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Interaction Between Forex and Stock Markets in India: An Entropy Approach

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Executive Summary

Interactions between the foreign exchange market and the stock market of a country are considered to be an important internal force of the markets in a financially liberalized environment. If causal relationship from a market to the other is not detected, then informational efficiency exists in the other whereas existence of causality implies that hedging of exposure to one market by taking position in the other market will be effective. The temporal relationship between the forex market and the stock market of developing and developed countries has been studied, especially after the East Asian financial crisis of 1997–98, using various methods like cross-correlation, cross-spectrum, and error correction model, but these methods identify only linear relations.

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. Entropy is the amount of disorder in the system and also is the amount of information needed to predict the next measurement with a certain precision. The mutual information between two random variables *X* and *Y* with a joint probability mass function *p(x,y)* and marginal mass functions *p(x)* and *p(y)*, is defined as the relative entropy between the joint distribution *p(x,y)* and the product distribution *p(x)*p(y)*. Mutual information is the reduction in the uncertainty of *X* due to the knowledge of *Y* and vice versa. 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. However, mutual information is a symmetric measure and does not contain either dynamic information or directional sense. Even time delayed mutual information does not distinguish information actually exchanged from shared information due to a common input signal or history and therefore does not quantify the actual overlap of the information content of two variables. Another information theoretic measure called transfer entropy has been introduced by Thomas Schreiber (2000) to study the relationship between dynamic systems; the concept has also been applied by some authors to study the causal structure between financial time series.

In this paper, an attempt has been made to study the interaction between the stock and the forex markets in India by computing transfer entropy between daily data series of the 50 stock index of the National Stock Exchange of India Limited, viz., Nifty and the exchange rate of Indian Rupee *vis-à-vis* US Dollar, viz., Reserve Bank of India reference rate. The entire period—November 1995 to March 2007—selected for the study, has been divided into three sub-periods for the purpose of analysis, considering the developments that took place during these sub-periods. The results obtained reveal 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.

KEY WORDS

Causal Relationship

Non-linear Characteristics

Transfer Entropy

Mutual Information

Time Delay

Interactions between different sub-systems of financial market are considered to be an important internal force of the market and, in a financially liberalized environment, exchange rate stability is construed to be important for the well-being of stock market. This is on account of the fact that any depreciation of the currency of a country leads to reduced stock returns for foreign investors who will reduce their investment in the stock market and hence is likely to have adverse impact on the liquidity of the 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 – as illustrated by Dornbusch R and Fischer S (1980). Also, Dornbusch R (1976) has considered a third approach, viz., asset market approach which 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 which in turn 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 the 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 of a country's stock market index and the exchange rate of the country's currency over time, furthers the understanding of the markets' internal dynamics. If the causal relationship from a market to the other is not detected, then informational efficiency exists in the other 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 a crisis in stock market can be prevented by controlling the exchange rate. Moreover, developing countries may exploit such interaction to attract foreign portfolio investment in their countries 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 stabilize 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 unexpected changes in the two markets will be more correlated, hedging of exposure to one market by taking position in the other market will be effective.

  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; however, hedging results in non-trivial risk exposure to hedgers.

METHODOLOGY AND EMPIRICAL EVIDENCE

Since we have a set of simultaneously recorded variables–value of the stock index and the exchange rate of the currency of a country – over a period of time, 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 real 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.

Granger (1969) and Engle and Granger (1991) introduced an error correction model which takes into account the non-stationary character of co-integrated variables and distinguishes between short-run deviations from equilibrium indicative of causal relationship and long-run deviations which account for efficiency and stability. This approach involves estimation of simultaneous linear equations in a pair of variables with time lags and has been used in a number of studies examining causal structure of bi-variate time series.

Literature Survey

Some of the recent studies are as follows:

(a) Nath and Samanta (2003) used Granger causality test in VAR framework and Geweke's feedback measures on daily data of the exchange rate of Indian Rupee *vis-à-vis* US 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 show significant 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 a strong bi-directional and contemporaneous causal relationship between returns in these markets.

(b) Hussain and Liew (2004) used Granger causality test, Sim causality test, and Geweke causality test on daily data of the Kuala Lumpur Stock Exchange Composite Index and the Stock Exchange of Thailand Index and the 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 the exchange rate to the stock prices in Thailand
- there was feedback relationship between the exchange rate and the stock prices in Malaysia
- the fall in the Thailand currency had been transmitted to the Malaysian currency via the close ties between the stock markets of the two countries, during the 1997 currency crisis.

(c) Tahir and Abdul Ghani (2004) used Granger causality test on the monthly data of stock price index of the Bahrain stock market and the 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.

(d) Murinde and Poshakwale (2004) used a bi-variate vector autoregressive model on the daily data of stock price indices and the 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 that:

- during the pre-Euro period, 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, exchange rates uni-directionally Granger caused stock prices in all the three countries.

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

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

(g) Tahir and Keung (2006) used Granger causality test on the monthly data of exchange rate of Pakistan Rupee *vis-à-vis* US dollar and the main and sectoral indices of the Karachi Stock Exchange and found evidence in favour of portfolio balance model, i.e., uni-directional causation from stock prices to exchange rate.

(h) Azman-Saini, *et. al.*,(2006) used Granger non-causality test, proposed by Toda and Yamamoto [1995], on the daily data of the Kuala Lumpur Stock Exchange Composite Index and the exchange rate of Malaysian Ringitt *vis-à-vis* US dollar for the period January 1993-August 1998 and found that both stock and forex markets were not efficient since there was feedback relationship during the pre-crisis period and that there was uni-directional causality from exchange rate to stock prices during the crisis period.

(i) Tabak (2006) used Granger causality test and impulse response functions on the 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.

(j) Lean, Narayan and Smyth (2006) used Granger causality test in a panel data framework on weekly data of stock price indices and nominal exchange rates for eight Asian countries and found no evidence of a long-run equilibrium relationship between the exchange rate and the stock prices.

(k) Chakravarty (2006) used Granger non-causality test proposed by Toda and Yamamoto [1995], on the monthly data of five macro-economic variables pertaining to India and also stock price index of BSE (Bombay Stock Exchange) for the period from April 1991 to December 2005 and found no causal relation between stock prices and exchange rate.

(l) Narayan (2007) used several variants of the EGARCH model on daily data of exchange rate of Indian Rupee *vis-à-vis* US Dollar and stock price index of BSE (Bombay Stock Exchange) for the period from January 1992 to September 2006 and found that over the entire period, depreciation had reduced mean returns of stock markets and an appreciation of the rupee during 2002–2006 had increased mean returns and reduced volatility of stock markets.

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).

BASIC CONCEPTS OF ENTROPY

(i) The *entropy* of a random variable X with $p(x)$ as the probability mass function is defined by Shannon (1948)) 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 $0 \le H(X) < \infty$. If logarithm is taken to the base e, then entropy is measured in nats. Entropy of a dynamic 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.

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

(iii) The *conditional entropy* of a random variable Y given another variable X is defined as

$H(Y/X) = \sum_x p(x) \log p(Y/X = x) = -E[\log p(Y/X)$
Then, we get the chain rule $H(X,Y) = H(X) + H(Y/X) = H(Y) + H(X/Y)$
Conditioning reduces entropy, i.e., $H(X/Y) \le H(X)$ with equality if X and Y are independent.
It follows that $H(X,Y) \le H(X) + H(Y)$ with equality if X and Y are independent.

(iv) The relative entropy or cross entropy or 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 $D(p \| q) \ge 0$
$= 0$ if $p = q$.
However, $D(p \| q) \ne D(q \| p)$ in general.

Since relative entropy is not symmetric and does not satisfy the triangle property, it is not a true distance between distributions.

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

i.e., $I(X;Y) = D(p(x,y) \| p(x)\, p(y)) = \sum_x \sum_y p(x,y) \log\{p(x,y)/p(x)\, p(y)\}$
It may be noted that $I(X;Y) \ge 0$
$= 0$ if, X and Y are independent.

Also, $I(X;Y) = H(X) - H(X/Y) = H(Y) - H(Y/X)$, where H denotes the entropy,
i.e., mutual information is the reduction in the uncertainty of X due to the knowledge of Y and *vice versa*. Due to symmetry, X says as much about Y as Y says about X.

Also, $I(X;Y) = H(X) + H(Y) - H(X,Y)$ and $I(X;X) = H(X)$.

Thus, the mutual information of a random variable with itself is the entropy of the random variable. That is why entropy is referred to as self-information.

ENTROPIC MEASURES TO STUDY CAUSAL RELATIONSHIP

Harry Joe (1989) 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. Granger, Maasoumi and Racine (2004) 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 by Dionisio, *et. al.* (2005) 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), 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, time delayed mutual information does not distinguish information actually exchanged from shared information due to a common input signal or history and therefore 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 Schreiber (2000) to study the relationship between dynamic systems. Marschinski and Kantz (2002) 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. Back, *et. al.* (2005) have applied transfer entropy on daily closing prices of 135 stocks in the 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 dynamic 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, $n = 1, 2, \ldots$ grows with n is given by

$$\begin{aligned} h_n(X) &= -\Sigma\, p(x_{n+1}) \log p(x_{n+1}/x_n, x_{n-1}, \ldots, x_1) \\ &= -\Sigma\, p(x_{n+1}) \log \{p(x_{n+1}, x_n, x_{n-1}, \ldots, x_1)/p(x_n, x_{n-1}, \ldots, x_1)\} \\ &= -\Sigma\, p(x_{n+1}) \log p(x_{n+1}, x_n, x_{n-1}, \ldots, x_1) + \Sigma\, p(x_{n+1}) \log p(x_n, x_{n-1}, \ldots, x_1) \\ &= H_{n+1}(X) - H_n(X) \end{aligned}$$

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 generalized 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

$$\begin{aligned} T_{y\to x}(k,l) &= \Sigma\, p(x_{n+1}, x_n, x_{n-1}, \ldots, x_{n-k+1}, y_n, y_{n-1}, \ldots, y_{n-l+1}) \log \{p(x_{n+1}/x_n, x_{n-1}, \ldots, x_{n-k+1}, y_n, y_{n-1}, \ldots, y_{n-l+1})/p(x_{n+1}/x_n, x_{n-1}, \ldots, x_{n-k+1})\} \\ &= -H_{k+1,l}(X,Y) + H_{k,l}(X,Y) + H_{k+1}(X) - H_k(X) \\ &= h_k(X) - h_{k,l}(X,Y) \end{aligned}$$

Obviously, $0 \le T_{y\to x}(k,l) \le H(X)$. 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 generalized 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 neutralizing undesirable effects due to non-homogeneous 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 values of k, it is proposed that the concept of mutual information of a time series be used. The mutual information $I(k)$ between a time series $\{x_1, x_2, \ldots, x_n)$ and itself with a delay of k, viz., $\{x_{k+1}, x_{k+2}, \ldots, x_n\}$ measures the information carried over by the delayed time series from the original time series. If $I(k)$ is small or around 0, then the two time series are essentially independent and if $I(k)$ is very large, then the delayed series is related to the original series. If the delay k 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 $x_{k+i} = x_i$ and $I(k)$ will tend to be large. If the delay k is too long, then the data are independent and no information can be gained from the plot and $I(k)$ will tend to be small.

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. It may also be noted that Fraser and Swinney (1986) have suggested that in the construction of multi-dimensional 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 good criterion for the choice of k. Also, the choices for l are $l = k$ or $l = 1$ and, for computational reasons, $l = 1$ is usually preferred.

PRESENTATION OF DATA

In this paper, 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. The National Stock Exchange of India (NSEIL) being the leading stock exchange of India, the 50 stock indices 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, in case it 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 of the Reserve Bank of India (RBI) reference rate for the Indian Rupee *vis-à-vis* the US Dollar during the period, are taken as representative of the forex market. The RBI reference rate is based on 12 noon rates of a few select banks in Mumbai, the commercial capital of India and 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 safely so that meaningful analysis may be made.

Further, during this period, there were important developments in both the markets in India. Starting from mid-June 1998, by May 1999, authorized dealers were permitted gradually, to provide 100 per cent 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 three 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

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 generally chosen to be 1). Hence transfer entropy $T_{y \to x}$ (forex market to stock 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 $T_{y \to x}$ (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 1. The transfer entropy in both the directions behaves reasonably for partitions S = 6, 7, 8 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 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 I, 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, 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., $k \geq 7$), if the time series are partitioned into 6 or more bins. 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 either X or Y only) tend to zero for the same values of S and k. For interpreting the transfer entropy values, the following measures have been defined:

(a) The *net information flow (NIF)* is defined to measure the disparity in influences of the two variables on each other. If NIF $_{y\rightarrow x} = T_{y\rightarrow x} - T_{x\rightarrow y}$ is positive, the variable Y may be said to influence the variable X.

(b) The *normalized directionality index (d)* is defined in order that relevant but small-scale causal structure is not neglected and quantified as $d(X,Y) = \frac{T_{Y\rightarrow X} - T_{X\rightarrow Y}}{T_{Y\rightarrow X} + T_{X\rightarrow Y}}$. 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 bi-directional 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.

(c) The relative explanation added (REA) is defined to compare the measured amount of information flow from Y to X with the total flow of information in X. $REA_{y\rightarrow x}(k,l) = T_{y\rightarrow x}(k,l) \ / \ h_k(X)$ and $REA_{x\rightarrow y}(k,l) = T_{x\rightarrow y}(k,l) \ / \ h_k(Y)$. The ratio $REA_{y\rightarrow x}$ 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. 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.

For the entire period considered in the study, i.e., from November 1995 to March 2007, the values of net information flow, normalized directionality index, and relative explanation added are given in Table I. It may be observed from the table that:

(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 $S \geq 6$, $d(X,Y)$ 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 $d(X,Y) = -1$.

(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 realized 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.

For the first sub-period November 1995 to mid-June 1998, the values of transfer entropy, net information flow, normalized directionality index, and relative explanation added are given in Table 3.

(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 $S \geq 6$, $d(X,Y)$ ranges generally from –0.02 to – 1 if $k \geq 3$ implying that there is no information flow at all from the forex market to the stock market as k increases, resulting in $d(X,Y) = -1$. 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 normalized 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.

For the mid sub-period mid-June 1998 to mid-May 2003, the values of transfer entropy, net information flow, normalized directionality index, and relative explanation added are given in Table 4.

(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 $S \geq 6$, $d(X,Y)$ 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 $d(X,Y) = -1$. 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 normalized 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 realized 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.

For the last sub-period mid-May 2003 to March 2007, the values of transfer entropy, net information flow, normalized directionality index, and relative explanation added are given in Table 5.

(i) For $S \geq 6$ and $k \geq 3$, generally there is an 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 $d(X,Y)$. 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 normalized 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.

Thus, the results obtained for the different sub-periods are more or less consistent with those obtained for the entire period chosen for the analysis 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
- 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 realized in the respective markets, implying that the information generation in the markets tend to zero if 8 or more past values are considered.

CONCLUSION

Entropic analysis is a novel area in the Indian financial market and there is a lot of scope for the application of entropic analysis in the Indian markets. This paper applies entropic analysis to study interaction between forex and stock markets and transfer entropy is found to be suited for this study. 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 were computed and it was found that only low level interactions existed between the two markets in India although theory suggests interactive relationship between the two markets. It may be noted that transfer entropy quantifies information transmission, also including non-linear dynamic relationship, and thus transfer entropy proves to be a promising measure to identify directional information. It may further be noted that, 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.

Table 1: Transfer Entropy Values for the period November 1995 to March 2007

Bins	Block	Forex Market (Y) to Stock Market (X)				Stock Market (X) to Forex Market (Y)					
		$H_{k,l}$ (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)	d (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

Bins	Block	Forex Market (*Y*) to Stock Market (*X*)				Stock Market (*X*) to Forex Market (*Y*)					
		$H_{k,l}$ (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)	d (X,Y)
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 2: Mutual Information (MI)

Delay (Days)	MI-Forex Market	MI-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 3: Transfer Entropy Values for the First Sub-period November 1995 to June 1998

Bins	Block	Forex Market (*Y*) to Stock Market (*X*)				Stock Market (*X*) to Forex Market (*Y*)					
		$H_{k,l}(X,Y)$	$h_k(X)$	$T_{Y\to X}(k,l)$	$REA_{Y\to X}(k,l)$	$h_{k,l}(Y,X)$	$h_k(Y)$	$T_{X\to Y}(k,l)$	$REA_{X\to Y}(k,l)$	$NIF_{Y\to X}(k,l)$	$d(X,Y)$
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

Bins	Block	Forex Market (*Y*) to Stock Market (*X*)				Stock Market (*X*) to Forex Market (*Y*)					
		$H_{k,l}$ (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)	$d(X,Y)$
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

Bins	Block	Forex Market (*Y*) to Stock Market (*X*)				Stock Market (*X*) to Forex Market (*Y*)					
		$H_{k,l}$ (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)	d (X,Y)
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 4: Transfer Entropy Values for the Mid Sub-period June 1998 to May 2003

Bins	Block	Forex Market (*Y*) to Stock Market (*X*)				Stock Market (*X*) to Forex Market (*Y*)					
		$h_{k,l}$ (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)	d (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

Bins	Block	Forex Market (*Y*) to Stock Market (*X*)				Stock Market (*X*) to Forex Market (*Y*)					
		$h_{k,l}$ (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)	$d(X,Y)$
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: Transfer Entropy Values for the Last Sub-period May 2003 to March 2007

Bins	Block	Forex Market (*Y*) to Stock Market (*X*)				Stock Market (*X*) to Forex Market (*Y*)					
		$h_{k,l}$ (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)	d (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

Bins	Block	Forex Market (*Y*) to Stock Market (*X*)				Stock Market (*X*) to Forex Market (*Y*)					
		$h_{k,l}$ (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)	d (X,Y)
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

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