function of derivatives market.
- Relationship between the markets reduces arbitrage opportunities and the direction of causality serves as a guide to choose the dynamic relationship model between equities and futures prices.
- In case there is no causal relationship between the two markets, hedging results in non-trivial risk exposure to hedgers, however market players may diversify their portfolios across markets thereby reducing their risk exposure.
- Absence of causal relationship also suggests that margins prescribed by market regulators or stock / derivatives exchange authorities, on positions taken by participants in the two markets may be levied separately without netting their positions across the markets i.e. cross-margining may not be possible in such a situation.

LEAD – LAG RELATIONSHIP BETWEEN MARKET SEGMENTS

The continuous time relationship between the theoretical value of the futures price and the spot price of an asset at any time t is given by the cost of carry model $F_t = S_t e^{(r-d)(T-t)}$ where

F_t = futures price at time t

S_t = spot price at time t

r = continuously compounded cost of carrying the asset from the present time t to the expiry date T

d = yield on the asset during the remaining period for expiry (T – t).

In perfectly efficient and continuous equities and derivatives markets, risk-less arbitrage opportunities do not appear (in the absence of transaction costs) and hence, if a stock index is taken as an asset, the cost of carry model should be satisfied at every instant t. So, the instantaneous rate of change in the index value ($R S_t$) equals the net cost of carry of the stock portfolio (r – d) plus the instantaneous change in the price of a futures contract on the index ($R F_t$).

i.e. $R S_t = (r - d) + R F_t$ where $R F_t = \log (F_t / F_{t-1})$ and $R S_t = \log (S_t / S_{t-1})$.

This implies that

- the contemporaneous rates of return of the futures contract and of the underlying stock index are perfectly positively correlated
- the non-contemporaneous rates of return of the futures contract and of the underlying stock index are not correlated.

However this does not hold exactly, due to several reasons such as

- infrequent trading of the constituent stocks in the index (in some markets) whereas the index futures contract is traded as a single unit
- differential transaction costs and other incidental charges
- greater speed of reflection of investors' views in derivatives market due to high degree of leverage and less capital requirement in the derivatives market.

Hence there may be lead – lag relationship in the price movements of the index futures and the stock index. It is often believed that derivatives market potentially provides an important function of price discovery, implying that futures prices contain useful information about subsequent stock prices, apart from what is contained already in the current stock price. It is also alleged that futures trading influences unduly the underlying stock prices, especially on the expiry days of futures contracts.

APPROACHES TO STUDY THE RELATIONSHIP

We have a set of simultaneously recorded variables - index futures price and stock index value - over a period of time and it is required to measure to what extent the time series corresponding to such variables contribute to the generation of information and at what rate they exchange information. Various methods have been proposed for the simultaneous analysis of two series and generally cross-correlation and cross-spectrum are used for measuring relationships between such time series, however these methods suffer from the drawbacks that

- they measure only linear relations i.e. the non-linear characteristics of the interactions between capital market segments which have been evidenced by different studies are not considered
- they lack directional information i.e. they simply say how far the two market segments move together and do not identify the market segment where price discovery happens.

Introducing time delay in the observations pertaining to one market segment may facilitate identifying asymmetric relationship and hence direction of information flow, however non-linear relationships will still remain unexplored.

Garbade and Silber (1983)[1] has presented an analytical model of simultaneous price dynamics which suggests that over short intervals, the correlation of price changes is a function of the elasticity of arbitrage between an asset in spot market and its counterpart futures contract. Granger (1988)[2] has introduced an error correction model which takes into account non-stationarity of co-integrated variables and distinguishes between short run deviations from equilibrium indicative of price discovery and long run deviations which account for efficiency and stability. These approaches involve estimation of simultaneous linear equations in a pair of variables with time lags and have been used in a number of studies examining the source of price discovery.

A statistically rigorous approach to the detection of interdependence, including non-linear dynamic relationships, between time series is provided by tools defined using the information theoretic concept of entropy which is model independent (providing qualitative inferences across diverse model configurations).

ENTROPIC MEASURES TO STUDY CAUSAL RELATIONSHIP

Harry Joe (1989)[3] has proposed relative entropy based measures of multi-variate dependence for continuous and categorical variables, however these measures require the estimation of probability density or mass functions. C.W.Granger et al (2004)[4] have proposed a transformed metric entropy measure of dependence for both continuous and discrete variables. Metric entropy is a measure of distance unlike relative entropy which is a measure of only divergence, however the utility of metric entropy in studying statistical dependence based on causality is to be tested.

Since mutual information measures the deviation from independence of the variables, it has been proposed as a tool to measure the relationship between financial market segments. Further, mutual information is non-parametric and depends on higher moments of the probability distributions of the variables, unlike correlation which depends on the first two moments only. However mutual information is a symmetric measure and does not contain dynamical information nor directional sense. The conditional entropies $H(Y / X) = H(X,Y) - H(X)$ and $H(X / Y) = H(X,Y) - H(Y)$ are non-symmetric, however the absence of symmetry is not due to information flow but on account of the different individual entropies. Some authors, for example Vastano and Swinney (1988)[5], have proposed the introduction of time delay in one of the variables while computing mutual information and the use of such time delayed mutual information to define velocity of information transport in spatio-temporal systems. However this does not distinguish information actually exchanged from shared information due to a common input signal or history. Therefore mutual information does not quantify the actual overlap of the information content of two variables. Further, there may be causal relationship without detectable time delays and conversely there may be time delays which do not reflect the naively expected causal structure between the two time series. Another issue is that the estimation of time delayed mutual information calls for a large quantity of noise free stationary data – a condition rarely met in real world situations.

Another information theoretic measure called transfer entropy has been introduced by Thomas Schreiber (2000)[6] to study relationship between dynamical systems. Robert Marschinski and H.Kantz (2002)[7] have used an improved estimator called effective transfer entropy and concluded that the US stock index Dow Jones has higher relative impact on the German stock index DAX. Seung Ki Back et al (2005)[8] have applied transfer entropy on daily closing prices of 135 stocks in New York Stock Exchange for studying information flow among groups of companies and discriminated the market-leading companies from the market-sensitive ones.

TRANSFER ENTROPY

Transfer entropy is an information theoretic concept that quantifies the degree to which a dynamical process affects the transition probabilities i.e. the dynamics of another. Transfer entropy has the properties of mutual information and also takes the dynamics of information transport into account. Transfer entropy quantifies the exchange of information between two systems, separately for both the directions and conditional to common input signal.

The rate at which the entropy of a stochastic process X_n, n = 1,2,... grows with n is given by

$$h_n(X) = -\sum p(x_{n+1}) \log p(x_{n+1} / x_n, x_{n-1}, \ldots, x_1)$$

$$= -\sum p(x_{n+1}) \log \{p(x_{n+1}, x_n, x_{n-1}, \ldots, x_1) / p(x_n, x_{n-1}, \ldots, x_1)\}$$

$$= -\sum p(x_{n+1}) \log p(x_{n+1}, x_n, x_{n-1}, \ldots, x_1) + \sum p(x_{n+1}) \log p(x_n, x_{n-1}, \ldots, x_1)$$

$$= H_{n+1}(X) - H_n(X)$$

where $H_n(X)$ is the entropy of the process given by n dimensional delay vectors constructed from X_n. Thus $h_n(X)$ denotes the information still transmitted by x_{n+1} when $x_1, x_2, \ldots, x_n$ are known or the missing information required to forecast x_{n+1} using $x_1, x_2, \ldots, x_n$. Alternatively, $-h_n(X)$ denotes the information known about x_{n+1} from $x_1, x_2, \ldots, x_n$.

The generalization of the entropy rate to construct mutual information rate between two variables (X, Y) is done using the generalised Markov property

$$p(x_{n+1} / x_n, x_{n-1}, \ldots, x_{n-k+1}) = p(x_{n+1} / x_n, x_{n-1}, \ldots, x_{n-k+1}, y_n, y_{n-1}, \ldots, y_{n-l+1})$$

where k and l denote the number of past observations included in the variables X and Y respectively. In the absence of information flow from Y to X, the state of Y has no influence on the transition probabilities of X. Just as mutual information is quantified as the deviation from the independence of the variables X and Y and is defined as the relative entropy between the joint distribution p(x,y) and the product distribution p(x) p(y), the mutual information rate is quantified as the deviation from the independence of the entropy rates and is defined as the relative entropy between the transition probabilities $p(x_{n+1} / x_n, x_{n-1}, \ldots, x_{n-k+1}, y_n, y_{n-1}, \ldots, y_{n-l+1})$ and $p(x_{n+1} / x_n, x_{n-1}, \ldots, x_{n-k+1})$. This is termed as transfer entropy and denoted as $T_{Y \to X}$. If k and l denote block lengths taken in the variables X and Y respectively, then

$$T_{Y \to X}(k,l) = \sum p(x_{n+1}, x_n, x_{n-1}, \ldots, x_{n-k+1}, y_n, y_{n-1}, \ldots, y_{n-l+1}) \log \{ p(x_{n+1} / x_n, x_{n-1}, \ldots, x_{n-k+1}, y_n, y_{n-1}, \ldots, y_{n-l+1}) / p(x_{n+1} / x_n, x_{n-1}, \ldots, x_{n-k+1}) \}$$

$$= - H_{k+1,l}(X,Y) + H_{k,l}(X,Y) + H_{k+1}(X) - H_k(X)$$

$$= h_k(X) - h_{k,l}(X,Y)$$

Obviously, $0 \leq T_{Y \to X}(k,l) \leq H(X)$. Also, $T_{Y \to X}$ is asymmetric and takes into account only statistical dependencies originating in the variable Y and not those deriving from a common input signal. Further, transfer entropy is closely related to conditional entropy extended to two variables X and Y and may be explained as follows.

Transfer entropy = (Information about future observation x_{n+1} gained from past observations of X_n and Y_n) - (Information about future observation x_{n+1} gained from past observations of X_n only) = Information flow from Y_n to X_n.

COMPUTATIONAL ASPECTS

The computation of transfer entropy from a time series to another may be done in two ways –

(i) The symbolic encoding method divides the range of the data set into S disjoint intervals such that the number of data points in every interval is constant and assigns one symbol to each interval. Then $p(x_n) = 1 / S$ so that $H(X) = \log_2 S$.

However, determining the partition is a contentious issue, called the generating partition problem and even for a two dimensional deterministic system, the partition lines may exhibit considerably complicated geometry.

(ii) The correlation integral method computes the fraction of data points lying within boxes of constant size $\in$, after embedding the data set into an appropriate phase space and uses the formula $H_n(X, 2\in) \sim -\log_2\{C_n(X, \in)\}$ where C_n is the generalised correlation integral of order n. However, determining the box size $\in$ remains as a contentious issue. The parameter $\in$ plays the role of defining the resolution or the scale of concerns, just as the number of symbols S does in the symbolic encoding method.

The symbolic encoding method has the advantage of neutralising undesirable effects due to very inhomogeneous histograms and it also ignores the trivial information gained by just observing marginal distributions. Further, for data with an approximately symmetric distribution, the concrete meaning of partitions is intuitive with S = 2 corresponding to the two possible signs of the increments and S = 3 corresponding to the three possible moves viz. larger gain, roughly neutral and larger loss.

For a given partition, $T_{Y \to X}(k,l)$ is a non-increasing function of the block length k of the series X, since inclusion of more number of past observations in the variable X is likely to result in reduction of flow of information from Y in the estimation of the next value of X. The parameter k is to be chosen as large as possible in order to find an invariant value for $T_{Y \to X}$, however due to the finite size of real time series, it is required to find a reasonable compromise between unwanted finite sample effects and a high value for k. Further, a very small value of k may lead to misinterpretation of information contained in past observations of actually both series as an information flow from Y to X and hence k may be chosen as large as possible.

Further, in order to consider appropriate value of k, it is proposed that the concept of mutual information with delay k i.e. I(k), of a time series, as illustrated in the previous chapter, be used and that the value of k in respect of which the first minimum of I(k) occurs may be chosen. Also, the choices for l are l = k or l = 1 and, for computational reasons, l = 1 is preferred usually.

PRESENTATION OF DATA

In this study, the symbolic encoding method is used to compute transfer entropy between the equities segment and the derivatives segment of the Indian stock market. National Stock Exchange of India (NSEIL) being the leading stock exchange of India, the 50 stock index of the equities segment of the exchange viz. Nifty and the near month index futures contract traded in the derivatives segment of the exchange are considered as representatives of the two market segments, for identifying price discovery in the Indian stock market. Due to high liquidity in both the segments of the Exchange, there are a large number of trades every minute in the component stocks of the Nifty index and in the near month Nifty futures. Hence there is a need to look at high frequency data instead of daily closing values of the index and daily closing prices of the futures contract.

Further, electronic trading facility and digital communication network enable incredibly fast information transport, especially between these market segments which have a large number of common or closely connected participants. Hence a trading day appears to be too long a period for the purpose of measuring the time taken for information dissemination from one market segment to the other. So, analysis of minute-to-minute data may be more meaningful in the study of such price discovery.

In light of the above, the average of the values realised by the Nifty index and the average of the prices at which the near month Nifty futures was traded, during a minute were computed for every minute during the trading hours over the period October 2005 – September 2006. Thus two time series, each with 82777 data points were obtained for the variables Nifty index (X) and near month Nifty futures (Y). These price series were transformed to log returns series since such transformation satisfies additive property of the returns and makes the results invariant in spite of arbitrary scaling of the price data. Further, on account of such transformation, stationary character of the two series may be assumed so that meaningful analysis may be made. The summary statistics of the resultant time series are given below.

	Nifty index	Near month Nifty futures
Minimum	-0.02974	-0.05115
1st Quartile	-0.00024	-0.00030
Mean	0.00000	0.00000
Median	0.00002	0.00002
3rd Quartile	0.00026	0.00033
Maximum	0.02792	0.02999
Number of data points	82776	82776
Standard Deviation	0.00075	0.00088

EMPIRICAL RESULTS

The symbolic encoding method partitions the range of the data set into disjoint bins and assigns a symbol to each bin, with marginal equal probability for every symbol. The transfer entropy value depends on the number of bins (S) into which the data set is partitioned and also on the block length k chosen for the variable X and the block length l for Y (however, l is chosen to be 1 generally). Hence transfer entropy $T_{Y \to X}$ (derivatives market to equities market) was computed for the number of bins S ranging from 2 to 8, the block length k for X ranging from 1 to 10 and the block length l for Y equal to 1. Similarly, transfer entropy $T_{X \to Y}$ (equities market to derivatives market) was computed for the number of bins ranging from 2 to 8, the block length for Y ranging from 1 to 10 and the block length for X equal to 1. The computed values are presented in table 4.1 and charts 4.1 and 4.2.

For a given partition, the transfer entropy $T_{Y \to X}$ is expected to decrease with increase in the block length of the series X. The transfer entropy in both the directions behaves reasonably for partitions S = 5, 6, 7, 8 of the data analysed and for block length of the transferee series k = 5, 6 or more. Further transfer entropy approaches zero for k = 10 or more. Hence, meaningful results may be obtained from transfer entropy values computed for partitions S = 5, 6, 7, 8 and block length of the transferee series k = 5, 6, ... , 10. Further, in order to consider appropriate values of k, the mutual information of the two time series containing the values of the Nifty index (X) and near month Nifty futures (Y), for delays ranging from a day to 20 days are computed and given in table 4.2. It may be observed that the first minimum has occurred for k = 8 and 3 for the two series. Hence, meaningful results may be obtained from transfer entropy values computed for partitions S = 6, 7, 8 and block length of the transferee series $k \geq 3$.

From the transfer entropy values given in the table 4.1, a flow of information from minute t of one series to minute t+1 of the other series is observed in both the directions, which suggests interactions between equities and derivatives markets at a time scale of a minute or less. The flow from the derivatives market to the equities market is more pronounced than the flow in the reverse direction. For the interpretation of the transfer entropy values, the following measures have been defined.

NET INFORMATION FLOW (NIF)

The net information flow is defined to measure the disparity in influences of the two variables on each other. If the net information flow defined as $NIF_{Y \to X} = T_{Y \to X} - T_{X \to Y}$ is positive, then the variable Y may be said to influence the variable X.

NORMALISED DIRECTIONALITY INDEX (NDI)

The normalised directionality index is defined in order that relevant but small-scale causal structure is not neglected and quantified as $NDI(X,Y) = \frac{T_{Y \to X} - T_{X \to Y}}{T_{Y \to X} + T_{X \to Y}}$. The index varies from -1 (in case of uni-directional causality from X to Y) through 0 (in case of equal feedback between the two variables) to +1 (in case of uni-directional causality from Y to X), with intermediate values corresponding to bidirectional causality between the two variables X and Y. The index thus has the property of coefficient of correlation between two variables and also has the additional feature of directionality.

RELATIVE EXPLANATION ADDED (REA)

The measured amount of information flow from Y to X is compared with the total flow of information in X. This ratio measures how much of x_{n+1} is additionally explained when the past values of X are already known and then the last value y_n of Y is taken into account. This is called relative explanation added and is defined as $REA_{Y \to X}$ (k,l) = $T_{Y \to X}$ (k,l) / h_k(X). Similarly, $REA_{X \to Y}$ (k,l) = $T_{X \to Y}$ (k,l) / h_k(Y). The ratio varies from 0 (in case of no information flow at all from a variable to the other) to 1 (in case of all the information in the current value of one variable being transferred from past values of the other variable) with intermediate values corresponding to the amount of information in one variable caused by the other variable.

The NIF values from the derivatives segment (Y) to the equities segment (X) and the REA for both the directions, in respect of the two market segments, are presented in the table 4.1 and charts 4.3 to 4.5 Also, the normalised directionality index values are presented in the table 4.1

(a) It is observed that NIF from the derivatives segment to the equities segment is generally positive except for one or two values of the block length of the transferee series, for each partition. Hence the information flow from the derivatives segment to the equities segment is dominant over that in the reverse direction.

(b) From the values of NDI(X,Y), it is observed that the information flow from the derivatives segment to the equities segment is dominant over that in the reverse direction.

(c) For partitions S = 5, 6, 7, 8, the REA by the derivatives segment to the equities segment increases with the block length taken for the equities segment initially and then stabilises for block length exceeding 6. This implies that the information flown from the derivatives segment in the prediction of the next price for the Nifty index in the equities segment cannot be compensated by the inclusion of more number of past values realised by the index.

For partitions S = 5, 6, 7, 8, the REA by the equities segment to the derivatives segment increases with the block length taken for the derivatives segment initially, however the REA falls for block length exceeding 7. This implies that the contribution of information from the equities segment to the prediction of the next price for the index futures contract in the derivatives segment, diminishes if we take into account a longer memory of the derivatives segment.

It is also observed that the REA by the last value of index futures contract in the derivatives segment to the current value of Nifty index in the equities segment is generally larger than the REA by the last value of Nifty index in the equities segment to the current value of index futures contract in the derivatives segment, thus reinforcing the observation made from the values of NIF.

CONCLUSION

Transfer entropy values between the Nifty index and the near month Nifty futures contract for the period October 2005 – September 2006 have been computed and found to be in consonance with the results of previous studies using other methods, however it may be noted that transfer entropy quantifies information transmission, including non-linear dynamic relationship also. Thus transfer entropy proves to be a promising measure to identify directional information. Specifically, in the Indian stock market, apart from information flow from index futures to Nifty index, information dissemination in the reverse direction also is observed during the period considered, however the flow from index futures to Nifty index is generally more pronounced. It is to be noted that, in the computation of transfer entropy, determination of the appropriate partition which is referred to as generating partition problem and the block length of the transferee time series, has to be done with utmost care.

Table 4.1 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI)
(between equities and derivatives segments of the Indian capital market)

Bins	Block	Derivatives segment (Y) to Equities segment (X)				Equities segment (X) to Derivatives segment (Y)					
		h(X,Y)	h(X)	T(Y->X)	REA(Y->X)	h(Y,X)	h(Y)	T(X->Y)	REA(X-Y)	NIF(Y->X)	NDI(X,Y)
2	1	0.830353	0.885448	0.055095	0.062223	0.965109	0.973049	0.007940	0.008160	0.047155	0.748076
2	2	0.828952	0.883913	0.054961	0.062179	0.961821	0.972754	0.010933	0.011239	0.044028	0.668164
2	3	0.827527	0.881660	0.054133	0.061399	0.960438	0.971959	0.011521	0.011853	0.042612	0.649039
2	4	0.825637	0.879551	0.053913	0.061296	0.958861	0.970639	0.011778	0.012134	0.042135	0.641412
2	5	0.824413	0.878170	0.053757	0.061215	0.957790	0.969594	0.011804	0.012174	0.041953	0.639908
2	6	0.823512	0.877424	0.053912	0.061443	0.956919	0.968870	0.011950	0.012334	0.041962	0.637120
2	7	0.822186	0.876762	0.054576	0.062247	0.955817	0.968266	0.012449	0.012857	0.042127	0.628527
2	8	0.819701	0.875350	0.055649	0.063573	0.953281	0.966782	0.013500	0.013964	0.042149	0.609539
2	9	0.815076	0.872973	0.057898	0.066323	0.948758	0.964465	0.015707	0.016286	0.042191	0.573208
2	10	0.805046	0.867815	0.062769	0.072330	0.938641	0.959624	0.020984	0.021867	0.041785	0.498908
3	1	1.324156	1.404745	0.080589	0.057369	1.530081	1.542113	0.012032	0.007802	0.068557	0.740189
3	2	1.310044	1.385834	0.075790	0.054689	1.519856	1.535409	0.015553	0.010130	0.060237	0.659459
3	3	1.300159	1.375113	0.074954	0.054508	1.510672	1.527878	0.017206	0.011261	0.057748	0.626606
3	4	1.289697	1.365642	0.075945	0.055611	1.501436	1.520669	0.019233	0.012648	0.056712	0.595852
3	5	1.275954	1.357725	0.081771	0.060226	1.488010	1.512790	0.024779	0.016380	0.056992	0.534885
3	6	1.248420	1.345182	0.096763	0.071933	1.458525	1.500994	0.042469	0.028294	0.054294	0.389953
3	7	1.184901	1.316014	0.131113	0.099629	1.382171	1.470765	0.088594	0.060237	0.042519	0.193526
3	8	1.069856	1.252481	0.182626	0.145811	1.200852	1.380859	0.180007	0.130359	0.002619	0.007222
3	9	0.891366	1.127299	0.235933	0.209291	0.895429	1.150498	0.255070	0.221704	-0.019137	-0.038975
3	10	0.675723	0.940471	0.264748	0.281506	0.554100	0.786516	0.232416	0.295501	0.032332	0.065033
4	1	1.679581	1.779275	0.099694	0.056031	1.922542	1.941187	0.018645	0.009605	0.081049	0.684888
4	2	1.653333	1.743312	0.089979	0.051614	1.903706	1.924140	0.020434	0.010620	0.069545	0.629862
4	3	1.634206	1.726410	0.092204	0.053408	1.886011	1.910135	0.024125	0.012630	0.068079	0.585228
4	4	1.600382	1.707896	0.107514	0.062951	1.855809	1.894637	0.038828	0.020494	0.068686	0.469353
4	5	1.523160	1.677891	0.154731	0.092218	1.771935	1.865862	0.093926	0.050339	0.060805	0.244534
4	6	1.352640	1.599440	0.246799	0.154303	1.521842	1.770392	0.248550	0.140393	-0.001751	-0.003535
4	7	1.058974	1.417482	0.358508	0.252919	1.048194	1.442899	0.394705	0.273550	-0.036197	-0.048057
4	8	0.710118	1.108245	0.398127	0.359241	0.561720	0.880388	0.318668	0.361963	0.079459	0.110853
4	9	0.412066	0.740600	0.328533	0.443604	0.250564	0.418045	0.167481	0.400629	0.161052	0.324692
4	10	0.212598	0.426997	0.214399	0.502109	0.103233	0.176205	0.072971	0.414126	0.141428	0.492146
5	1	1.967588	2.076851	0.109262	0.052609	2.228399	2.252090	0.023691	0.010520	0.085571	0.643618
5	2	1.933599	2.029853	0.096254	0.047419	2.202577	2.227472	0.024896	0.011177	0.071358	0.589005
5	3	1.897621	2.006135	0.108514	0.054091	2.165822	2.205543	0.039721	0.018010	0.068793	0.464081
5	4	1.806376	1.972341	0.165965	0.084146	2.070811	2.175208	0.104397	0.047994	0.061568	0.227724
5	5	1.562880	1.876057	0.313177	0.166934	1.752040	2.068884	0.316844	0.153147	-0.003667	-0.005820
5	6	1.139569	1.626277	0.486708	0.299277	1.109487	1.641171	0.531684	0.323966	-0.044976	-0.044164
5	7	0.668104	1.173829	0.505725	0.430834	0.511153	0.896235	0.385081	0.429665	0.120644	0.135432
5	8	0.325118	0.681887	0.356769	0.523208	0.193537	0.359897	0.166360	0.462243	0.190409	0.363981
5	9	0.139828	0.331855	0.192027	0.578647	0.067968	0.126148	0.058180	0.461204	0.133847	0.534945
5	10	0.056990	0.143147	0.086157	0.601878	0.023912	0.041166	0.017254	0.419132	0.068903	0.666302
6	1	2.201063	2.320375	0.119312	0.051419	2.478166	2.507636	0.029470	0.011752	0.089842	0.603850
6	2	2.154726	2.260900	0.106174	0.046961	2.445132	2.478567	0.033435	0.013490	0.072739	0.521019
6	3	2.085714	2.229667	0.143952	0.064562	2.379211	2.449829	0.070617	0.028825	0.073335	0.341778
6	4	1.876615	2.165170	0.288555	0.133271	2.132807	2.383464	0.250657	0.105165	0.037898	0.070284
6	5	1.405025	1.945371	0.540345	0.277759	1.454348	2.066182	0.611835	0.296119	-0.071490	-0.062048
6	6	0.797374	1.439485	0.642111	0.446070	0.652234	1.208842	0.556608	0.460447	0.085503	0.071329
6	7	0.354006	0.810405	0.456399	0.563174	0.220709	0.453696	0.232987	0.513531	0.223412	0.324074
6	8	0.137293	0.357665	0.220372	0.616141	0.072168	0.140898	0.068729	0.487793	0.151643	0.524533
6	9	0.051958	0.139423	0.087465	0.627336	0.025238	0.043173	0.017935	0.415422	0.069530	0.659677
6	10	0.018967	0.051714	0.032747	0.633233	0.008490	0.013433	0.004944	0.368049	0.027803	0:737656
7	1	2.402930	2.529718	0.126788	0.050119	2.687744	2.720519	0.032775	0.012047	0.094013	0.589190
7	2	2.344550	2.462806	0.118256	0.048017	2.643848	2.686617	0.042769	0.015919	0.075487	0.468791
7	3	2.221989	2.422569	0.200581	0.082797	2.521623	2.648818	0.127195	0.048020	0.073386	0.223891

7	4	1.834428	2.297994	0.463566	0.201726	2.035024	2.514968	0.479944	0.190835	-0.016378	-0.017359
7	5	1.137899	1.887099	0.749200	0.397011	1.064734	1.843370	0.778636	0.422398	-0.029436	-0.019266
7	6	0.500188	1.151312	0.651124	0.565550	0.362785	0.789849	0.427064	0.540691	0.224060	0.207812
7	7	0.180143	0.498998	0.318854	0.638989	0.107159	0.229919	0.122761	0.533932	0.196093	0.444036
7	8	0.063446	0.180086	0.116640	0.647691	0.035252	0.066038	0.030787	0.466201	0.085853	0.582342
7	9	0.022829	0.062918	0.040089	0.637163	0.012394	0.021212	0.008818	0.415708	0.031271	0.639397
7	10	0.007942	0.022104	0.014162	0.640699	0.003717	0.006002	0.002285	0.380706	0.011877	0.722138
8	1	2.579643	2.711615	0.131972	0.048669	2.871663	2.907814	0.036152	0.012433	0.095820	0.569936
8	2	2.505154	2.638573	0.133420	0.050565	2.816043	2.869805	0.053762	0.018734	0.079658	0.425564
8	3	2.301532	2.584474	0.282942	0.109478	2.602732	2.817110	0.214378	0.076099	0.068564	0.137867
8	4	1.702770	2.370042	0.667272	0.281544	1.812983	2.553471	0.740488	0.289993	-0.073216	-0.052009
8	5	0.859998	1.733485	0.873487	0.503891	0.729949	1.519831	0.789882	0.519717	0.083605	0.050262
8	6	0.303630	0.849757	0.546127	0.642686	0.207003	0.491926	0.284924	0.579201	0.261203	0.314304
8	7	0.098303	0.301804	0.203501	0.674282	0.059254	0.125582	0.066328	0.528165	0.137173	0.508370
8	8	0.034569	0.098497	0.063929	0.649045	0.019741	0.035957	0.016216	0.450983	0.047713	0.595333
8	9	0.011993	0.032656	0.020662	0.632717	0.006979	0.011324	0.004345	0.383698	0.016317	0.652497
8	10	0.003872	0.010048	0.006176	0.614650	0.002172	0.003155	0.000982	0.311252	0.005194	0.725622

Table 4.2 – Mutual information for Nifty index (equities) and Nifty futures (derivatives)

Delay	Nifty index	Nifty futures
1	1.841461	1.607819
2	1.597199	1.569245
3	1.583008	1.544251
4	1.580323	1.55539
5	1.571533	1.559082
6	1.565186	1.541657
7	1.555481	1.542847
8	1.536469	1.538544
9	1.540894	1.541931
10	1.548554	1.534485
11	1.534394	1.537537
12	1.543183	1.548859
13	1.536438	1.544159
14	1.542969	1.536621
15	1.543915	1.546326
16	1.544434	1.530548
17	1.544342	1.543518
18	1.535584	1.535858
19	1.544525	1.547394
20	1.534729	1.540558

Chart 4.1

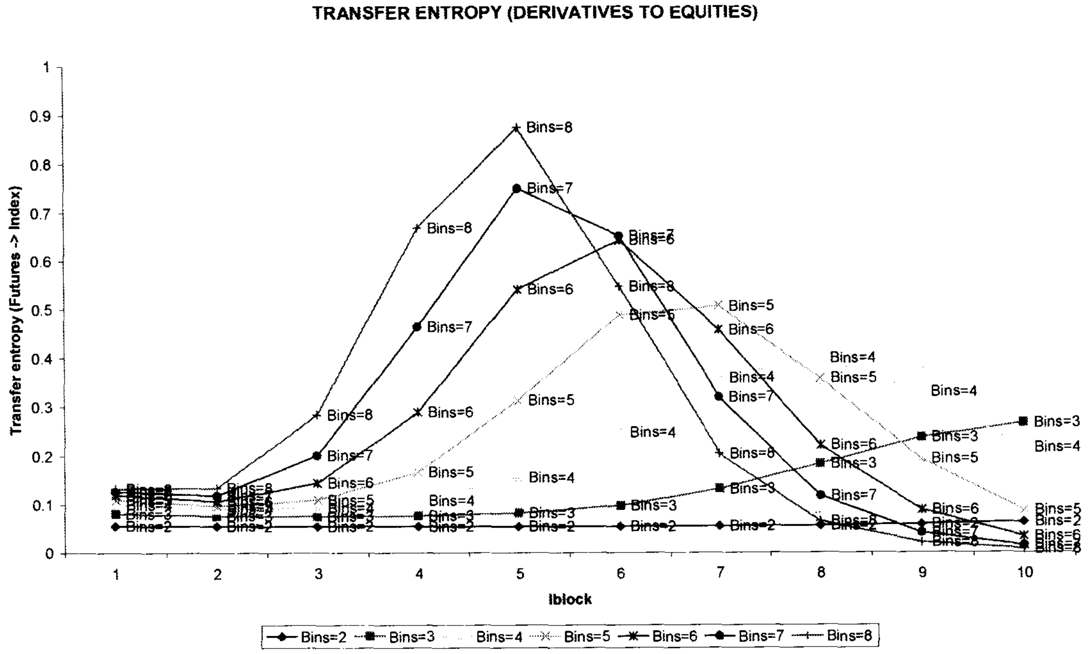


Chart 4.2

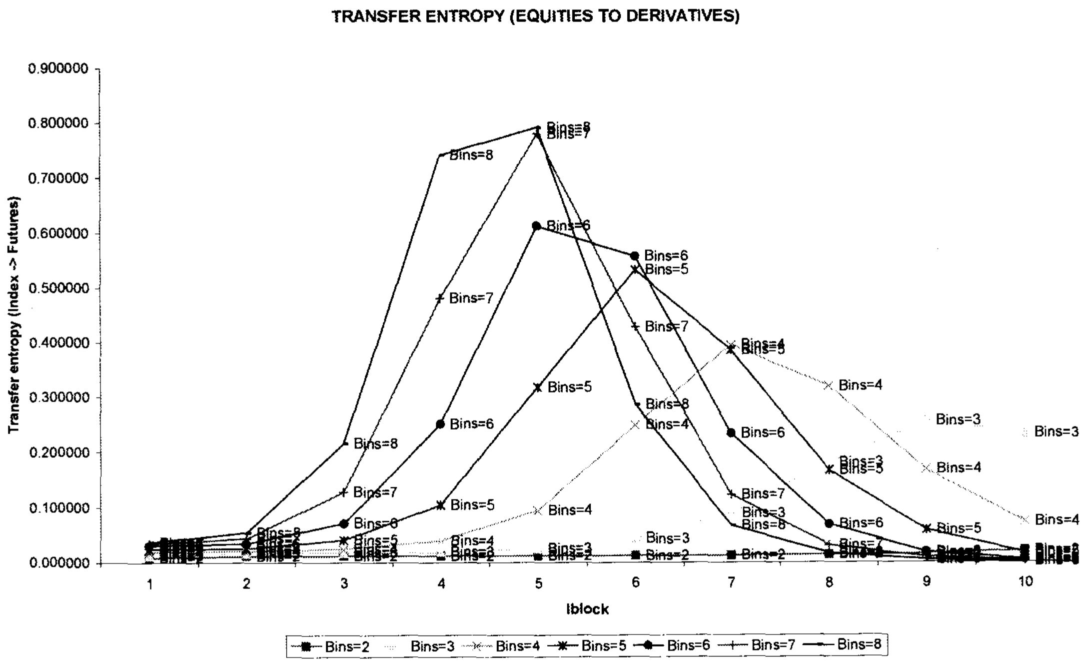


Chart 4.3

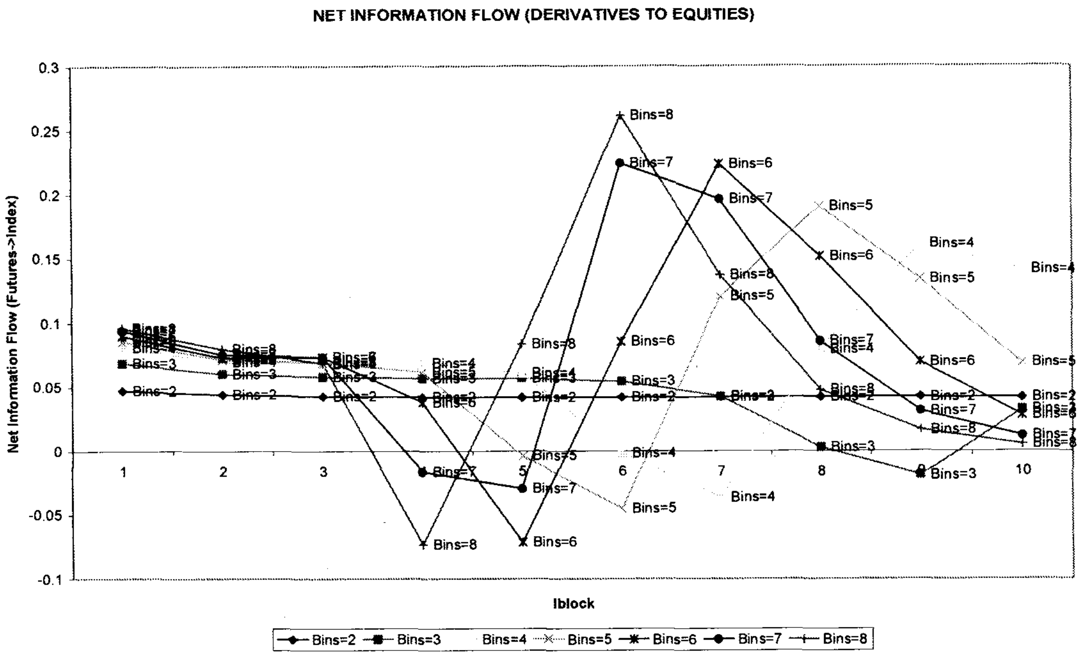


Chart 4.4

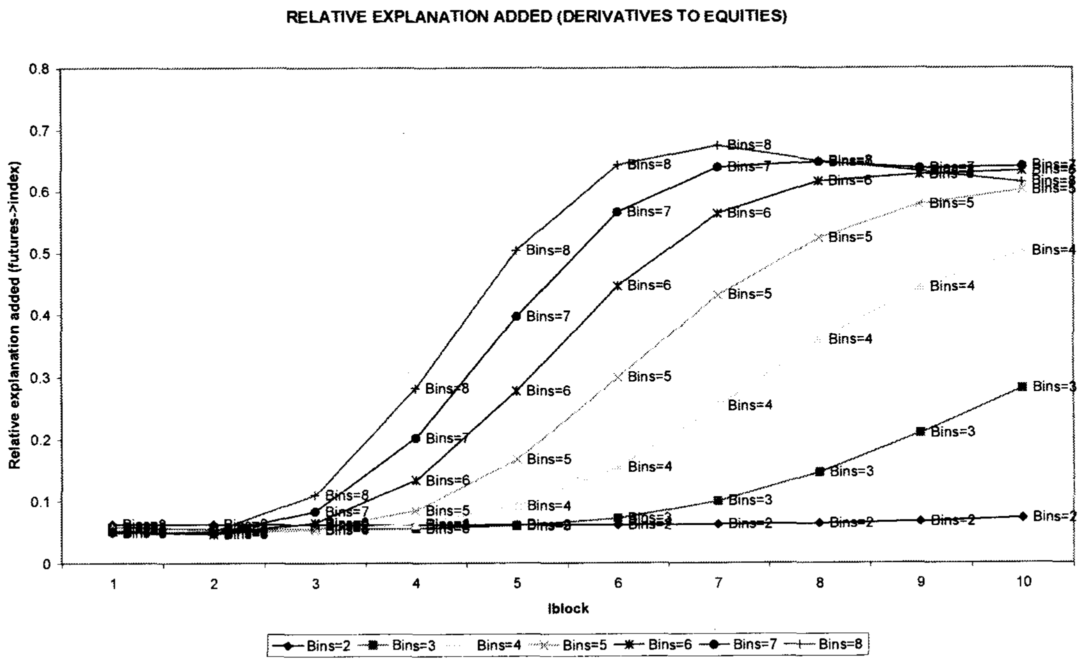
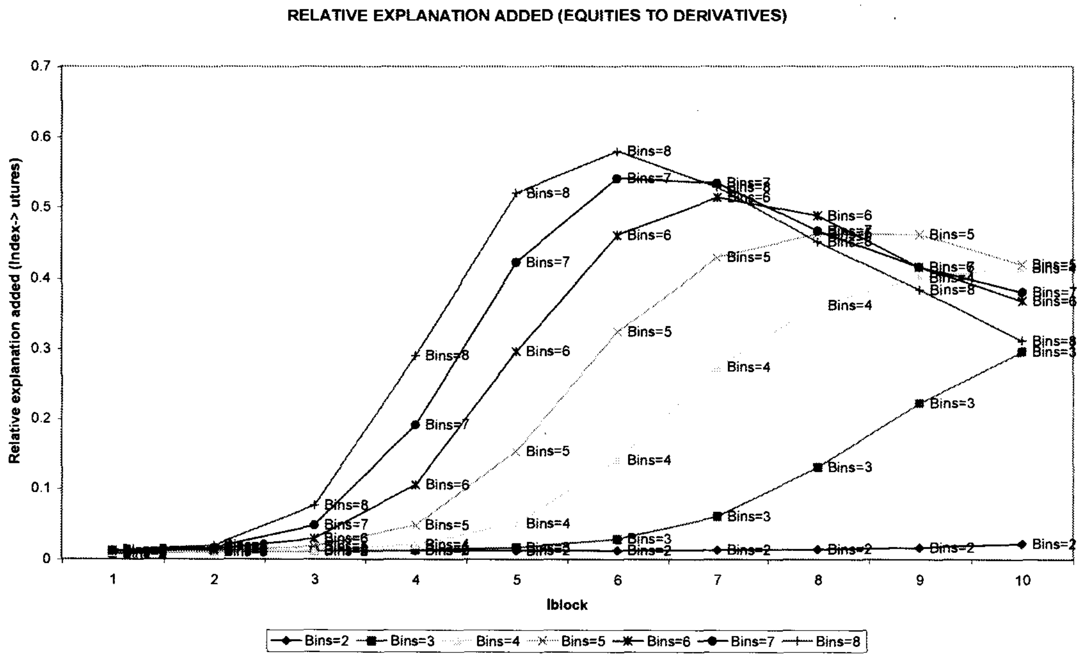


Chart 4.5



RELATIVE EXPLANATION ADDED (EQUITIES TO DERIVATIVES)
Relative explanation added (Index-> utures)
lblock
Bins=2
Bins=3
Bins=4
Bins=5
Bins=6
Bins=7
Bins=8

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CHAPTER - V

INTERACTIONS BETWEEN STOCK AND OTHER MARKETS OF INDIA

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INTERACTIONS BETWEEN STOCK AND OTHER MARKETS OF INDIA

This chapter is divided into two parts – the first deals with the interactions between the stock market and the forex market of India and in the second, we study the interactions between the stock market and the commodities market of India.

V(i) INTERACTIONS BETWEEN STOCK AND FOREX MARKETS OF INDIA

The different approaches in the study of interactions between the stock market and the foreign exchange market and the implications of such interactions are explained. The data analysed are presented and then the results obtained are interpreted.

The temporal relationship between the stock market and the foreign exchange market of developing and developed nations has been studied using various methods. By identifying lead – lag relationship between the value of a representative index of the stock market and the exchange rate of the local currency vis-à-vis US dollar or the currency of a developed economy, researchers have arrived at mixed results such as stock market leading forex market or the other way and also, no relationship between the two markets. In a financially liberalised environment, exchange rate stability is construed to be important for the well being of stock market. There are two approaches to the economic theory behind the possible interaction between the stock and the forex markets – flow oriented approach and stock oriented approach. Also a third approach viz. asset market approach propounds no such interaction between the markets.

FLOW ORIENTED APPROACH (TRADITIONAL APPROACH)

This approach postulates that changes in the exchange rate lead to changes in stock prices. Exchange rate movements affect international competitiveness and trade balance, thereby influencing real economic variables like real income and output. Classical economists argue that changes in the exchange rate affect the values of the incomes and the costs of a company with considerable exports / imports and thus have an impact on the company's stock price. An appreciation of the local currency decreases the profits of an exporter and the costs of an importer whereas a depreciation of the local currency increases the profits of an exporter and the costs of an importer. Further, changes in the exchange rate have an impact on a company's transaction exposure i.e. future payables and receivables which are denominated in foreign currency. Hence currency appreciation affects negatively the domestic stock market for an export-dominant economy and affects positively the domestic stock market for an import-dominant economy.

STOCK ORIENTED APPROACH (PORTFOLIO BALANCE APPROACH)

This approach postulates that causation runs from stock prices to exchange rate via portfolio adjustments (inflows / outflows of foreign capital), by way of direct and indirect channels.

According to the direct channel, a persistent increase in stock prices attracts capital inflows from foreign investors and also leads local investors to sell their foreign assets (which have become less attractive now) resulting in an appreciation of the local currency. According to the indirect channel, the increase in wealth due to rise in stock prices leads investors to increase their demand for local money, resulting in an increase in domestic interest rates and this again contributes to appreciation of the local currency.

Similarly, a decrease in stock prices results in depreciation of the local currency and thus changes in the stock prices lead to changes in the exchange rate of the local currency.

ASSET MARKET APPROACH

This approach postulates a weak or no association between stock prices and exchange rate. The exchange rate is treated like the price of an asset and hence is determined by expected future exchange rates. Any information that affects future value of exchange rate will affect the current exchange rate and such information may be different from the ones that cause changes in stock prices. No relationship between the forex and the stock markets may be expected to exist under such scenario.

IMPLICATIONS OF INTERACTIONS

The identification and quantification of causal relationships between the stock and the forex markets, by analysing the values over time of a nation's stock market index and the exchange rate of the nation's currency, furthers the understanding of the markets' internal dynamics. If causal relationship from a market to the other is not detected, then informational efficiency exists in the second market. Bidirectional causality implies informational inefficiency of both the markets. If causality is not found in both the directions, then the two markets are independent of each other and both the markets are informationally efficient. Presence or absence of causal relationship has a lot of implications including the following, for all the participants of the markets.

- If exchange rate leads stock prices, then crisis in stock market can be prevented by controlling the exchange rate. Moreover, developing nations may exploit such interaction to attract foreign portfolio investment in their nations and also should be cautious in the implementation of their exchange rate policies on account of the exchange rate risk in their stock markets.
- If stock prices lead exchange rate, then policy makers can focus on domestic economic policies to stabilise the stock market.

- If there is feedback in both the directions, then investors may predict the behaviour of one market using information on the other market. Since an impulse in a market is reflected quickly in the other market, policy intervention becomes more effective in the desired direction within reasonable time horizon.
- If the markets are not related, investors may reduce risk exposure by diversifying their portfolios across the markets.

PRESENTATION OF DATA

The interactions between the stock and the forex markets may be studied by measuring the extent of information exchange between a set of simultaneously recorded variables – value of the stock index and the exchange rate of the currency of a nation - over a period of time. As seen in the previous chapter, various methods are available for such analysis and among the entropic measures, transfer entropy is suitable to identify directional information. Accordingly, the symbolic encoding method is used to compute transfer entropy between the stock market and the forex market in India. Linkages, if any, have important implications for the financial reforms which are aimed at promoting the growth of the stock market and maintaining a stable exchange rate.

National Stock Exchange of India Limited (NSEIL) being the leading stock exchange of India, the 50 stock index of the Exchange viz. Nifty and the exchange rate of Indian Rupee vis-à-vis US Dollar are considered as representatives of the two markets, for identifying causal relationship, if exists. Due to high liquidity in both the markets and the incredibly fast information transport enabled by digital communication network, between the two markets which have a large number of common or closely connected participants, there is a need to look at daily data. The use of lower frequency data such as weekly or monthly observations may not be adequate to capture fast-moving exchange rate and stock prices and the effects of short term capital movements.

In India, the system of market determined exchange rate was adopted in March 1993, although the exchange rate system in India is still not exactly full float but a managed float system. However, this was an important step towards current account convertibility in August 1994. Further the computation and dissemination of the index Nifty commenced from November 1995. Hence the data for the period from November 1995 to March 2007 has been considered for the study. Since the foreign exchange transactions in India are predominantly in US Dollar, the daily values, during the period, of Reserve Bank of India (RBI) reference rate for the Indian Rupee vis-à-vis US Dollar are taken as representative of the forex market. The RBI reference rate is based on the exchange rates at 12 noon, of a few select banks in Mumbai, the commercial capital of India. It may be noted that the SDR (Special Drawing Right) - Rupee rate is based on this rate. Also, daily closing values of the index Nifty during the period are taken as representative of the stock market.

Thus two time series, each with 2816 data points were obtained for the variables viz. the stock index - Nifty (X) and the exchange rate - RBI reference rate (Y). These price series were transformed to log returns series since such transformation satisfies additive property of the returns and makes the results invariant in spite of arbitrary scaling of the price data. Further, on account of such transformation, stationarity of the two series may be assumed so that meaningful analysis may be made. The summary statistics of the resultant series are given below.

	Stock index	Exchange rate
Minimum	-0.13054	-0.02991
1st Quartile	-0.00820	-0.00066
Mean	0.00048	0.00008
Median	0.00094	0.00000
3rd Quartile	0.00940	0.00069
Maximum	0.09934	0.02977
Number of data points	2815	2815
Standard Deviation	0.01619	0.00254
Skewness	-0.30533	0.48346
Kurtosis	4.45239	25.58634

Further, during this period there were important developments in both the markets in India. Starting from mid-June 1998, by May 1999, authorised dealers were permitted gradually, to provide 100% forward cover against exchange risk for FII (Foreign Institutional Investors) investments and also to NRI (Non-Resident Indians) and OCB (Overseas Corporate Bodies) to cover their portfolio equity investments. Starting from June 2000, by July 2001, both futures and options contracts on stock price indices and individual stock prices were made available, in stages, for trading. From June 2002 till March 2007, the Indian rupee has generally appreciated, except for insignificantly brief spells of minor depreciation. Further, the stock market started rising from mid-May 2003 and, except for brief spells of deep falls, has been in up-trend generally till March 2007. Hence the entire period considered for the study, has been divided into 3 sub-periods viz. November 1995 to mid-June 1998, mid-June 1998 to mid-May 2003 and mid-May 2003 to March 2007 for further analysis.

EMPIRICAL RESULTS

As in the last chapter, transfer entropy $T_{Y \to X}$ (forex market to stock market) is computed for the number of bins S ranging from 2 to 8, the block length k for X ranging from 1 to 10 and the block length l for Y equal to 1. Similarly, transfer entropy $T_{X \to Y}$ (stock market to forex market) was computed for the number of bins ranging from 2 to 8, the block length for Y ranging from 1 to 10 and the block length for X equal to 1. The computed transfer entropy values for the entire period considered in the study i.e. from November 1995 to March 2007 are presented in table 5.1 given below. The transfer entropy in both the directions behaves reasonably for partitions $S \geq 6$ of the data analysed and for block length of the transferee series $k \geq 3$. Further, in order to consider appropriate values of k, the mutual information of the two time series containing the values of the stock index (X) and the exchange rate (Y), for delays ranging from a day to 20 days are computed and given in table 5.2. It may be observed that the first minimum has occurred for $k = 3$ for both the series. Hence, meaningful results may be obtained from transfer entropy values computed for partitions S = 6, 7, 8 and block length of the transferee series $k \geq 3$.

From the transfer entropy values given in table 5.1, a flow of information from day t of one series to day t+1 of the other series is observed in both the directions in small quantities, which suggests only low level interactions between stock and forex markets at a time scale of a day or less. The flow from the stock market to the forex market is more pronounced than the flow in the reverse direction. Further, if the time series are partitioned into 6 or more bins, transfer entropy in both the directions reduces below 0.1

and approaches zero when 7 or more past values of the transferee variable are considered (i.e. $k \geq 7$).. Moreover the entropy rates h(X,Y) and h(Y,X) pertaining to the conditional transition probabilities (given lagged values of both X and Y) and even the entropy rates h(X) and h(Y) pertaining to the conditional transition probabilities (given lagged values of X or Y only) tend to zero for the same values of S and k. For interpreting the transfer entropy values, the measures net information flow, relative explanation added and normalised directionality index, which have been explained in the last chapter are used.

ENTIRE PERIOD

For the entire period considered in the study i.e. from November 1995 to March 2007, the values of net information flow, normalised directionality index and relative explanation added are given in table 5.1. It may be observed from the table as follows.

(i) For $S \geq 6$, NIF from the forex market to the stock market is positive but small if $k = 3$ and there is insignificant net flow from the stock market to the forex market if $k \geq 4$.

(ii) For $S \geq 6$, NDI(X,Y) ranges from 0.051 to 0.076 if $k = 3$ and ranges from - 0.03 to – 1 if $k \geq 4$. This implies that though net flow from the stock market to the forex market is insignificantly small for $k \geq 4$, there is no information flow at all from the forex market to the stock market for higher values of k resulting in NDI(X,Y) = - 1.

(iii) For partitions S = 6, 7, 8,

- the REA by one market to the other increases with the block length taken for the transferee market till the entropy rates of the markets do not completely vanish, thereby implying that whatever information flown from one market towards the prediction of the next price in the other market cannot be compensated by the inclusion of more number of past values realised by the transferee market.
- when the entropy rate of the stock market alone becomes zero, whatever entropy rate retained by the forex market is entirely caused by the stock market and hence REA by the stock market becomes 1 whereas the REA by the forex market is not defined at all
- when the entropy rates of both the stock and the forex markets become zero, the REA by any market is not defined at all.

FIRST SUB-PERIOD

For the first sub-period November 1995 to mid-June 1998, the values of transfer entropy, net information flow, normalised directionality index and relative explanation added are given in table 5.3. It may be observed from the table as follows.

(i) For $S \geq 6$, the net flow is generally from the stock market to the forex market if $k \geq 3$, however such net flow is insignificantly small. Further, for $S = 7$ and 8, the entropy rates of both the stock and the forex markets become zero for higher values of k, resulting in zero value for the transfer entropy in both the directions and hence there is no NIF in such cases.

(ii) For S ≥ 6, NDI(X,Y) ranges generally from - 0.02 to – 1 if k ≥ 3 implying that there is no information flow at all from the forex market to the stock market as k increases, resulting in NDI(X,Y) = - 1. Further, for S = 7 and 8, the entropy rates of both the stock and the forex markets become zero for higher values of k, resulting in zero value for the transfer entropy in both the directions and hence the normalised directionality index is not defined at all in such cases.

(iii) For partitions S = 6, 7, 8,

- no conclusive evidence could be drawn from the values of REA by one market to the other
- when the entropy rate of the stock market alone becomes zero, whatever entropy rate retained by the forex market is entirely caused by the stock market and hence REA by the stock market becomes 1 whereas the REA by the forex market is not defined at all
- when the entropy rates of both the stock and the forex markets become zero, the REA by any market is not defined at all.

MID SUB-PERIOD

For the mid sub-period mid-June 1998 to mid-May 2003, the values of transfer entropy, net information flow, normalised directionality index and relative explanation added are given in table 5.4. It may be observed from the table as follows.

(i) For S $\geq$ 6, NIF from the forex market to the stock market is positive but small if k = 3 and there is insignificant net flow from the stock market to the forex market if k $\geq$ 4.

(ii) For S $\geq$ 6, NDI(X,Y) ranges from 0.004 to 0.045 if k = 3 and ranges from - 0.03 to – 1 if k $\geq$ 4, implying that there is no information flow at all from the forex market to the stock market for higher values of k resulting in NDI(X,Y) = - 1. Further, for k = 10, the entropy rates of both the stock and the forex markets become zero, resulting in zero value for the transfer entropy in both the directions and hence the normalised directionality index is not defined at all in such cases.

(iii) For partitions S = 6, 7, 8,

- the REA by one market to the other increases generally with the block length taken for the transferee market till the entropy rates of the markets do not completely vanish, thereby implying that whatever information flown from one market towards the prediction of the next price in the other market cannot be compensated by the inclusion of more number of past values realised by the transferee market.
- when the entropy rate of the stock market alone becomes zero, whatever entropy rate retained by the forex market is entirely caused by the stock market and hence REA by the stock market becomes 1 whereas the REA by the forex market is not defined at all
- when the entropy rates of both the stock and the forex markets become zero, the REA by any market is not defined at all.

LAST SUB-PERIOD

For the last sub-period mid-May 2003 to March 2007, the values of transfer entropy, net information flow, normalised directionality index and relative explanation added are given in table 5.5. It may be observed from the table as follows.

(i) For $S \geq 6$ and $k \geq 3$, generally there is insignificantly small net flow from the stock market to the forex market and in a few cases, such small net flow is in the reverse direction. Further, the entropy rates of both the stock and the forex markets become zero for higher values of k, resulting in zero value for the transfer entropy in both the directions and hence there is no NIF in such cases.

(ii) For $S \geq 6$ and $k \geq 3$, no conclusive evidence could be drawn from the values of NDI(X,Y). Further, the entropy rates of both the stock and the forex markets become zero for higher values of k, resulting in zero value for the transfer entropy in both the directions and hence the normalised directionality index is not defined at all in such cases.

(iii) For partitions S = 6, 7, 8,

- no conclusive evidence could be drawn from the values of REA by one market to the other

- when the entropy rates of both the stock and the forex markets become zero, the REA by any market is not defined at all.

CONCLUSION

Transfer entropy values between the Nifty (stock) index and the RBI reference (forex) rate for the period November 1995 – March 2007 and three sub-periods have been computed and the results obtained for the different sub-periods are more or less consistent with those obtained for the entire period and reiterate that

- there exist only low level interactions between the stock and the forex markets of India at a time scale of a day or less, although theory suggests interactive relationship between the two markets
- the flow from the stock market to the forex market is more pronounced than the flow in the reverse direction
- the entropy rates of both the markets become zero on considering 8 or more past values realised in the respective markets, implying that the information generation in the markets tend to zero if 8 or more past values are considered.

Table 5.1 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI)
(stock and forex markets of India for the entire period November 1995 to March 2007)

Bins	Block	Forex market (Y) to stock market (X) $h_{k,l}$ (X,Y)	h_k (X)	$T_{Y \to X}$ (k,l)	$REA_{Y \to X}$ (k,l)	Stock market (X) to forex market (Y) $h_{k,l}$ (Y,X)	h_k (Y)	$T_{X \to Y}$ (k,l)	$REA_{X \to Y}$ (k,l)	$NIF_{Y \to X}$ (k,l)	NDI(X,Y)
2	1	0.99157	0.992429	0.000858	0.000865	0.998248	0.999959	0.001711	0.001711	-0.000853	-0.332036
2	2	0.99123	0.992203	0.000974	0.000982	0.997011	0.999167	0.002156	0.002158	-0.001182	-0.377636
2	3	0.98879	0.990173	0.001383	0.001397	0.993873	0.996155	0.002282	0.002291	-0.000899	-0.245293
2	4	0.9848	0.98785	0.003046	0.003083	0.990727	0.994606	0.003879	0.003900	-0.000833	-0.120289
2	5	0.97896	0.984835	0.00588	0.005971	0.973795	0.984797	0.011002	0.011172	-0.005122	-0.303400
2	6	0.96422	0.979669	0.015446	0.015767	0.957168	0.975499	0.018331	0.018791	-0.002885	-0.085413
2	7	0.92707	0.961584	0.034514	0.035893	0.92682	0.963204	0.036384	0.037774	-0.001870	-0.026376
2	8	0.84461	0.923437	0.078826	0.085362	0.840072	0.920091	0.080019	0.086969	-0.001193	-0.007510
2	9	0.70468	0.845765	0.141087	0.166816	0.692598	0.851609	0.159011	0.186718	-0.017924	-0.059727
2	10	0.48786	0.691216	0.203354	0.294197	0.486964	0.676576	0.189611	0.280251	0.013743	0.034973
3	1	1.56942	1.573855	0.00444	0.002821	1.53089	1.537925	0.007034	0.004574	-0.002594	-0.226076
3	2	1.55366	1.567482	0.01382	0.008817	1.504502	1.515473	0.010971	0.007239	0.002849	0.114921
3	3	1.51766	1.553307	0.035643	0.022947	1.467437	1.497804	0.030367	0.020274	0.005276	0.079927
3	4	1.41229	1.522477	0.110188	0.072374	1.364155	1.461902	0.097746	0.066862	0.012442	0.059836
3	5	1.1216	1.418222	0.296619	0.209148	1.074584	1.365756	0.291172	0.213195	0.005447	0.009267
3	6	0.64792	1.124845	0.476925	0.423992	0.66202	1.069376	0.407356	0.380929	0.069569	0.078673
3	7	0.28819	0.655747	0.367557	0.560516	0.342138	0.683804	0.341665	0.499653	0.025892	0.036508
3	8	0.11002	0.291862	0.181838	0.623027	0.155959	0.359009	0.20305	0.565585	-0.021212	-0.055112
3	9	0.0345	0.105378	0.070879	0.672617	0.063606	0.176507	0.112901	0.639640	-0.042022	-0.228654
3	10	0.01355	0.037082	0.023533	0.634621	0.032839	0.087808	0.054969	0.626014	-0.031436	-0.400448
4	1	1.97608	1.986239	0.010163	0.005117	1.924274	1.931017	0.006743	0.003492	0.003420	0.202295
4	2	1.93038	1.966801	0.036425	0.018520	1.849572	1.891936	0.042365	0.022392	-0.005940	-0.075390
4	3	1.73716	1.925359	0.188195	0.097745	1.648803	1.836273	0.18747	0.102093	0.000725	0.001930
4	4	1.13167	1.74472	0.613046	0.351372	1.128464	1.641864	0.5134	0.312693	0.099646	0.088461
4	5	0.46191	1.17953	0.71762	0.608395	0.564548	1.140609	0.57606	0.505046	0.141560	0.109424
4	6	0.13373	0.476309	0.342578	0.719235	0.218996	0.583421	0.364425	0.624635	-0.021847	-0.030901
4	7	0.03352	0.143367	0.109851	0.766222	0.076855	0.260879	0.184024	0.705400	-0.074173	-0.252396
4	8	0.00642	0.026211	0.019793	0.755141	0.023801	0.103695	0.079894	0.770471	-0.060101	-0.602897
4	9	0.00071	0.005705	0.004992	0.875022	0.006417	0.041454	0.035037	0.845202	-0.030045	-0.750581
4	10	0.00071	0.000713	0	0.000000	0.002139	0.015689	0.01355	0.863662	-0.013550	-1.000000
5	1	2.2725	2.29833	0.025835	0.011241	2.201113	2.223881	0.022767	0.010238	0.003068	0.063125
5	2	2.14128	2.263519	0.122238	0.054004	2.058324	2.169097	0.110773	0.051069	0.011465	0.049204
5	3	1.5359	2.137012	0.601112	0.281286	1.519394	2.034542	0.515148	0.253201	0.085964	0.077011
5	4	0.63189	1.569245	0.937354	0.597328	0.717213	1.543765	0.826552	0.535413	0.110802	0.062816
5	5	0.17952	0.636785	0.457268	0.718089	0.234063	0.769142	0.535079	0.695683	-0.077811	-0.078411

5	6	0.05073	0.168831	0.118103	0.699534	0.065749	0.263741	0.197991	0.750702	-0.079888	-0.252735
5	7	0.01498	0.044575	0.029599	0.664027	0.020236	0.086043	0.065807	0.764815	-0.036208	-0.379515
5	8	0.00357	0.011412	0.007846	0.687522	0.008113	0.03022	0.022107	0.731535	-0.014261	-0.476113
5	9	0	0.001426	0.001426	1.000000	0.000713	0.007844	0.007131	0.909102	-0.005705	-0.666706
5	10	0	0.000713	0.000713	1.000000	0	0.002139	0.002139	1.000000	-0.001426	-0.500000
6	1	2.50128	2.55584	0.05456	0.021347	2.440512	2.486222	0.045709	0.018385	0.008851	0.088273
6	2	2.21155	2.501579	0.29003	0.115939	2.116892	2.40413	0.287238	0.119477	0.002792	0.004837
6	3	1.17357	2.211431	1.037858	0.469315	1.191771	2.121463	0.929693	0.438232	0.108165	0.054974
6	4	0.30909	1.191407	0.882316	0.740566	0.382209	1.228778	0.846569	0.688952	0.035747	0.020676
6	5	0.06383	0.325027	0.261192	0.803601	0.094004	0.442916	0.348912	0.787761	-0.087720	-0.143779
6	6	0.01569	0.066685	0.050997	0.764745	0.021312	0.131554	0.110242	0.837998	-0.059245	-0.367436
6	7	0.00285	0.012836	0.009983	0.777734	0.007843	0.035303	0.02746	0.777838	-0.017477	-0.466763
6	8	0	0.003566	0.003566	1.000000	0.002852	0.013105	0.010253	0.782373	-0.006687	-0.483899
6	9	0	0.000713	0.000713	1.000000	0	0.003835	0.003835	1.000000	-0.003122	-0.686456
6	10	0	0	0	ND	0	0.000713	0.000713	1.000000	-0.000713	-1.000000
7	1	2.69724	2.768977	0.071737	0.025907	2.623036	2.694774	0.071738	0.026621	-0.000001	-0.000007
7	2	2.14683	2.682722	0.535897	0.199759	2.056632	2.572629	0.515997	0.200572	0.019900	0.018918
7	3	0.82778	2.179838	1.352056	0.620255	0.897072	2.058023	1.160952	0.564110	0.191104	0.076046
7	4	0.16761	0.819847	0.652235	0.795557	0.247377	0.94433	0.696953	0.738040	-0.044718	-0.033144
7	5	0.03307	0.165874	0.1328	0.800608	0.053845	0.271564	0.217718	0.801719	-0.084918	-0.242264
7	6	0.00713	0.022821	0.015691	0.687568	0.014261	0.077661	0.063399	0.816356	-0.047708	0.603212
7	7	0.00143	0.004992	0.003566	0.714343	0.001427	0.020236	0.018809	0.929482	-0.015243	-0.681251
7	8	0	0.001427	0.001427	1.000000	0	0.004992	0.004992	1.000000	-0.003565	-0.555382
7	9	0	0	0	ND	0	0.000713	0.000713	1.000000	-0.000713	-1.000000
7	10	0	0	0	ND	0	0	0	ND	0.000000	ND
8	1	2.85319	2.955806	0.102619	0.034718	2.761533	2.868998	0.107465	0.037457	-0.004846	-0.023067
8	2	1.97284	2.829869	0.857029	0.302851	1.908638	2.692558	0.78392	0.291143	0.073109	0.044553
8	3	0.56788	1.9718	1.403916	0.711997	0.655683	1.922971	1.267288	0.659026	0.136628	0.051148
8	4	0.08648	0.58057	0.494093	0.851048	0.148848	0.732654	0.583806	0.796837	-0.089713	-0.083230
8	5	0.01141	0.098249	0.08684	0.883877	0.027905	0.176596	0.14869	0.841978	-0.061850	-0.262599
8	6	0.00143	0.014977	0.013551	0.904787	0.005975	0.044039	0.038064	0.864325	-0.024513	-0.474920
8	7	0.00071	0.002852	0.002139	0.750000	0	0.01141	0.01141	1.000000	-0.009271	-0.684257
8	8	0	0	0	ND	0	0.002139	0.002139	1.000000	-0.002139	-1.000000
8	9	0	0	0	ND	0	0.000713	0.000713	1.000000	-0.000713	-1.000000
8	10	0	0	0	ND	0	0	0	ND	0.000000	ND

Table 5.2 – Mutual information for stock and forex markets of India

Delay	Forex market	Stock market
1	2.017578	1.445313
2	1.816406	1.520508
3	1.75	1.398438
4	1.770508	1.456055
5	1.793945	1.484375
6	1.766602	1.405274
7	1.753906	1.457031
8	1.696289	1.432617
9	1.670899	1.431641
10	1.727539	1.382813
11	1.704102	1.463867
12	1.719727	1.415039
13	1.707031	1.386719
14	1.698242	1.402344
15	1.768555	1.384766
16	1.713867	1.40332
17	1.760742	1.399414
18	1.762695	1.451172
19	1.668945	1.397461
20	1.723633	1.405274

Table 5.3 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI)
(stock and forex markets of India for the first sub-period November 1995 to June 1998)

		Forex market (Y) to stock market (X)				Stock market (X) to forex market (Y)					
Bins	Block	$h_{k,l}$ (X,Y)	h_k (X)	$T_{Y \to X}$ (k,l)	$REA_{Y \to X}$ (k,l)	$h_{k,l}$ (Y,X)	h_k (Y)	$T_{X \to Y}$ (k,l)	$REA_{X \to Y}$ (k,l)	$NIF_{Y \to X}$ (k,l)	NDI(X,Y)
2	1	0.981334	0.985583	0.004249	0.004311	0.998393	0.999333	0.000940	0.000941	0.003309	0.637695
2	2	0.976796	0.982956	0.006159	0.006266	0.987615	0.990926	0.003310	0.003340	0.002849	0.300877
2	3	0.967856	0.979885	0.012028	0.012275	0.971868	0.982407	0.010539	0.010728	0.001489	0.065981
2	4	0.954237	0.974782	0.020545	0.021077	0.941941	0.960052	0.018111	0.018865	0.002434	0.062966
2	5	0.925080	0.960863	0.035783	0.037240	0.905036	0.936823	0.031787	0.033931	0.003996	0.059139
2	6	0.833471	0.918049	0.084578	0.092128	0.805412	0.887435	0.082024	0.092428	0.002554	0.015330
2	7	0.658331	0.823257	0.164927	0.200335	0.644134	0.804729	0.160595	0.199564	0.004332	0.013308
2	8	0.465598	0.661913	0.196315	0.296587	0.466846	0.641087	0.174240	0.271788	0.022075	0.059573
2	9	0.308987	0.480469	0.171482	0.356905	0.303815	0.462230	0.158415	0.342719	0.013067	0.039609
2	10	0.150531	0.259982	0.109451	0.420995	0.177928	0.299047	0.121119	0.405017	-0.011668	-0.050605
3	1	1.555823	1.573398	0.017574	0.011169	1.519103	1.538198	0.019096	0.012415	-0.001522	-0.041505
3	2	1.519073	1.561587	0.042514	0.027225	1.473872	1.525349	0.051478	0.033748	-0.008964	-0.095370
3	3	1.342542	1.504592	0.162050	0.107704	1.305333	1.458170	0.152837	0.104814	0.009213	0.029258
3	4	0.945253	1.355866	0.410613	0.302842	0.921304	1.300810	0.379506	0.291746	0.031107	0.039370
3	5	0.519350	0.984303	0.464953	0.472368	0.516942	0.992386	0.475444	0.479092	-0.010491	-0.011156
3	6	0.166684	0.478278	0.311594	0.651491	0.211332	0.542936	0.331604	0.610761	-0.020010	-0.031110
3	7	0.050552	0.181704	0.131151	0.721784	0.067540	0.211976	0.144436	0.681379	-0.013285	-0.048206
3	8	0.009480	0.060029	0.050550	0.842093	0.029626	0.086914	0.057288	0.659134	-0.006738	-0.062483
3	9	0.003160	0.018956	0.015797	0.833351	0.009477	0.034752	0.025275	0.727296	-0.009478	-0.230765
3	10	0.003160	0.006319	0.003160	0.500079	0.003160	0.015800	0.012640	0.800000	-0.009480	-0.60000

4	1	1.919819	1.965421	0.045602	0.023202	1.883236	1.922410	0.039173	0.020377	0.006429	0.075836
4	2	1.717481	1.922395	0.204914	0.106593	1.673009	1.843131	0.170121	0.092300	0.034793	0.092773
4	3	1.076897	1.714107	0.637210	0.371745	1.105083	1.618981	0.513899	0.317421	0.123311	0.107124
4	4	0.412118	1.082340	0.670222	0.619234	0.521266	1.110434	0.589168	0.530575	0.081054	0.064360
4	5	0.105460	0.442878	0.337418	0.761876	0.195955	0.533290	0.337335	0.632555	0.000083	0.000123
4	6	0.018957	0.133123	0.114166	0.857598	0.083345	0.204244	0.120898	0.591929	-0.006732	-0.028639
4	7	0.006318	0.041074	0.034756	0.846180	0.015799	0.063190	0.047392	0.749992	-0.012636	-0.153820
4	8	0.003159	0.012638	0.009480	0.750119	0.000000	0.006319	0.006319	1.000000	0.003161	0.200076
4	9	0.000000	0.003160	0.003160	1.000000	0.000000	0.003159	0.003159	1.000000	0.000001	0.000158
4	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
5	1	2.163985	2.278620	0.114636	0.050309	2.079000	2.175357	0.096357	0.044295	0.018279	0.086633
5	2	1.611443	2.153257	0.541815	0.251626	1.554223	2.054559	0.500336	0.243525	0.041479	0.039801
5	3	0.653366	1.650008	0.996642	0.604023	0.719311	1.561843	0.842533	0.539448	0.154109	0.083792
5	4	0.147722	0.691744	0.544022	0.786450	0.261179	0.793161	0.531982	0.670711	0.012040	0.011190
5	5	0.022120	0.157629	0.135509	0.859670	0.062418	0.281967	0.219549	0.778634	-0.084040	-0.236694
5	6	0.009478	0.042265	0.032787	0.775748	0.015798	0.084535	0.068737	0.813119	-0.035950	-0.354103
5	7	0.000000	0.003160	0.003160	1.000000	0.003160	0.034755	0.031595	0.909078	-0.028435	-0.818156
5	8	0.000000	0.003160	0.003160	1.000000	0.000000	0.000000	0.000000	ND	0.003160	1.000000
5	9	0.000000	0.003160	0.003160	1.000000	0.000000	0.000000	0.000000	ND	0.003160	1.000000
5	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
6	1	2.365939	2.541132	0.175194	0.068943	2.209417	2.389667	0.180250	0.075429	-0.005056	-0.014224
6	2	1.375697	2.354182	0.978485	0.415637	1.346330	2.148725	0.802394	0.373428	0.176091	0.098879
6	3	0.336749	1.359034	1.022285	0.752214	0.495894	1.354626	0.858732	0.633926	0.163553	0.086949
6	4	0.075054	0.364412	0.289358	0.794041	0.129764	0.556962	0.427198	0.767015	-0.137840	-0.192365
6	5	0.018956	0.094013	0.075057	0.798368	0.035950	0.181868	0.145918	0.802329	-0.070861	-0.320674
6	6	0.000000	0.006319	0.006319	1.000000	0.015799	0.054132	0.038333	0.708139	-0.032014	-0.716967
6	7	0.000000	0.006319	0.006319	1.000000	0.003160	0.018957	0.015798	0.833360	-0.009479	-0.428584
6	8	0.000000	0.000000	0.000000	ND	0.000000	0.003159	0.003159	1.000000	-0.003159	-1.000000
6	9	0.000000	0.000000	0.000000	ND	0.000000	0.003160	0.003160	1.000000	-0.003160	-1.000000
6	10	0.000000	0.000000	0.000000	ND	0.000000	0.003159	0.003159	1.000000	-0.003159	-1.000000
7	1	2.361551	2.743219	0.381667	0.139131	2.203278	2.556994	0.353716	0.138333	0.027951	0.038009
7	2	1.040081	2.407122	1.367042	0.567916	1.065178	2.151703	1.086525	0.504960	0.280517	0.114330
7	3	0.248894	1.107615	0.858722	0.775289	0.316816	1.215207	0.898390	0.739290	-0.039668	-0.022576
7	4	0.031596	0.202275	0.170679	0.843797	0.083759	0.403208	0.319448	0.792266	-0.148769	-0.303532
7	5	0.009480	0.037914	0.028435	0.749987	0.016989	0.102296	0.085307	0.833923	-0.056872	-0.500009
7	6	0.003160	0.006320	0.003160	0.500000	0.006319	0.049004	0.042685	0.871051	-0.039525	-0.862144
7	7	0.000000	0.000000	0.000000	ND	0.000000	0.015797	0.015797	1.000000	-0.015797	-1.00000
7	8	0.000000	0.000000	0.000000	ND	0.000000	0.006319	0.006319	1.000000	-0.006319	-1.00000
7	9	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
7	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
8	1	2.343922	2.917113	0.573192	0.196493	2.203497	2.709689	0.506192	0.186808	0.067000	0.062072
8	2	0.792759	2.375027	1.582268	0.666211	0.851357	2.146752	1.295395	0.603421	0.286873	0.099690
8	3	0.135083	0.827309	0.692225	0.836719	0.227872	1.007107	0.779235	0.773736	-0.087010	-0.059132
8	4	0.028438	0.159592	0.131154	0.821808	0.063607	0.316584	0.252976	0.799080	-0.121822	-0.317137
8	5	0.000000	0.028438	0.028438	1.000000	0.018955	0.089817	0.070862	0.788960	-0.042424	-0.427231
8	6	0.000000	0.006319	0.006319	1.000000	0.015796	0.030820	0.015024	0.487476	-0.008705	-0.407862
8	7	0.000000	0.000000	0.000000	ND	0.000000	0.006318	0.006318	1.000000	-0.006318	-1.00000
8	8	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
8	9	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
8	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND

Table 5.4 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI)
(stock and forex markets of India for the mid sub-period June 1998 to May 2003)

Bins	Block	Forex market (Y) to stock market (X) $h_{k,l}$ (X,Y)	h_k (X)	$T_{Y\to X}$ (k,l)	$REA_{Y\to X}$ (k,l)	Stock market (X) to forex market (Y) $h_{k,l}$ (Y,X)	h_k (Y))	$T_{X\to Y}$ (k,l)	$REA_{X\to Y}$ (k,l)	$NIF_{Y\to X}$ (k,l)	NDI(X,Y)
2	1	0.989433	0.990106	0.000674	0.000681	0.996160	0.999669	0.003509	0.003510	-0.002835	0.677743
2	2	0.989131	0.989867	0.000736	0.000744	0.994207	0.999249	0.005042	0.005046	-0.004306	0.745241
2	3	0.986636	0.988625	0.001988	0.002011	0.990854	0.997625	0.006772	0.006788	-0.004784	0.546119
2	4	0.968855	0.980394	0.011539	0.011770	0.981933	0.990921	0.008988	0.009070	0.002551	0.124275
2	5	0.949440	0.975186	0.025745	0.026400	0.951283	0.976140	0.024857	0.025465	0.000888	0.017549
2	6	0.906538	0.953145	0.046607	0.048898	0.905201	0.953345	0.048144	0.050500	-0.001537	0.016221
2	7	0.818090	0.916833	0.098742	0.107699	0.818774	0.920484	0.101710	0.110496	-0.002968	0.014807
2	8	0.637829	0.807209	0.169380	0.209834	0.635496	0.814238	0.178742	0.219521	-0.009362	0.026893
2	9	0.430089	0.641722	0.211633	0.329789	0.453019	0.643619	0.190599	0.296136	0.021034	0.052293
2	10	0.268965	0.437031	0.168066	0.384563	0.273854	0.431880	0.158026	0.365903	0.010040	0.030789
3	1	1.565369	1.573339	0.007969	0.005065	1.543019	1.550241	0.007222	0.004659	0.000747	0.049174
3	2	1.540386	1.561704	0.021317	0.013650	1.511140	1.531222	0.020082	0.013115	0.001235	0.029832
3	3	1.464272	1.542581	0.078309	0.050765	1.435827	1.504591	0.068764	0.045703	0.009545	0.064900
3	4	1.228741	1.473486	0.244746	0.166100	1.214209	1.434677	0.220468	0.153671	0.024278	0.052187
3	5	0.743645	1.217957	0.474312	0.389432	0.736671	1.190354	0.453682	0.381132	0.020630	0.022231
3	6	0.320330	0.741640	0.421310	0.568079	0.379332	0.773416	0.394084	0.509537	0.027226	0.033390
3	7	0.100483	0.333727	0.233244	0.698907	0.156272	0.374224	0.217952	0.582411	0.015292	0.033892
3	8	0.032945	0.127897	0.094953	0.742418	0.071457	0.186949	0.115492	0.617773	-0.020539	0.097598
3	9	0.013179	0.052713	0.039535	0.750005	0.023063	0.069407	0.046344	0.667714	-0.006809	0.079286
3	10	0.000000	0.014826	0.014826	1.000000	0.006589	0.026978	0.020389	0.755764	-0.005563	0.157972
4	1	1.958975	1.984250	0.025275	0.012738	1.932098	1.961289	0.029190	0.014883	-0.003915	0.071881
4	2	1.853940	1.956632	0.102692	0.052484	1.804142	1.911678	0.107536	0.056252	-0.004844	0.023042
4	3	1.423660	1.871955	0.448295	0.239480	1.441588	1.824512	0.382925	0.209878	0.065370	0.078643
4	4	0.678969	1.447776	0.768807	0.531026	0.685697	1.408517	0.722820	0.513178	0.045987	0.030830
4	5	0.224285	0.683637	0.459352	0.671924	0.258972	0.741184	0.482212	0.650597	-0.022860	0.024279
4	6	0.054360	0.214619	0.160258	0.746709	0.069404	0.272473	0.203070	0.745285	-0.042812	0.117833
4	7	0.009884	0.059303	0.049419	0.833331	0.023062	0.086095	0.063033	0.732133	-0.013614	0.121065
4	8	0.000000	0.016473	0.016473	1.000000	0.009883	0.028626	0.018744	0.654789	-0.002271	0.064486
4	9	0.000000	0.004942	0.004942	1.000000	0.003294	0.010506	0.007212	0.686465	-0.002270	0.186770
4	10	0.000000	0.001647	0.001647	1.000000	0.000000	0.001647	0.001647	1.000000	0.000000	0.000000
5	1	2.216343	2.285863	0.069520	0.030413	2.200346	2.260439	0.060093	0.026585	0.009427	0.072732
5	2	1.933547	2.219748	0.286201	0.128934	1.884598	2.176685	0.292087	0.134189	-0.005886	0.010178
5	3	1.043218	1.920509	0.877292	0.456802	1.065877	1.887908	0.822031	0.435419	0.055261	0.032519
5	4	0.309066	1.056498	0.747432	0.707462	0.346287	1.085526	0.739239	0.680996	0.008193	0.005511
5	5	0.077640	0.339744	0.262104	0.771475	0.084853	0.386037	0.301184	0.780195	-0.039080	0.069378
5	6	0.024710	0.071455	0.046745	0.654188	0.019768	0.089392	0.069624	0.778862	-0.022879	0.196607
5	7	0.004942	0.011127	0.006186	0.555945	0.006589	0.023063	0.016474	0.714304	-0.010288	0.454016
5	8	0.001647	0.005564	0.003917	0.703990	0.001647	0.004941	0.003294	0.666667	0.000623	0.086396
5	9	0.000000	0.001647	0.001647	1.000000	0.001647	0.001648	0.000001	0.000607	0.001646	0.998786
5	10	0.000000	0.000000	0.000000	ND	0.001647	0.001647	0.000000	0.000000	0.000000	ND
6	1	2.438495	2.543273	0.104778	0.041198	2.416585	2.503117	0.086532	0.034570	0.018246	0.095374

6	2	1.787621	2.421875	0.634254	0.261886	1.766917	2.370903	0.603986	0.254749	0.030268	0.024444
6	3	0.615649	1.799253	1.183604	0.657831	0.672197	1.754548	1.082351	0.616883	0.101253	0.044684
6	4	0.134894	0.687892	0.552998	0.803902	0.177941	0.769942	0.592001	0.768890	-0.039003	-0.034064
6	5	0.021414	0.169079	0.147665	0.873349	0.036241	0.182512	0.146272	0.801438	0.001393	0.004739
6	6	0.001648	0.028004	0.026356	0.941151	0.011531	0.051285	0.039754	0.775158	-0.013398	-0.202662
6	7	0.000000	0.004941	0.004941	1.000000	0.000000	0.013178	0.013178	1.000000	-0.008237	-0.454606
6	8	0.000000	0.001647	0.001647	1.000000	0.000000	0.006589	0.006589	1.000000	-0.004942	-0.600049
6	9	0.000000	0.000000	0.000000	ND	0.000000	0.001647	0.001647	1.000000	-0.001647	-1.000000
6	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
7	1	2.580857	2.756005	0.175148	0.063551	2.556325	2.725745	0.169420	0.062155	0.005728	0.016624
7	2	1.586741	2.575100	0.988358	0.383813	1.545873	2.524141	0.978269	0.387565	0.010089	0.005130
7	3	0.382574	1.567232	1.184658	0.755892	0.440254	1.552095	1.111841	0.716349	0.072817	0.031708
7	4	0.074127	0.456447	0.382319	0.837598	0.090199	0.492700	0.402501	0.816929	-0.020182	-0.025715
7	5	0.011530	0.067135	0.055605	0.828256	0.014826	0.109158	0.094332	0.864179	-0.038727	-0.258288
7	6	0.003294	0.013178	0.009884	0.750038	0.001647	0.022036	0.020389	0.925259	-0.010505	-0.347009
7	7	0.000000	0.003294	0.003294	1.000000	0.000000	0.006589	0.006589	1.000000	-0.003295	-0.333401
7	8	0.000000	0.000000	0.000000	ND	0.000000	0.001647	0.001647	1.000000	-0.001647	-1.000000
7	9	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
7	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
8	1	2.661205	2.946918	0.285713	0.096953	2.610573	2.888114	0.277541	0.096098	0.008172	0.014509
8	2	1.284896	2.653742	1.368846	0.515817	1.316869	2.596714	1.279845	0.492871	0.089001	0.033602
8	3	0.263230	1.337690	1.074460	0.803220	0.292072	1.358056	1.065984	0.784934	0.008476	0.003960
8	4	0.041183	0.269787	0.228604	0.847350	0.042830	0.312155	0.269324	0.862789	-0.040720	-0.081779
8	5	0.003294	0.034594	0.031300	0.904781	0.008237	0.065706	0.057469	0.874639	-0.026169	-0.294799
8	6	0.000000	0.003295	0.003295	1.000000	0.000000	0.013178	0.013178	1.000000	-0.009883	-0.599951
8	7	0.000000	0.000000	0.000000	ND	0.000000	0.003295	0.003295	1.000000	-0.003295	-1.000000
8	8	0.000000	0.000000	0.000000	ND	0.000000	0.001648	0.001648	1.000000	-0.001648	-1.000000
8	9	0.000000	0.000000	0.000000	ND	0.000000	0.001647	0.001647	1.000000	-0.001647	-1.000000
8	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND

Table 5.5 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI)
(stock and forex markets of India for the last sub-period May 2003 to March 2007)

Bins	Block	Forex market (Y) to stock market (X) $h_{k,l}$ (X,Y)	H_k (X)	$T_{Y \to X}$ (k,l)	$REA_{Y \to X}$ (k,l)	Stock market (X) to forex market (Y) $h_{k,l}$ (Y,X))	h_k (Y))	$T_{X \to Y}$ (k,l)	$REA_{X \to Y}$ (k,l)	$NIF_{Y \to X}$ (k,l)	NDI(X,Y)
2	1	0.998718	0.999905	0.001188	0.001188	0.998246	0.999839	0.001593	0.001593	-0.000405	-0.145631
2	2	0.997071	0.999042	0.001971	0.001973	0.994336	0.997860	0.003524	0.003532	-0.001553	-0.282621
2	3	0.985894	0.993505	0.007612	0.007662	0.988538	0.992461	0.003923	0.003953	0.003689	0.319809
2	4	0.974468	0.990617	0.016149	0.016302	0.972802	0.985711	0.012909	0.013096	0.003240	0.111501
2	5	0.932920	0.973014	0.040094	0.041206	0.939098	0.972232	0.033134	0.034080	0.006960	0.095046
2	6	0.882766	0.956677	0.073911	0.077258	0.880538	0.958663	0.078125	0.081494	-0.004214	-0.027717
2	7	0.790617	0.915336	0.124719	0.136255	0.761044	0.900529	0.139485	0.154892	-0.014766	-0.055889
2	8	0.571363	0.791907	0.220544	0.278497	0.543236	0.746279	0.203043	0.272074	0.017501	0.041316
2	9	0.348268	0.563651	0.215384	0.382123	0.360257	0.553333	0.193076	0.348933	0.022308	0.054615
2	10	0.187426	0.338935	0.151509	0.447015	0.196513	0.344952	0.148438	0.430315	0.003071	0.010238
3	1	1.558301	1.572199	0.013897	0.008839	1.555432	1.568557	0.013124	0.008367	0.000773	0.028607
3	2	1.529981	1.554766	0.024785	0.015941	1.517263	1.555872	0.038609	0.024815	-0.013824	-0.218065
3	3	1.416970	1.506917	0.089947	0.059689	1.406667	1.520737	0.114070	0.075010	-0.024123	-0.118240
3	4	1.120989	1.445579	0.324589	0.224539	1.104795	1.421334	0.316539	0.222706	0.008050	0.012556
3	5	0.657894	1.134888	0.476994	0.420301	0.650290	1.140090	0.489799	0.429614	-0.012805	-0.013245
3	6	0.292955	0.637890	0.344934	0.540742	0.282454	0.622245	0.339790	0.546071	0.005144	0.007513
3	7	0.117303	0.290328	0.173025	0.595964	0.112866	0.263203	0.150336	0.571179	0.022689	0.070166
3	8	0.031459	0.104228	0.072769	0.698171	0.037856	0.109838	0.071982	0.655347	0.000787	0.005437
3	9	0.010661	0.030654	0.019993	0.652215	0.017058	0.055719	0.038661	0.693857	-0.018668	-0.318273
3	10	0.008529	0.010661	0.002132	0.199981	0.002133	0.027719	0.025585	0.923013	-0.023453	-0.846159
4	1	1.929968	1.969805	0.039837	0.020224	1.949940	1.978639	0.028700	0.014505	0.011137	0.162496
4	2	1.781262	1.912388	0.131126	0.068567	1.791310	1.924358	0.133048	0.069139	-0.001922	-0.007276
4	3	1.266523	1.778060	0.511538	0.287694	1.302453	1.797668	0.495216	0.275477	0.016322	0.016213
4	4	0.585424	1.255620	0.670196	0.533757	0.589131	1.284330	0.695199	0.541293	-0.025003	-0.018312
4	5	0.195667	0.630989	0.435322	0.689904	0.208220	0.611443	0.403223	0.659461	0.032099	0.038279
4	6	0.060501	0.229783	0.169282	0.736704	0.054104	0.166837	0.112733	0.675707	0.056549	0.200518
4	7	0.027719	0.084762	0.057042	0.672967	0.022127	0.061308	0.039181	0.639085	0.017861	0.185621
4	8	0.002132	0.012792	0.010659	0.833255	0.011466	0.030653	0.019187	0.625942	-0.008528	-0.285733
4	9	0.000000	0.004264	0.004264	1.000000	0.002132	0.010662	0.008530	0.800038	-0.004266	-0.333438
4	10	0.000000	0.000000	0.000000	ND	0.000000	0.004265	0.004265	1.000000	-0.004265	1.000000
5	1	2.227202	2.286732	0.059530	0.026033	2.196670	2.279520	0.082850	0.036345	-0.023320	-0.163787
5	2	1.823251	2.182885	0.359633	0.164751	1.788671	2.191849	0.403179	0.183945	-0.043546	-0.057086
5	3	0.903543	1.819709	0.916166	0.503468	0.878464	1.841849	0.963386	0.523054	-0.047220	-0.025123
5	4	0.272639	0.870953	0.598313	0.686964	0.244753	0.895823	0.651071	0.726785	-0.052758	-0.042227
5	5	0.063437	0.278163	0.214725	0.771939	0.049037	0.264988	0.215951	0.814946	-0.001226	-0.002847
5	6	0.014923	0.082626	0.067703	0.819391	0.017056	0.059697	0.042642	0.714307	0.025061	0.227115
5	7	0.008529	0.026390	0.017861	0.676809	0.004264	0.008528	0.004264	0.500000	0.013597	0.614554
5	8	0.004264	0.006396	0.002132	0.333333	0.002132	0.002132	0.000000	0.000000	0.002132	1.000000
5	9	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
5	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
6	1	2.410514	2.527951	0.117437	0.046455	2.371716	2.519821	0.148106	0.058776	-0.030669	-0.115495
6	2	1.643941	2.374695	0.730753	0.307725	1.606833	2.344852	0.738020	0.314741	-0.007267	-

											0.004948
6	3	0.589989	1.628238	1.038249	0.637652	0.554990	1.644509	1.089519	0.662519	-0.051270	- 0.024096
6	4	0.145544	0.597719	0.452175	0.756501	0.146873	0.573668	0.426796	0.743977	0.025379	0.028874
6	5	0.023455	0.130200	0.106746	0.819862	0.027714	0.156202	0.128489	0.822582	-0.021743	- 0.092431
6	6	0.008529	0.026388	0.017859	0.676785	0.012793	0.037856	0.025064	0.662088	-0.007205	- 0.167859
6	7	0.006396	0.008528	0.002131	0.249883	0.002132	0.006397	0.004265	0.666719	-0.002134	- 0.333646
6	8	0.002131	0.002131	0.000000	0.000000	0.000000	0.000000	0.000000	ND	0.000000	ND
6	9	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
6	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
7	1	2.495922	2.732057	0.236136	0.086432	2.497903	2.732966	0.235063	0.086010	0.001073	0.002277
7	2	1.370246	2.465147	1.094901	0.444152	1.393387	2.467608	1.074222	0.435329	0.020679	0.009533
7	3	0.360835	1.404694	1.043859	0.743122	0.340171	1.393476	1.053306	0.755884	-0.009447	- 0.004505
7	4	0.074382	0.366779	0.292397	0.797202	0.061308	0.370278	0.308970	0.834427	-0.016573	- 0.027559
7	5	0.019994	0.082101	0.062107	0.756471	0.017056	0.081820	0.064764	0.791542	-0.002657	- 0.020943
7	6	0.002132	0.019189	0.017056	0.888843	0.002131	0.012792	0.010660	0.833333	0.006396	0.230769
7	7	0.000000	0.002132	0.002132	1.000000	0.000000	0.000000	0.000000	ND	0.002132	1.000000
7	8	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
7	9	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
7	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
8	1	2.486922	2.888985	0.402063	0.139171	2.549659	2.892606	0.342947	0.118560	0.059116	0.079349
8	2	1.099203	2.496565	1.397362	0.559714	1.138975	2.531674	1.392699	0.550110	0.004663	0.001671
8	3	0.232443	1.185045	0.952602	0.803853	0.211400	1.149306	0.937906	0.816063	0.014696	0.007774
8	4	0.041312	0.246943	0.205631	0.832706	0.032785	0.248554	0.215769	0.868097	-0.010138	- 0.024058
8	5	0.006395	0.049318	0.042923	0.870331	0.002132	0.037049	0.034917	0.942455	0.008006	0.102852
8	6	0.002132	0.006395	0.004263	0.666615	0.000000	0.004265	0.004265	1.000000	-0.000002	- 0.000235
8	7	0.000000	0.004265	0.004265	1.000000	0.000000	0.000000	0.000000	ND	0.004265	1.000000
8	8	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
8	9	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND
8	10	0.000000	0.000000	0.000000	ND	0.000000	0.000000	0.000000	ND	0.000000	ND

V(ii) INTERACTIONS BETWEEN STOCK AND COMMODITIES MARKETS OF INDIA

A brief history of the commodity derivatives trading in India and a comparative analysis of the stock and the commodities markets of India are given, followed by the implications of interactions between the two markets. Then the data analysed are presented and the results obtained are interpreted.

The history of organised commodity derivatives market in India dates back to the nineteenth century with the establishment of the first derivatives market in the form of Cotton Trade Association where cotton futures contracts were traded in 1875, barely about a decade after trading in commodity derivatives started in Chicago. Subsequently, derivatives trading started in oilseeds at Mumbai from 1900, in raw jute and jute goods at Kolkata from 1912, in wheat at Hapur from 1913 and in bullion at Mumbai from 1920. Later in 1939, in order to restrict speculative activity in cotton market, options contracts in cotton were prohibited and in 1943, forward trading in commodities including oilseeds, food-grains, spices, vegetable oils, sugar and cloth was prohibited. After independence, the government enacted Forward Contracts (Regulation) Act, 1952 which regulated forward contracts all over India in commodities which are defined as any movable property other than security, currency and actionable claims. The Act prohibited options trading in goods and cash settlement of forward trades, which severely affected the growth of the commodity derivatives market. Further the Act allowed only those associations / exchanges which are recognised by the Government, to organise forward trading in approved commodities and also provided for three-tier regulation - the exchange which organises forward trading in commodities to regulate trading on a day-to-day basis; the Forward Markets Commission to provide regulatory oversight under the powers delegated to it by the Government and the Ministry of Consumer Affairs, Food & Public Distribution, Government of India to be the ultimate regulatory authority. Consequent to repeated defaults on forward contracts during 1960's, forward trading was banned in many commodities. Subsequently, during 1970's and 1980's the Government relaxed forward trading rules for some commodities, however the market did not flourish.

During the liberalisation era, the Government set up K.N. Kabra Committee in 1993 to examine the role of commodity futures trading. The Committee recommended allowing futures trading in 17 commodity groups, strengthening of the Forward Markets Commission, and certain amendments to Forward Contracts (Regulation) Act, particularly allowing options trading in goods and registration of brokers with Forward Markets Commission. The Government accepted most of these recommendations and trading in futures contracts was permitted in all recommended commodities. Further, the SEBI (Securities and Exchange Board of India) appointed Ramamoorthy Committee recommended fruitful cooperation between the commodity derivatives market and the stock market towards convergence of the two markets in terms of infrastructural facilities and regulatory environment. Since 2002, the commodities futures market in India experienced an unprecedented boom with the setting up of multi-commodity exchanges which provide for electronic trading, the rapid increase in the number of commodities in which derivatives trading has been facilitated and the huge growth in the trading volumes. On account of such developments, the commodity derivatives market in India has become as matured as the highly developed stock market in India. In this background, the interactions in terms of price dynamics, if any, between the two markets in India merit qualitative and quantitative analysis.

COMPARISON OF STOCK AND COMMODITIES MARKETS IN INDIA

The most important policy goal in commodity derivatives trading is safeguarding of the interests of producers (particularly farmers), consumers as well as manufacturers and other functionaries in the supply-chain. Unlike securities market where the impact of the price volatility is on the willing participants in the market, the impact of sharp rise or fall in price of commodities is borne by the entire economy. If commodity derivatives markets function well, then some of the core policy goals of addressing volatility of agricultural prices may be addressed in a market-oriented fashion.

There is close resemblance between commodity derivatives and securities derivatives in so far as trade practices and mechanism are concerned. A commodity futures contract is tradable and fungible. Most of the commodity futures contracts are squared off and do not result in delivery. In this case, the users of commodity futures markets are using the contracts for purely financial purposes. Thus, almost all commodity futures contracts are akin to securities.

Though derivatives in commodities resemble securities and financial futures and provide many of the same economic functions, there are some major differences.

- There are actively traded spot markets for financial instruments and prices are generally not discovered in the futures market. Further, futures contracts are often settled from spot prices or spot price indices.
- The spot market of securities is highly organised and effectively regulated by even agencies other than SEBI like Department of Company Affairs whereas the spot market for agricultural commodities is not so organised, though there are many laws to curb free market in agricultural sector.
- The settlement and delivery process in the two markets is different. While financial futures are fully cash settled in India, commodity futures are settled either in cash or physical form. The moot point about cash settlement is that of well-respected and trusted settlement prices. If there is an underlying with a highly fractured spot market, where good data are not available, then it is difficult to construct a well-respected settlement price. In this case, a cash settled contract will not be trusted and a physically settled contract will be preferred.
- The costs involved in dealing with physical goods (or warehouse receipts) are always higher than the costs of moving money. Further, the scale and mode of depositing / warehousing are structurally different.
- There are other supplementary legislations such as Depository Act which make the functioning of stock markets smooth. In case of commodity futures markets such supplemental institutions (like dematerialised warehouse receipts) do not exist which makes the delivery mechanism complex.

- Agricultural commodities have different shelf life, demand-supply factors, and price determination. Precious metals also have different market conditions.
- Unlike the stock market, the factors affecting commodity prices are more complex and commodity-specific.
- Indirect taxation cascades in commodities and income tax treatment also is different. Loss due to speculation is not adjusted in corporate taxation in case of commodity futures but is only carried forward.
- The investor base and the number of registered brokers in stock market are much larger when compared to the commodity derivatives market in India.
- Financial institutions are not permitted to deal in commodity derivatives though they can invest in a restricted way in stock market in India. Banks and financial institutions are considered as stable institutions to provide market-making services, all over the world.
- Both commodity and financial derivatives are traded in the same exchanges world over whereas in India, only financial derivatives are traded in stock exchanges and there are separate commodity derivatives exchanges.
- The regulator of commodity exchanges does not have jurisdiction over spot markets even in non-agricultural commodities, like bullion and other metals. Both the spot and the derivatives segments of stock exchanges are regulated by SEBI.

It is apprehended that the possibilities of interactions are limited in so far as commodity futures trading requires highly specialised knowledge which is different from that required for securities trading. It is also stated that the firms that engage in commodity futures trading differ from the firms that engage in securities trading.

IMPLICATIONS OF INTERACTIONS

The identification and quantification of causal relationships between the stock and the commodity derivatives markets, by analysing the values over time of a nation's stock market index, stock derivatives prices, commodity spot price index and the commodity derivatives index, furthers the understanding of the markets' internal dynamics. The inter-linkage of the two markets has a potential of providing growth impetus to commodity derivatives and open new avenues of business opportunities to the securities market participants thereby deepening and broadening the market.

If causal relationship from a market to the other is not detected, then informational efficiency exists in the second market. If causality is not found in both the directions, then the two markets are independent of each other. Presence or absence of causal relationship has a lot of implications including the following, for all the participants of the markets.

- At present, the government engages in many policy measures which interact with agricultural spot markets. These policies are unaffected by the question regarding the integration of commodity futures and stock markets. Whether the two markets are closely integrated or not, has no impact upon the conduct of policies such as public procurement, support prices, etc. To the extent that interactions between commodity derivatives and stock markets help strengthen price discovery on the commodity derivatives markets, this will facilitate the design of public policy. If shortages or gluts are expected to take place on a future date, this will be revealed in the futures price well ahead of time. This information will help the policy-makers to respond pro-actively, if desired.

- If there is feedback in both the directions, then investors may predict the behaviour of one market using information on the other market. Since an impulse in a market is reflected quickly in the other market, policy intervention becomes more effective in the desired direction within reasonable time horizon.
- If the markets are not related, investors may reduce risk exposure by diversifying their portfolios across the markets.

PRESENTATION OF DATA

The interactions among the stock, the stock derivatives, the commodities and the commodities derivatives markets may be studied by measuring the extent of information exchange among a set of simultaneously recorded variables – value of stock index, price of futures contract on stock index, value of commodities index and value of commodities futures index - over a period of time. As seen in the previous chapter, various methods have been used by researchers for the analysis of information transmission between two time series. Also, among the different entropic measures, transfer entropy is suitable to identify directional information. The symbolic encoding method is used to compute transfer entropy between the stock market and the commodities market in India.

National Stock Exchange of India (NSEIL) being the leading stock exchange of India, the 50 stock index viz. Nifty of the Exchange is taken as the representative of the stock market and the price of the near month futures contract on the Nifty is taken as the representative of the stock derivatives market. National Commodity & Derivatives Exchange Ltd. (NCDEX), a leading commodity derivatives exchange of India has launched two indices – NCDEXAGRI and FUTEXAGRI. NCDEXAGRI is an equally weighted, composite index of spot prices of important agricultural commodities in every sub-sector and is updated three times a day with price data received from various mandis and spot markets. FUTEXAGRI is constructed on the basis of online prices of the nearest month expiry futures contracts traded in NCDEX, for the same basket of commodities in NCDEXAGRI. It is proposed to compute the transfer entropy among Nifty, Nifty futures contract, NCDEXAGRI and FUTEXAGRI so that informational transfer may be analysed between any two of the markets. Due to high liquidity in these markets and the incredibly fast information transport, enabled by digital communication network, between the two markets which have a large number of closely connected participants, there is a need to look at daily data. The use of lower frequency data such as weekly or monthly observations may not be adequate to capture the dynamics of the fast-moving stock prices, stock derivatives prices and commodity derivatives prices.

Data on the stock index Nifty and Nifty futures contract are available in the web-site of NSEIL from end 1995 and daily values of NCDEXAGRI and FUTEXAGRI are available in the web-site of NCDEX from June 2005. Hence the data for the period from June 2005 to September 2007 has been considered for the study. Thus four time series, each with

575 data points were obtained for the variables viz. the stock derivatives price – near month Nifty futures contract (W), the stock index - Nifty (X), the commodities spot index - NCDEXAGRI (Y) and the commodities derivatives index – FUTEXAGRI (Z). These price series are transformed to log returns series to carry out further analysis. The summary statistics of the resultant time series are given below.

	Nifty	Near month Nifty futures	NCDEXAGRI	FUTEXAGRI
Minimum	-0.07006	-0.07924	-0.05684	-0.41198
1st Quartile	-0.00495	-0.00523	-0.00219	-0.00370
Mean	0.00156	0.00151	0.00026	0.00028
Median	0.00248	0.00244	0.00037	-0.00003
3rd Quartile	0.01030	0.01057	0.00259	0.00419
Maximum	0.06130	0.06235	0.02335	0.40695
Number of data points	574	574	574	574
Standard Deviation	0.01471	0.01617	0.00573	0.02733
Skewness	-0.68525	-0.66764	-3.37063	0.52891
Kurtosis	2.65870	2.80750	33.23873	180.60740

EMPIRICAL RESULTS

The symbolic encoding method partitions the range of the data set into disjoint bins and assigns a symbol to each bin, with marginal equal probability for every symbol. The transfer entropy value depends on the number of bins (S) into which the data set is partitioned and also on the block length k chosen for the transferee variable and the block length l for the transferor variable (however, l is chosen to be 1 generally). Hence, for example, transfer entropy $T_{Z \to Y}$ from commodity derivatives (Z) to commodity spot (Y) is computed for the number of bins S ranging from 2 to 8, the block length k of Y ranging from 1 to 10 and the block length l of Z equal to 1. Further, transfer entropy $T_{Y \to Z}$ from commodity spot (Y) to commodity derivatives (Z) is computed for the number of bins ranging from 2 to 8, the block length for Z ranging from 1 to 10 and the block length for Y equal to 1. Similarly, transfer entropy between any two markets is computed for both the directions. Such transfer entropy values for the period from June 2005 to September 2007 between commodity spot and commodity derivatives markets are presented in table 5.6, between stock and commodity spot markets are given in table 5.7, between stock and commodity derivatives markets are given in table 5.8, between stock derivatives and commodity spot markets are given in table 5.9 and between stock derivatives and commodity derivatives markets are given in table 5.10.

The transfer entropy in all the cases behaves reasonably for partitions S = 4, 5, 6, 7, 8 of the data analysed and for block length of the transferee series k ≥ 3. Further, in order to consider appropriate values of k, the mutual information of the time series containing the values of near month Nifty futures contract (W), Nifty (X), NCDEXAGRI (Y) and FUTEXAGRI (Z), for delays ranging from a day to 20 days are computed and given in table 5.11. It may be observed that the first minimum has occurred for k = 2, 3 and 4 for these series. Hence, meaningful results may be obtained from transfer entropy values computed for partitions S = 4, 5, 6, 7, 8 and block length of the transferee series k ≥ 4. For interpreting the transfer entropy values, measures – net information flow, relative explanation added and normalised directionality index – which have been illustrated in the previous chapter have been computed and given in the respective tables.

From the transfer entropy values for S $\geq$ 4 and k = 4, 5, 6 i.e. when upto 6 past values of the transferee series are considered,

- a flow of information from day t of anyone market to day t+1 of the other markets is observed, suggesting interactions among the markets at a time scale of a day or less
- the information flows between any two markets in both the directions are more or less at the same level, and hence in such cases the NIF values are not significant
- also, the REA in such cases either increases or remains at high levels thereby implying that whatever information flown from one market towards the prediction of the next price in the other market cannot be compensated by the inclusion of more number of past values realised by the transferee market
- further, the absolute value of NDI has been generally less than 0.33 except in a few cases, indicating that the feedbacks in both the directions between any two markets do not vary much.

If the time series are partitioned into 4 or more bins and when 7 or more past values of the transferee market are considered (i.e. k $\geq$ 7), even the entropy rates (given lagged values of the same market only) and the conditional entropy rates (given lagged values of both the same and the transferor markets) approach or become zero in respect of all the markets and hence the transfer entropy between any two markets approaches or becomes zero. Hence, price data beyond 6 days in any market do not have significant informational value in the same market nor in any other market.

CONCLUSION

Transfer entropy values among Nifty index of stock market, Nifty futures contract of stock derivatives market, NCDEXAGRI index of commodities spot market and FUTEXAGRI index of commodities derivatives market of India, have been computed for the period from June 2005 to September 2007 and the results obtained across the markets are found to be more or less consistent and reiterate that

- there exist interactions between any two markets, with upto 6 days old price information and the feedback between any two markets is almost at the same level in both the directions
- information generation in the markets tend to zero if 7 or more past values are considered.

Table 5.6 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI) (commodity spot – Y and commodity derivatives - Z markets of India)

Bins	Block	FUTEXAGRI(Z) to NCDEXAGRI(Y)				NCDEXAGRI(Y) to FUTEXAGRI(Z)					
		h(Y,Z)	h(Y)	T(Z->Y)	REA(Z->Y)	h(Z,Y)	h(Z)	T(Y->Z)	REA(Y->Z)	NIF(Z->Y)	NDI(Y,Z)
2	1	0.964796	0.991233	0.026437	0.026670823	0.995021	0.996298	0.001276	0.001280741	0.025161	0.907913254
2	2	0.957691	0.988932	0.031241	0.031590645	0.993717	0.996026	0.00231	0.002319217	0.028931	0.862299186
2	3	0.953114	0.986098	0.032984	0.033449008	0.986257	0.995399	0.009141	0.009183252	0.023843	0.566005935
2	4	0.93705	0.979216	0.042166	0.043060979	0.976222	0.989756	0.013534	0.013674077	0.028632	0.514039497
2	5	0.896833	0.955616	0.058784	0.061514248	0.948712	0.986449	0.037737	0.038255399	0.021047	0.218056174
2	6	0.807908	0.911569	0.103662	0.113718216	0.856285	0.955284	0.098999	0.103633056	0.004663	0.023008867
2	7	0.617054	0.803198	0.186143	0.23175232	0.687603	0.869514	0.181911	0.209209972	0.004232	0.011498313
2	8	0.394818	0.581538	0.18672	0.32107962	0.43709	0.644433	0.207343	0.321744852	-0.020623	-0.052334271
2	9	0.238947	0.398074	0.159127	0.399742259	0.228355	0.361839	0.133484	0.368904402	0.025643	0.08763512
2	10	0.148312	0.270216	0.121904	0.451135388	0.117491	0.179582	0.062091	0.345752915	0.059813	0.325079486
3	1	1.507158	1.552344	0.045185	0.029107595	1.568974	1.581231	0.012256	0.007750923	0.032929	0.573266482
3	2	1.457165	1.523794	0.066629	0.043725727	1.527417	1.571639	0.044222	0.028137505	0.022407	0.202136201
3	3	1.279649	1.457905	0.178256	0.122268598	1.369934	1.511138	0.141205	0.093442823	0.037051	0.115979728
3	4	0.874069	1.272292	0.398222	0.312995759	0.960127	1.360366	0.400239	0.294214204	-0.002017	-0.00252611
3	5	0.466171	0.929889	0.463718	0.498681025	0.500091	0.866797	0.366707	0.42305984	0.097011	0.116820905
3	6	0.162721	0.47675	0.31403	0.65868904	0.218588	0.424867	0.206279	0.48551429	0.107751	0.207090402
3	7	0.043891	0.221264	0.177373	0.801635151	0.077144	0.148067	0.070924	0.478999372	0.106449	0.428716416
3	8	0.014185	0.08999	0.075805	0.842371375	0.03546	0.056738	0.021277	0.375004406	0.054528	0.561669516
3	9	0.003546	0.028368	0.024822	0.875	0.014185	0.021276	0.007092	0.333333333	0.01773	0.555555556
3	10	0	0.014185	0.014185	1	0.003546	0.003546	0	0	0.014185	1
4	1	1.892944	1.96928	0.076336	0.038763406	1.943596	1.988591	0.044995	0.022626573	0.031341	0.258309913
4	2	1.675602	1.918674	0.243072	0.126687494	1.759322	1.947945	0.188623	0.096831789	0.054449	0.126128401
4	3	1.018655	1.685279	0.666625	0.39555765	1.103738	1.723981	0.620244	0.359774267	0.046381	0.036041742
4	4	0.420382	1.010551	0.590169	0.584007141	0.387306	0.998184	0.610878	0.611989373	-0.020709	-0.017242456
4	5	0.126791	0.398413	0.271622	0.681759882	0.10685	0.383113	0.276263	0.721100563	-0.004641	-0.008470756
4	6	0.042555	0.114815	0.07226	0.629360275	0.024823	0.086445	0.061622	0.712846318	0.010638	0.07945803
4	7	0.010638	0.024822	0.014184	0.571428571	0	0.017731	0.017731	1	-0.003547	-0.111138963
4	8	0.003547	0.007092	0.003546	0.5	0	0	0	NA	0.003546	1
4	9	0.003547	0.007092	0.003546	0.5	0	0	0	NA	0.003546	1
4	10	0	0	0	NA	0	0	0	NA	0	NA
5	1	2.142648	2.28875	0.146102	0.063834844	2.19407	2.300939	0.106869	0.046445821	0.039233	0.155088923
5	2	1.543819	2.149866	0.606047	0.281899895	1.622654	2.185847	0.563193	0.257654355	0.042854	0.036651158
5	3	0.661267	1.555506	0.894238	0.5748856	0.691087	1.603141	0.912054	0.568916895	-0.017816	-0.0098633
5	4	0.140974	0.658754	0.51778	0.785999022	0.146727	0.546949	0.400223	0.731737328	0.117557	0.128057316
5	5	0.028369	0.139636	0.111267	0.796836059	0.024822	0.156496	0.131674	0.841388917	-0.020407	-0.083999819
5	6	0	0.024822	0.024822	1	0	0.024823	0.024823	1	-0.000001	-0.0000201
5	7	0	0.003547	0.003547	1	0	0.007092	0.007092	1	-0.003545	-0.333208008
5	8	0	0	0	NA	0	0	0	NA	0	NA
5	9	0	0	0	NA	0	0	0	NA	0	NA
5	10	0	0	0	NA	0	0	0	NA	0	NA
6	1	2.257476	2.526744	0.269269	0.106567583	2.334964	2.551707	0.216743	0.084940395	0.052526	0.108075521
6	2	1.365308	2.270288	0.904981	0.39861947	1.419446	2.37573	0.956285	0.402522593	-0.051304	-0.027564034
6	3	0.401962	1.346492	0.94453	0.701474647	0.407536	1.280855	0.873319	0.681825031	0.071211	0.039173221
6	4	0.089991	0.33474	0.244749	0.731161498	0.073599	0.284623	0.211024	0.741415838	0.033725	0.073995169
6	5	0.017731	0.070922	0.053191	0.74999295	0.014184	0.053191	0.039007	0.733338347	0.014184	0.153842817
6	6	0.003547	0.007092	0.003546	0.5	0.003547	0.010638	0.007092	0.666666667	-0.003546	-0.333333333
6	7	0	0	0	NA	0	0.003547	0.003547	1	-0.003547	-1
6	8	0	0	0	NA	0	0	0	NA	0	NA
6	9	0	0	0	NA	0	0	0	NA	0	NA
6	10	0	0	0	NA	0	0	0	NA	0	NA
7	1	2.356776	2.741844	0.385068	0.14044125	2.363341	2.767436	0.404095	0.14601783	-0.019027	-0.024110355
7	2	1.116447	2.351417	1.234969	0.525202038	1.14999	2.318683	1.168694	0.50403354	0.066275	0.027572501
7	3	0.239395	0.998057	0.758662	0.76013895	0.279518	1.009968	0.73045	0.723240736	0.028212	0.018945519

7	4	0.039007	0.208819	0.169812	0.813201864	0.03546	0.193296	0.157836	0.816550782	0.011976	0.036551421
7	5	0.010639	0.031915	0.021276	0.666645778	0.007092	0.042554	0.035461	0.833317667	-0.014185	-0.250013219
7	6	0	0.003547	0.003547	1	0	0	0	NA	0.003547	1
7	7	0	0	0	NA	0	0	0	NA	0	NA
7	8	0	0	0	NA	0	0	0	NA	0	NA
7	9	0	0	0	NA	0	0	0	NA	0	NA
7	10	0	0	0	NA	0	0	0	NA	0	NA
8	1	2.327146	2.940391	0.613245	0.208558998	2.334021	2.930249	0.596229	0.203473834	0.017016	0.014068926
8	2	0.890742	2.328055	1.437313	0.617387905	0.898853	2.324353	1.4255	0.613288945	0.011813	0.004126361
8	3	0.14539	0.739737	0.594347	0.803457175	0.16272	0.743926	0.581206	0.781268567	0.013141	0.011178569
8	4	0.024822	0.104175	0.079352	0.761718263	0.031915	0.116153	0.084238	0.725233098	-0.004886	-0.029867351
8	5	0.003547	0.024823	0.021276	0.857108327	0.007092	0.01773	0.010637	0.599943598	0.010639	0.333375114
8	6	0	0	0	NA	0	0.003547	0.003547	1	-0.003547	-1
8	7	0	0	0	NA	0	0	0	NA	0	NA
8	8	0	0	0	NA	0	0	0	NA	0	NA
8	9	0	0	0	NA	0	0	0	NA	0	NA
8	10	0	0	0	NA	0	0	0	NA	0	NA

Table 5.7 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI)
(stock - X and commodity spot – Y markets of India)

Bins	Block	NCDEXAGRI (Y) to NIFTY(X)				NIFTY(X) to NCDEXAGRI(Y)					
		h(X,Y)	h(X)	T(Y->X)	REA(Y->X)	h(Y,X)	h(Y)	T(X->Y)	REA(X->Y)	NIF(Y->X)	NDI(X,Y)
2	1	0.999585	0.999846	0.000261	0.00026104	0.986564	0.991233	0.004669	0.004710295	-0.004408	-0.894117647
2	2	0.998124	0.999359	0.001235	0.001235792	0.983084	0.988932	0.005848	0.00591345	-0.004613	-0.651277707
2	3	0.990292	0.998531	0.008238	0.008250119	0.977217	0.986098	0.008881	0.009006204	-0.000643	-0.037560605
2	4	0.966664	0.989682	0.023018	0.023257976	0.956574	0.979216	0.022641	0.023121558	0.000377	0.008256861
2	5	0.923974	0.970726	0.046753	0.048162921	0.915256	0.955616	0.040361	0.042235584	0.006392	0.073375118
2	6	0.830558	0.938004	0.107447	0.114548552	0.813894	0.911569	0.097675	0.107150419	0.009772	0.047639941
2	7	0.640989	0.832155	0.191166	0.22972403	0.597772	0.803198	0.205426	0.255760099	-0.01426	-0.035956348
2	8	0.354747	0.61525	0.260503	0.423409996	0.368768	0.581538	0.21277	0.365874629	0.047733	0.100857222
2	9	0.178712	0.377139	0.198427	0.526137578	0.247894	0.398074	0.15018	0.377266538	0.048247	0.138399401
2	10	0.094875	0.192894	0.098019	0.508149554	0.154757	0.270216	0.115458	0.427280398	-0.017439	-0.081690299
3	1	1.563854	1.579512	0.015658	0.009913188	1.53408	1.552344	0.018263	0.011764789	-0.002605	-0.076796085
3	2	1.500995	1.547676	0.046682	0.030162644	1.473953	1.523794	0.049841	0.032708489	-0.003159	-0.032727951
3	3	1.323054	1.493361	0.170306	0.114042084	1.293003	1.457905	0.164902	0.113108879	0.005404	0.016121334
3	4	0.899231	1.318121	0.41889	0.317793283	0.882579	1.272292	0.389713	0.306307829	0.029177	0.03608322
3	5	0.447949	0.887578	0.439629	0.495313088	0.43568	0.929889	0.494209	0.531470961	-0.05458	-0.058446968
3	6	0.175567	0.444979	0.269412	0.605448796	0.143649	0.47675	0.333101	0.698691138	-0.063689	-0.105705603
3	7	0.070921	0.181789	0.110868	0.609871884	0.052321	0.221264	0.168942	0.763531347	-0.058074	-0.207547979
3	8	0.021276	0.070922	0.049645	0.69999436	0.014185	0.08999	0.075805	0.842371375	-0.02616	-0.208529295
3	9	0.007092	0.021277	0.014185	0.666682333	0.003546	0.028368	0.024822	0.875	-0.010637	-0.272694645
3	10	0.003547	0.007092	0.003546	0.5	0	0.014185	0.014185	1	-0.010639	-0.600022559
4	1	1.926498	1.977431	0.050932	0.025756651	1.915572	1.96928	0.053708	0.027272912	-0.002776	-0.026529052
4	2	1.662118	1.912159	0.250041	0.130763707	1.682228	1.918674	0.236445	0.123233546	0.013596	0.027947361
4	3	0.988593	1.636838	0.648245	0.396034916	1.026938	1.685279	0.658341	0.390642143	-0.010096	-0.007727008
4	4	0.370916	1.014262	0.643346	0.634299619	0.406598	1.010551	0.603953	0.597647224	0.039393	0.031582644
4	5	0.106853	0.434276	0.327423	0.753951404	0.112605	0.398413	0.285808	0.71736615	0.041615	0.067861866
4	6	0.028369	0.140974	0.112605	0.798764311	0.046101	0.114815	0.068714	0.598475809	0.043891	0.24206509
4	7	0.010638	0.024822	0.014184	0.571428571	0.007092	0.024822	0.01773	0.714285714	-0.003546	-0.111111111
4	8	0.003547	0.010639	0.007092	0.666604004	0	0.007092	0.007092	1	0	0
4	9	0	0	0	NA	0	0.007092	0.007092	1	-0.007092	-1
4	10	0	0	0	NA	0	0	0	NA	0	NA
5	1	2.192635	2.272418	0.079784	0.035109738	2.175169	2.28875	0.11358	0.049625341	-0.033796	-0.174779173
5	2	1.580817	2.16092	0.580103	0.268451863	1.521086	2.149866	0.62878	0.292474043	-0.048677	-0.040266097
5	3	0.608234	1.569467	0.961232	0.612457605	0.591488	1.555506	0.964018	0.6197456	-0.002786	-0.001447085
5	4	0.156965	0.608822	0.451857	0.742182444	0.157367	0.658754	0.501388	0.761115682	-0.049531	-0.051960409
5	5	0.024822	0.147842	0.12302	0.832104544	0.031915	0.139636	0.107721	0.771441462	0.015299	0.066303778
5	6	0.003546	0.052322	0.048777	0.932246474	0.003546	0.024822	0.021276	0.857142857	0.027501	0.392574194
5	7	0.003547	0.014185	0.010638	0.749947127	0	0.003547	0.003547	1	0.007091	0.499894254
5	8	0	0	0	NA	0	0	0	NA	0	NA
5	9	0	0	0	NA	0	0	0	NA	0	NA
5	10	0	0	0	NA	0	0	0	NA	0	NA
6	1	2.287804	2.500175	0.212371	0.084942454	2.270616	2.526744	0.256128	0.101366818	-0.043757	-0.093398278
6	2	1.296995	2.288172	0.991177	0.433174167	1.241806	2.270288	1.028483	0.453018736	-0.037306	-0.018471426
6	3	0.336032	1.267249	0.931217	0.734833486	0.324971	1.346492	1.021521	0.758653598	-0.090304	-0.046244811

6	4	0.056738	0.36795	0.311213	0.845802419	0.063829	0.33474	0.27091	0.809314692	0.040303	0.069234509
6	5	0.007092	0.106852	0.099759	0.933618463	0.014184	0.070922	0.056738	0.80000564	0.043021	0.274899838
6	6	0.003546	0.014184	0.010638	0.75	0	0.007092	0.007092	1	0.003546	0.2
6	7	0	0.003547	0.003547	1	0	0	0	NA	0.003547	1
6	8	0	0	0	NA	0	0	0	NA	0	NA
6	9	0	0	0	NA	0	0	0	NA	0	NA
6	10	0	0	0	NA	0	0	0	NA	0	NA
7	1	2.343438	2.711665	0.368227	0.135793691	2.335298	2.741844	0.406546	0.148274665	-0.038319	-0.049458357
7	2	0.99162	2.286609	1.294989	0.566336002	0.983317	2.351417	1.368099	0.581818963	-0.07311	-0.027453092
7	3	0.237189	1.012999	0.77581	0.765854655	0.209287	0.998057	0.788771	0.790306566	-0.012961	-0.008284007
7	4	0.039007	0.250973	0.211966	0.844576907	0.028368	0.208819	0.180451	0.864150293	0.031515	0.080309976
7	5	0.003546	0.059414	0.055868	0.940317097	0	0.031915	0.031915	1	0.023953	0.272866045
7	6	0	0.014185	0.014185	1	0	0.003547	0.003547	1	0.010638	0.599932326
7	7	0	0	0	NA	0	0	0	NA	0	NA
7	8	0	0	0	NA	0	0	0	NA	0	NA
7	9	0	0	0	NA	0	0	0	NA	0	NA
7	10	0	0	0	NA	0	0	0	NA	0	NA
8	1	2.292738	2.881165	0.588427	0.204232316	2.312346	2.940391	0.628046	0.213592682	-0.039619	-0.032568746
8	2	0.780281	2.240476	1.460195	0.651734274	0.721894	2.328055	1.606161	0.689915401	-0.145966	-0.047602431
8	3	0.160042	0.825438	0.665397	0.806113845	0.125451	0.739737	0.614285	0.830409997	0.051112	0.039941173
8	4	0.039006	0.158304	0.119298	0.753600667	0.024822	0.104175	0.079352	0.761718263	0.039946	0.20108734
8	5	0.007092	0.031915	0.024822	0.777753407	0.003547	0.024823	0.021276	0.857108327	0.003546	0.076923077
8	6	0	0	0	NA	0	0	0	NA	0	NA
8	7	0	0	0	NA	0	0	0	NA	0	NA
8	8	0	0	0	NA	0	0	0	NA	0	NA
8	9	0	0	0	NA	0	0	0	NA	0	NA
8	10	0	0	0	NA	0	0	0	NA	0	NA

Table 5.8 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI)
(stock - X and commodity derivatives – Z markets of India)

Bins	Block	FUTEXAGRI(Z) to NIFTY(X) h(X,Z)	h(X)	T(Z->X)	REA(Z->X)	NIFTY(X) to FUTEXAGRI (Z) h(Z,X)	h(Z)	T(X->Z)	REA(X->Z)	NIF(Z->X)	NDI(X,Z)
2	1	0.997228	0.999846	0.002618	0.002618403	0.991442	0.996298	0.004856	0.004874044	-0.002238	-0.299438052
2	2	0.992949	0.999359	0.006411	0.006415112	0.989496	0.996026	0.00653	0.006556054	-0.000119	-0.00919558
2	3	0.981955	0.998531	0.016576	0.016600386	0.98562	0.995399	0.009779	0.009824201	0.006797	0.257901726
2	4	0.957798	0.989682	0.031884	0.032216409	0.971564	0.989756	0.018192	0.018380288	0.013692	0.273424395
2	5	0.916538	0.970726	0.054189	0.055823167	0.948591	0.986449	0.037858	0.038378061	0.016331	0.177420231
2	6	0.815618	0.938004	0.122387	0.130475989	0.855233	0.955284	0.100051	0.104734299	0.022336	0.100414498
2	7	0.619467	0.832155	0.212688	0.255587	0.675426	0.869514	0.194089	0.223215497	0.018599	0.045722841
2	8	0.376094	0.61525	0.239156	0.388713531	0.410683	0.644433	0.23375	0.362721959	0.005406	0.011431447
2	9	0.204877	0.377139	0.172262	0.456759974	0.199518	0.361839	0.162321	0.448600068	0.009941	0.029711611
2	10	0.109529	0.192894	0.083364	0.432175184	0.075808	0.179582	0.103774	0.577864151	-0.02041	-0.109063899
3	1	1.568259	1.579512	0.011253	0.007124352	1.565479	1.581231	0.015751	0.009961226	-0.004498	-0.166567916
3	2	1.5223	1.547676	0.025377	0.016396843	1.536649	1.571639	0.03499	0.022263382	-0.009613	-0.159242633
3	3	1.357121	1.493361	0.136239	0.091229783	1.364861	1.511138	0.146278	0.096799895	-0.010039	-0.035534145
3	4	0.891093	1.318121	0.427029	0.323967982	0.912951	1.360366	0.447415	0.328893107	-0.020386	-0.0233131
3	5	0.468936	0.887578	0.418642	0.471667842	0.425045	0.866797	0.441752	0.509637205	-0.02311	-0.026859787
3	6	0.204405	0.444979	0.240574	0.540641244	0.170681	0.424867	0.254186	0.59827193	-0.013612	-0.027512329
3	7	0.088653	0.181789	0.093137	0.51233573	0.067376	0.148067	0.080691	0.544962753	0.012446	0.071599512
3	8	0.042553	0.070922	0.028369	0.40000282	0.017731	0.056738	0.039007	0.687493391	-0.010638	-0.15789005
3	9	0.003547	0.021277	0.017731	0.833341167	0.007092	0.021276	0.014184	0.666666667	0.003547	0.111138963
3	10	0	0.007092	0.007092	1	0	0.003546	0.003546	1	0.003546	0.333333333
4	1	1.939575	1.977431	0.037855	0.019143525	1.942383	1.988591	0.046208	0.023236553	-0.008353	-0.099365952
4	2	1.701593	1.912159	0.210566	0.110119504	1.718065	1.947945	0.229879	0.118011032	-0.019313	-0.043848835
4	3	1.011594	1.636838	0.625244	0.381982823	0.993785	1.723981	0.730196	0.423552232	-0.104952	-0.077430207
4	4	0.405329	1.014262	0.608933	0.600370516	0.322364	0.998184	0.67582	0.677049522	-0.066887	-0.052062147
4	5	0.104175	0.434276	0.330101	0.760117989	0.08069	0.383113	0.302423	0.789383289	0.027678	0.043758023
4	6	0.0461	0.140974	0.094874	0.672989346	0.024823	0.086445	0.061622	0.712846318	0.033252	0.212478274
4	7	0.003547	0.024822	0.021276	0.857142857	0.003547	0.017731	0.014184	0.799954881	0.007092	0.2
4	8	0.003547	0.010639	0.007092	0.666604004	0	0	0	NA	0.007092	1
4	9	0	0	0	NA	0	0	0	NA	0	NA
4	10	0	0	0	NA	0	0	0	NA	0	NA
5	1	2.17804	2.272418	0.094378	0.041531972	2.185691	2.300939	0.115247	0.050086943	-0.020869	-0.099553965
5	2	1.573561	2.16092	0.587359	0.271809692	1.569372	2.185847	0.616475	0.282030261	-0.029116	-0.024186059
5	3	0.600539	1.569467	0.968927	0.617360543	0.554512	1.603141	1.048629	0.654109027	-0.079702	-0.039504232
5	4	0.13522	0.608822	0.473602	0.777898959	0.104176	0.546949	0.442774	0.809534344	0.030828	0.033641213
5	5	0.031915	0.147842	0.115928	0.784134414	0.031915	0.156496	0.124581	0.796065075	-0.008653	-0.035977864
5	6	0.010638	0.052322	0.041684	0.796682084	-0.000001	0.024823	0.024824	1.000040285	0.01686	0.253503338
5	7	0	0.014185	0.014185	1	0	0.007092	0.007092	1	0.007093	0.333364666
5	8	0	0	0	NA	0	0	0	NA	0	NA
5	9	0	0	0	NA	0	0	0	NA	0	NA
5	10	0	0	0	NA	0	0	0	NA	0	NA
6	1	2.266243	2.500175	0.233932	0.09356625	2.332613	2.551707	0.219094	0.085861739	0.014838	0.032753087
6	2	1.293224	2.288172	0.994948	0.434822207	1.314047	2.37573	1.061683	0.446887062	-0.066735	-0.032448699
6	3	0.343639	1.267249	0.923609	0.72882993	0.318525	1.280855	0.962329	0.751317675	-0.03872	-0.020530898
6	4	0.068715	0.36795	0.299235	0.813249083	0.061623	0.284623	0.223001	0.783496063	0.076234	0.145976149
6	5	0.014185	0.106852	0.092667	0.867246285	0.003547	0.053191	0.049644	0.933315787	0.043023	0.302316757
6	6	0.003547	0.014184	0.010637	0.749929498	0.003547	0.010638	0.007092	0.666666667	0.003545	0.199954876

6	7	0	0.003547	0.003547	1	0	0.003547	0.003547	1	0	0
6	8	0	0	0	NA	0	0	0	NA	0	NA
6	9	0	0	0	NA	0	0	0	NA	0	NA
6	10	0	0	0	NA	0	0	0	NA	0	NA
7	1	2.335739	2.711665	0.375926	0.138632906	2.361566	2.767436	0.405869	0.146658857	-0.029943	-0.038300322
7	2	0.983408	2.286609	1.303201	0.569927347	0.922678	2.318683	1.396005	0.602068071	-0.092804	-0.034381963
7	3	0.210156	1.012999	0.802843	0.792540763	0.176905	1.009968	0.833063	0.824840985	-0.03022	-0.018472944
7	4	0.03546	0.250973	0.215512	0.858705917	0.039007	0.193296	0.154289	0.798200687	0.061223	0.16555661
7	5	0.007092	0.059414	0.052321	0.880617363	0.010638	0.042554	0.031916	0.75001175	0.020405	0.242233223
7	6	0	0.014185	0.014185	1	0	0	0	NA	0.014185	1
7	7	0	0	0	NA	0	0	0	NA	0	NA
7	8	0	0	0	NA	0	0	0	NA	0	NA
7	9	0	0	0	NA	0	0	0	NA	0	NA
7	10	0	0	0	NA	0	0	0	NA	0	NA
8	1	2.289794	2.881165	0.591371	0.205254125	2.327457	2.930249	0.602792	0.205713576	-0.011421	-0.009564021
8	2	0.716939	2.240476	1.523537	0.680005945	0.726304	2.324353	1.598049	0.687524227	-0.074512	-0.023869917
8	3	0.121036	0.825438	0.704403	0.853368757	0.130335	0.743926	0.613591	0.824801123	0.090812	0.068901679
8	4	0.010638	0.158304	0.147666	0.932800182	0.014185	0.116153	0.101968	0.877876594	0.045698	0.18306
8	5	0.003547	0.031915	0.028368	0.888861037	0.003546	0.01773	0.014184	0.8	0.014184	0.333333333
8	6	0	0	0	NA	0	0.003547	0.003547	1	-0.003547	-1
8	7	0	0	0	NA	0	0	0	NA	0	NA
8	8	0	0	0	NA	0	0	0	NA	0	NA
8	9	0	0	0	NA	0	0	0	NA	0	NA
8	10	0	0	0	NA	0	0	0	NA	0	NA

Table 5.9 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI) (stock derivatives - W and commodity spot – Y markets of India)

Bins	Block	NCDEXAGRI(Y) to NIFTYFUTURES(W)				NIFTYFUTURES(W) to NCDEXAGRI(Y)					
		h(W,Y)	h(W)	T(Y->W)	REA(Y->W)	h(Y,W)	h(Y)	T(W->Y)	REA(W->Y)	NIF(Y->W)	NDI(W,Y)
2	1	0.998617	0.999927	0.00131	0.001310096	0.985202	0.991233	0.006031	0.006084341	-0.004774246	-0.645653719
2	2	0.993279	0.995009	0.00173	0.001738678	0.981162	0.988932	0.00777	0.007856961	-0.006118283	-0.637610832
2	3	0.9782	0.99004	0.011839	0.011958103	0.975436	0.986098	0.010662	0.010812313	0.00114579	0.050319237
2	4	0.957498	0.984083	0.026585	0.027014998	0.955416	0.979216	0.0238	0.024305158	0.002709839	0.052802632
2	5	0.915452	0.964795	0.049343	0.051143507	0.911662	0.955616	0.043954	0.045995463	0.005148045	0.052996697
2	6	0.7994	0.913338	0.113938	0.124748998	0.811278	0.911569	0.100291	0.110020196	0.014728802	0.06273737
2	7	0.636474	0.828501	0.192027	0.231776425	0.597195	0.803198	0.206003	0.256478477	-0.024702052	-0.050592533
2	8	0.391212	0.673079	0.281867	0.418772536	0.376552	0.581538	0.204987	0.352491153	0.066281384	0.08593868
2	9	0.191087	0.40533	0.214243	0.52856438	0.245216	0.398074	0.152858	0.383993931	0.144570449	0.158423245
2	10	0.102837	0.228356	0.12552	0.549668062	0.156965	0.270216	0.113251	0.419112858	0.130555204	0.134762361
3	1	1.56078	1.574393	0.013614	0.008647142	1.533412	1.552344	0.018932	0.01219575	-0.003548608	-0.170255079
3	2	1.502048	1.54285	0.040802	0.026445863	1.478738	1.523794	0.045056	0.029568301	-0.003122438	-0.055743723
3	3	1.310653	1.482014	0.171361	0.115627113	1.308904	1.457905	0.149001	0.102202133	0.01342498	0.061630753
3	4	0.864838	1.30168	0.436842	0.335598611	0.897192	1.272292	0.3751	0.294822258	0.040776353	0.06468116
3	5	0.436081	0.881298	0.445217	0.505183264	0.433721	0.929889	0.496169	0.533578739	-0.028395475	-0.027335882
3	6	0.182656	0.470918	0.288261	0.612125678	0.144519	0.47675	0.332232	0.69686838	-0.084742702	-0.064738798
3	7	0.086444	0.172022	0.085578	0.49748288	0.070052	0.221264	0.151212	0.683400824	-0.185917944	-0.157439673
3	8	0.03546	0.074468	0.039008	0.523822313	0.01773	0.08999	0.07226	0.802978109	-0.279155796	-0.210397729
3	9	0.01773	0.028369	0.010639	0.375022031	0.007092	0.028368	0.021276	0.75	-0.374977969	-0.333307223
3	10	0.003546	0.007092	0.003547	0.500141004	0.003547	0.014185	0.010638	0.749947127	-0.249806123	-0.19983081
4	1	1.940895	1.978524	0.037629	0.019018723	1.909778	1.96928	0.059502	0.030215104	-0.011196381	-0.227412363
4	2	1.671878	1.895475	0.223597	0.117963571	1.705417	1.918674	0.213257	0.111148116	0.006815455	0.029747305
4	3	1.02444	1.651441	0.627001	0.379669028	1.016831	1.685279	0.668448	0.39663937	-0.016970341	-0.021860308
4	4	0.389338	1.060836	0.671497	0.632988511	0.380036	1.010551	0.630515	0.623931895	0.009056616	0.007205402
4	5	0.106852	0.398638	0.291786	0.731957315	0.103305	0.398413	0.295108	0.740708762	-0.008751447	-0.005942588
4	6	0.039007	0.116621	0.077614	0.665523362	0.039007	0.114815	0.075808	0.660262161	0.005261201	0.003968365
4	7	0.014185	0.03546	0.021276	0.6	0.007092	0.024822	0.01773	0.714285714	-0.114285714	-0.086956522
4	8	0	0.007092	0.007092	1	0	0.007092	0.007092	1	0	0
4	9	0	0	0	NA	0	0.007092	0.007092	1	NA	NA
4	10	0	0	0	NA	0	0	0	NA	NA	NA
5	1	2.168036	2.258545	0.09051	0.040074473	2.181944	2.28875	0.106805	0.04666521	-0.006590738	-0.075982956
5	2	1.553097	2.108916	0.555819	0.263556728	1.580246	2.149866	0.56962	0.264956048	-0.001399321	-0.002647657
5	3	0.613586	1.5374	0.923813	0.600893066	0.562295	1.555506	0.993211	0.638513127	-0.037620061	-0.030353294
5	4	0.168005	0.672675	0.50467	0.750243431	0.130336	0.658754	0.528419	0.802149209	-0.051905778	-0.033435986
5	5	0.031915	0.170679	0.138764	0.81301156	0.014185	0.139636	0.125451	0.898414449	-0.085402889	-0.049901596
5	6	0.014185	0.045231	0.031046	0.686387654	0.003547	0.024822	0.021276	0.857142857	-0.170755203	-0.110626386
5	7	0.007092	0.014184	0.007092	0.5	0	0.003547	0.003547	1	-0.5	-0.333333333
5	8	0	0.003547	0.003547	1	0	0	0	NA	NA	NA
5	9	0	0	0	NA	0	0	0	NA	NA	NA
5	10	0	0	0	NA	0	0	0	NA	NA	NA
6	1	2.342093	2.508913	0.166821	0.066491345	2.297071	2.526744	0.229674	0.090897218	-0.024405873	-0.155067639
6	2	1.306556	2.301215	0.994659	0.432232103	1.260465	2.270288	1.009823	0.444799514	-0.012567411	-0.014329484

6	3	0.395559	1.269804	0.874245	0.688488145	0.362708	1.346492	0.983784	0.730627438	-0.042139293	-0.029694053
6	4	0.070053	0.372831	0.302778	0.812105217	0.049644	0.33474	0.285095	0.851690865	-0.039585648	-0.023792368
6	5	0.010638	0.078483	0.067844	0.864441981	0.010637	0.070922	0.060285	0.85001833	0.014423651	0.00841294
6	6	0.003547	0.021277	0.017731	0.833341167	0	0.007092	0.007092	1	-0.166658833	-0.09090443
6	7	0	0	0	NA	0	0	0	NA	NA	NA
6	8	0	0	0	NA	0	0	0	NA	NA	NA
6	9	0	0	0	NA	0	0	0	NA	NA	NA
6	10	0	0	0	NA	0	0	0	NA	NA	NA
7	1	2.339589	2.682836	0.343248	0.127942222	2.334929	2.741844	0.406915	0.148409246	-0.020467023	-0.074061569
7	2	0.992113	2.276255	1.284142	0.564146811	1.022913	2.351417	1.328504	0.56498018	-0.000833369	-0.000738065
7	3	0.177774	1.093244	0.91547	0.837388543	0.200856	0.998057	0.797201	0.798752977	0.038635566	0.023613829
7	4	0.031915	0.236719	0.204804	0.8651777	0.028368	0.208819	0.180451	0.864150293	0.001027407	0.000594108
7	5	0.007092	0.038138	0.031046	0.814043736	0.003546	0.031915	0.028369	0.88889237	-0.074848634	-0.043952697
7	6	0.003547	0.007092	0.003546	0.5	0	0.003547	0.003547	1	-0.5	-0.333333333
7	7	0	0	0	NA	0	0	0	NA	NA	NA
7	8	0	0	0	NA	0	0	0	NA	NA	NA
7	9	0	0	0	NA	0	0	0	NA	NA	NA
7	10	0	0	0	NA	0	0	0	NA	NA	NA
8	1	2.287748	2.87128	0.583531	0.203230267	2.3223	2.940391	0.618091	0.210207078	-0.006976811	-0.016875136
8	2	0.784158	2.238132	1.453974	0.649637287	0.668162	2.328055	1.659893	0.712995612	-0.063358325	-0.046496988
8	3	0.121906	0.794285	0.672379	0.846521085	0.144988	0.739737	0.594748	0.803999259	0.042521826	0.025762679
8	4	0.021276	0.187542	0.166266	0.886553412	0.021276	0.104175	0.082899	0.795766739	0.090786673	0.053965158
8	5	0.003546	0.034593	0.031047	0.897493713	0.003547	0.024823	0.021276	0.857108327	0.040385386	0.023016835
8	6	0.003547	0.007092	0.003546	0.5	0	0	0	NA	NA	NA
8	7	0	0	0	NA	0	0	0	NA	NA	NA
8	8	0	0	0	NA	0	0	0	NA	NA	NA
8	9	0	0	0	NA	0	0	0	NA	NA	NA
8	10	0	0	0	NA	0	0	0	NA	NA	NA

Table 5.10 – Transfer entropy (T), Relative explanation added (REA) and Net information flow (NIF) and Normalised directionality index (NDI) (stock derivatives - W and commodity derivatives – Z markets of India)

Bins	Block	FUTEXAGRI(Z) to NIFTYFUTURES(W)				NIFTYFUTURES(W) to FUTEXAGRI(Z)					
		h(W,Z)	h(W)	T(Z->W)	REA(Z->W)	h(Z,W)	h(Z)	T(W->Z)	REA(W->Z)	NIF(Z->W)	NDI(W,Z)
2	1	0.997801	0.999927	0.002126	0.002126155	0.986926	0.996298	0.009372	0.009406824	-0.007280669	-0.631291246
2	2	0.992383	0.995009	0.002626	0.002639172	0.98652	0.996026	0.009506	0.009543928	-0.006904755	-0.566748664
2	3	0.982693	0.99004	0.007347	0.007420912	0.982853	0.995399	0.012546	0.012603991	-0.005183079	-0.258831646
2	4	0.959266	0.984083	0.024817	0.025218401	0.967351	0.989756	0.022405	0.022636892	0.002581509	0.053944063
2	5	0.920955	0.964795	0.04384	0.045439705	0.938277	0.986449	0.048172	0.048833746	-0.003394041	-0.03600209
2	6	0.817355	0.913338	0.095983	0.105090339	0.832357	0.955284	0.122927	0.128681104	-0.023590765	-0.100913803
2	7	0.638975	0.828501	0.189527	0.228758927	0.652629	0.869514	0.216886	0.249433592	-0.020674664	-0.043235023
2	8	0.427945	0.673079	0.245134	0.364197962	0.382788	0.644433	0.261645	0.406008072	-0.04181011	-0.054284319
2	9	0.214171	0.40533	0.191158	0.471610786	0.192426	0.361839	0.169414	0.468202709	0.003408077	0.003626334
2	10	0.106384	0.228356	0.121972	0.534130918	0.086446	0.179582	0.093136	0.518626588	0.01550433	0.014727352
3	1	1.567186	1.574393	0.007207	0.004577637	1.561753	1.581231	0.019478	0.012318251	-0.007740614	-0.458135941
3	2	1.51612	1.54285	0.02673	0.01732508	1.527859	1.571639	0.04378	0.02785627	-0.01053119	-0.233087094
3	3	1.321483	1.482014	0.160531	0.10831949	1.353414	1.511138	0.157724	0.104374319	0.00394517	0.01854859
3	4	0.884546	1.30168	0.417134	0.320458177	0.915404	1.360366	0.444963	0.327090651	-0.006632473	-0.01024243
3	5	0.488828	0.881298	0.39247	0.445331772	0.409231	0.866797	0.457566	0.527881384	-0.082549612	-0.084821718
3	6	0.234111	0.470918	0.236807	0.502862494	0.170681	0.424867	0.254186	0.59827193	-0.095409436	-0.086646493
3	7	0.093538	0.172022	0.078484	0.456243969	0.06383	0.148067	0.084237	0.568911371	-0.112667402	-0.109902761
3	8	0.0461	0.074468	0.028368	0.38094215	0.017731	0.056738	0.039007	0.687493391	-0.306551241	-0.28691599
3	9	0.014184	0.028369	0.014185	0.500017625	0.007092	0.021276	0.014184	0.666666667	-0.166649042	-0.142839878
3	10	0.003546	0.007092	0.003547	0.500141004	0	0.003546	0.003546	1	-0.499858996	-0.333208008
4	1	1.945941	1.978524	0.032584	0.016468842	1.920436	1.988591	0.068155	0.03427301	-0.017804168	-0.350877372
4	2	1.728668	1.895475	0.166807	0.088002743	1.703233	1.947945	0.244712	0.125625724	-0.03762298	-0.176114076
4	3	1.041555	1.651441	0.609886	0.369305352	0.989481	1.723981	0.7345	0.426048779	-0.056743427	-0.0713436
4	4	0.375156	1.060836	0.685679	0.646357213	0.310854	0.998184	0.68733	0.688580462	-0.04222325	-0.031629379
4	5	0.107721	0.398638	0.290916	0.729774883	0.077145	0.383113	0.305968	0.798636434	-0.06886155	-0.045054332
4	6	0.036799	0.116621	0.079822	0.684456487	0.024823	0.086445	0.061622	0.712846318	-0.028389831	-0.020317594
4	7	0.014185	0.03546	0.021276	0.6	0	0.017731	0.017731	1	-0.4	-0.25
4	8	0.003547	0.007092	0.003546	0.5	0	0	0	NA	NA	NA
4	9	0	0	0	NA	0	0	0	NA	NA	NA
4	10	0	0	0	NA	0	0	0	NA	NA	NA
5	1	2.148082	2.258545	0.110463	0.048908921	2.203171	2.300939	0.097768	0.042490479	0.006418443	0.070224121
5	2	1.573364	2.108916	0.535553	0.253947051	1.582342	2.185847	0.603505	0.276096634	-0.022149583	-0.041788221
5	3	0.672647	1.5374	0.864753	0.56247756	0.608351	1.603141	0.99479	0.620525581	-0.058048021	-0.049068358
5	4	0.189752	0.672675	0.482924	0.717915784	0.111268	0.546949	0.435681	0.796566042	-0.078650258	-0.051932124
5	5	0.050983	0.170679	0.119696	0.701293071	0.024822	0.156496	0.131674	0.841388917	-0.140095847	-0.090813173
5	6	0.010639	0.045231	0.034592	0.764785214	-0.000001	0.024823	0.024824	1.000040285	-0.235255072	-0.133302172
5	7	0	0.014184	0.014184	1	0	0.007092	0.007092	1	0	0
5	8	0	0.003547	0.003547	1	0	0	0	NA	NA	NA
5	9	0	0	0	NA	0	0	0	NA	NA	NA
5	10	0	0	0	NA	0	0	0	NA	NA	NA

6	1	2.302188	2.508913	0.206725	0.082396241	2.352071	2.551707	0.199636	0.078236255	0.004159986	0.025897535
6	2	1.335702	2.301215	0.965513	0.41956662	1.328024	2.37573	1.047706	0.441003818	-0.021437198	-0.024910451
6	3	0.337417	1.269804	0.932388	0.734277101	0.293525	1.280855	0.98733	0.770836668	-0.036559567	-0.024290235
6	4	0.049645	0.372831	0.323186	0.866843154	0.062961	0.284623	0.221663	0.778795108	0.088048046	0.053503889
6	5	0.003546	0.078483	0.074937	0.954818241	0.003546	0.053191	0.049645	0.933334587	0.021483654	0.011378133
6	6	0	0.021277	0.021277	1	0	0.010638	0.010638	1	0	0
6	7	0	0	0	NA	0	0.003547	0.003547	1	NA	NA
6	8	0	0	0	NA	0	0	0	NA	NA	NA
6	9	0	0	0	NA	0	0	0	NA	NA	NA
6	10	0	0	0	NA	0	0	0	NA	NA	NA
7	1	2.272805	2.682836	0.410032	0.152835283	2.392713	2.767436	0.374722	0.135404035	0.017431249	0.060474916
7	2	0.994042	2.276255	1.282212	0.563298927	0.939806	2.318683	1.378877	0.594681119	-0.031382191	-0.027100805
7	3	0.206142	1.093244	0.887102	0.811440081	0.203933	1.009968	0.806035	0.798079741	0.01336034	0.008300823
7	4	0.039007	0.236719	0.197712	0.835218128	0.049644	0.193296	0.143652	0.743171095	0.092047033	0.058317069
7	5	0.003547	0.038138	0.034592	0.907021868	0.010638	0.042554	0.031916	0.75001175	0.157010118	0.094753731
7	6	0	0.007092	0.007092	1	0	0	0	NA	NA	NA
7	7	0	0	0	NA	0	0	0	NA	NA	NA
7	8	0	0	0	NA	0	0	0	NA	NA	NA
7	9	0	0	0	NA	0	0	0	NA	NA	NA
7	10	0	0	0	NA	0	0	0	NA	NA	NA
8	1	2.326355	2.87128	0.544924	0.189784347	2.320284	2.930249	0.609965	0.208161491	-0.018377144	-0.046180012
8	2	0.826444	2.238132	1.411688	0.630743852	0.712814	2.324353	1.611539	0.693327993	-0.06258414	-0.047266423
8	3	0.128999	0.794285	0.665286	0.837591041	0.111267	0.743926	0.632659	0.850432704	-0.012841663	-0.007607513
8	4	0.014185	0.187542	0.173357	0.924363609	0.017731	0.116153	0.098422	0.847347895	0.077015715	0.04346967
8	5	0	0.034593	0.034593	1	0.003546	0.01773	0.014184	0.8	0.2	0.111111111
8	6	0	0.007092	0.007092	1	0	0.003547	0.003547	1	0	0
8	7	0	0	0	NA	0	0	0	NA	NA	NA
8	8	0	0	0	NA	0	0	0	NA	NA	NA
8	9	0	0	0	NA	0	0	0	NA	NA	NA
8	10	0	0	0	NA	0	0	0	NA	NA	NA

Table 5.11 – Mutual information for stock derivatives, stock, commodities spot and commodities derivatives markets of India

Delay	niftyfutures	nifty	ncdex	futex
1	1.558594	1.476563	1.390625	1.296875
2	1.417969	1.410156	1.375	1.480469
3	1.527344	1.476563	1.300781	1.546875
4	1.421875	1.382813	1.464844	1.265625
5	1.386719	1.363281	1.476563	1.367188
6	1.523438	1.40625	1.292969	1.441406
7	1.507813	1.410156	1.304688	1.429688
8	1.417969	1.535156	1.378906	1.261719
9	1.410156	1.429688	1.46875	1.382813
10	1.535156	1.359375	1.214844	1.355469
11	1.355469	1.429688	1.371094	1.421875
12	1.527344	1.386719	1.359375	1.441406
13	1.496094	1.410156	1.402344	1.460938
14	1.464844	1.367188	1.402344	1.3125
15	1.410156	1.464844	1.457031	1.425781
16	1.464844	1.375	1.433594	1.410156
17	1.402344	1.324219	1.460938	1.4375
18	1.371094	1.34375	1.34375	1.40625
19	1.335938	1.472656	1.492188	1.417969
20	1.414063	1.480469	1.421875	1.359375

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CHAPTER - VI

SUMMARY OF FINDINGS AND SUGGESTIONS

CHAPTER VI

SUMMARY OF FINDINGS AND SUGGESTIONS

This chapter provides a summary of the findings pertaining to the application of sample entropy in the study of stock price manipulation and the application of transfer entropy in the studies of price discovery in securities market and interactions between stock and other markets. Then some suggestions have been given based on such findings. Also, the scope for further research as a continuation of this study, is outlined.

SUMMARY

Since entropy quantifies the irregularity or complexity of a random variable and it is feasible to compute entropy for short and noisy time series like the price data of a scrip during a trading day, it is opined that entropy theory may be useful in the study of manipulation in stock prices. Sample entropy (SampEn), which considers both linear and non-linear structure in a time series, has been computed for the time series of trade price data related to the scrips of Lupin Laboratories Ltd., Morepen Hotels Ltd. and Surya Rooshni Ltd. on various days during the periods October 1999 – January 2000, September 2000 – March 2001 and April 2000 - October 2000 respectively, during which the scrips have been reported to be subject to price manipulation. It is observed that SampEn values are very low on 16 days in respect of Lupin Laboratories Ltd., on 39 days in respect of Morepen Hotels Ltd. and on 25 days in respect of Surya Rooshni Ltd., implying that these are days of potential manipulation in the price of the respective scrips. Further, it appears that price manipulation has been rampant in the scrip of Morepen Hotels Ltd during the months of February and March 2001 and in the scrip of Surya Rooshni Ltd. during the months of June and October 2000, since sample entropy has remained at very low level continually for many days during these months. Thus, among the various versions of entropy, sample entropy is found to be suited to study price manipulation in the stock market.

Another entropic measure called transfer entropy quantifies the exchange of information between two non-linear dynamical systems and hence it is proposed that entropy theory may be applied in the study of price discovery in the securities market. Transfer entropy between the Nifty index (representative of the equities segment of the Indian securities market) and the near month Nifty futures contract (in the derivatives segment of the Indian securities market) for the period October 2005 – September 2006 has been computed and is found to be in consonance with the results of previous studies using other methods, however it may be noted that transfer entropy quantifies information transmission, including non-linear dynamic relationship also. Further, the computed transfer entropy values are interpreted using the notions of net information flow, normalised directionality index and relative explanation added. Specifically, in the Indian stock market, apart from information flow from derivatives segment to equities segment, information dissemination in the reverse direction also is observed during the period considered, however the flow from derivatives segment to equities segment is generally more pronounced. Thus transfer entropy proves to be a promising measure to identify causal relationship.

In a similar manner, the application of entropy theory in the study of interactions between the stock market and the foreign exchange market of India is illustrated by computing transfer entropy values between the Nifty (stock) index and the RBI reference (forex) rate for the period November 1995 – March 2007. Considering the important developments in the two markets, the period under study is divided into 3 sub-periods and transfer entropy is computed for each sub-period separately, to study the interactions between the two markets in view of the developments. Further, net information flow, normalised directionality index and relative explanation added which are computed from the transfer entropy values throw more light on the nature of relationship between the two markets. The results obtained for the different sub-periods are more or less consistent with those obtained for the entire period and reiterate that

- there exist only low level interactions between the stock and the forex markets of India at a time scale of a day or less, although theory suggests interactive relationship between the two markets
- the flow from the stock market to the forex market is more pronounced than the flow in the reverse direction
- the entropy rates of both the markets become zero on considering 8 or more past values realised in the respective markets, implying that the information generation in the markets tend to zero if 8 or more past values are considered.

Thus transfer entropy is found to be a useful measure to identify directional information.

Further, the application of entropy theory in the study of interactions between the stock market and the commodities market of India is illustrated by computing transfer entropy values among the Nifty index of stock market, Nifty futures contract of stock derivatives market, NCDEXAGRI index of commodities spot market and FUTEXAGRI index of commodities derivatives market of India for the period from June 2005 to September 2007 and the results obtained across the markets are found to be more or less consistent and reiterate that

- there exist interactions between any two markets, with upto 6 days old price information and the feedback between any two markets is almost at the same level in both the directions
- information generation in the markets tend to zero if 7 or more past values are considered.

SUGGESTIONS

Based on the analysis and the findings, the following suggestions are made.

(a) Stock exchanges may use the non-linear invariant of sample entropy (SampEn) to filter potential manipulation cases instead of using linear measures of variation. SampEn of the time series of order prices of each security may be computed on a day-to-day basis and the daily SampEn value of a security may be compared with the previous values over a period. Repeated drops in the value, if found, suggest that the security may have been subject to price manipulation on the days corresponding to low values of SampEn. Such scrips may be filtered out for detailed investigation in order to ascertain the facts behind the trading pattern of the participants.

(b) In the Indian stock market, apart from information flow from index futures to Nifty index, information dissemination in the reverse direction also is observed during the period October 2005 – September 2006. However, both the relative explanation added (REA) by the derivatives segment to the equities segment and that by the equities segment to the derivatives segment are found to be low. This suggests that hedging an exposure in a segment with a counter-exposure in the other segment may not be highly effective. Further, margins prescribed by market regulators or stock / derivatives exchange authorities, on positions taken by participants in the two segments may be levied separately without netting their positions across the markets i.e. application of cross-margining in the equities and the derivatives segments of the Indian capital market may not be advisable at this juncture.

(c) Interactions between the stock and the forex markets in India have been observed to exist at low level only, even by using the non-linear measure of transfer entropy to quantify the information transmission between the two markets. Hence any policy intervention in a market is not expected to have significant impact on the other. Specifically, any intervention to support exchange rate levels or allowing a full float exchange rate is not likely to affect foreign portfolio investment. Further, global investors may reduce risk exposure by diversifying their portfolios across the two markets.

Interactions among the stock market, the stock derivatives market, the commodities spot market and the commodities derivatives market of India have been observed to be significant between any two markets in both the directions. Hence, depending on information from one market, policy makers may take pro-active steps for the other markets since policy intervention would be effective in the desired direction.

SCOPE FOR FURTHER RESEARCH

Entropy theory is a novel area in the Indian stock market and there is a lot of scope for the application of entropy theory in the Indian financial market. In the absence of conspicuous research efforts to apply entropy theory in the Indian financial market, sample entropy may be used to study trading patterns in the derivatives and the commodities futures markets of India, with a view to identify potential price manipulation cases.

In the study of price discovery in the Indian securities market, data pertaining to one year period viz. October 2005 – September 2006 have been considered. Derivatives trading started in India from June 2000 and by July 2001, both futures and options contracts on stock price indices and individual stock prices were made available, in stages, for trading. Hence the study may be made for a longer period, perhaps starting from July 2001. However, it may be noted that in the current study, minute-wise trade data over the one year period have been considered. Such high frequency data over a longer period may be unwieldy on account of the enormous number of data points. Hence daily data or high frequency data, depending on the availability of computing resources, for longer period may be used to study price discovery in the Indian securities market.

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