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NONLINEAR DEPENDENCE IN STOCK RETURNS: EVIDENCES FROM INDIA

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Abstract

This paper examines non-linear dependence in Indian stock returns using a set of non-linearity tests. The daily data between 1997 and 2009 for eight indices from National Stock Exchange (NSE) and six indices from Bombay Stock Exchange (BSE) are used. The results suggest strong evidence of non-linear structure in stock returns. The non-linear dependence, however, is not consistent throughout the sample period as indicated by windowed Hinich test [1996, Journal of Non-parametric Statistics, 6, 205-221] suggesting episodic non-linear dependence in Indian stock returns. The existence of episodic non-linear dependency is associated with events such as uncertainties in international oil prices, sub-prime crisis followed by global economic meltdown, and political uncertainties among others.

Keywords: Non-linearity, predictability, market efficiency, random walk, episodic dependence, windowed test.

JEL Classification: G15, C49

1. Introduction

Non-linear dependence in stock returns has gained importance in recent times as it indicates possibility of predictability. The earlier studies which examined the EMH largely used conventional tests such as autocorrelation, variance ratio, and runs tests which are not capable of capturing non-linear patterns in returns series. The earlier evidences of rejection of linear dependence are not sufficient to prove independence in view of non-normality of series (Hsieh, 1989). The rejection of linear dependence does not necessarily imply independence (Granger and Anderson, 1978). The presence of non-linearity provides opportunities to market participants to make excess profits. The use of linear models in such conditions may give wrong inference of unpredictability. Further, the presence of non-linearity in stock returns contradicts EMH.

Hinich and Patterson (1985) were first among others who provided evidence of non-linear dependence in NYSE stock returns. The market crash of October 1987 has shifted the paradigm. The crash is the major event which influenced the role of non-linearities in dynamics of stock returns (Lima, 1998). The stylized fact that the stock return series follows a random walk has been challenged by later studies [see e.g Fama and French, 1988, Poterba and Summers, 1988;

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Lo and MacKinlay, 1988] and non-linear behviour in the US exchange rate and stock market were reported [Hsieh, 1989; Scheinkman and Le Baron, 1989]. Further, Willey (1992), Lee *et al* (1993), Pagan (1996), Blasco *et al* (1997), Lima (1998), Yadav *et al* (1999) and Dahl and Nielson (2001) examined non-linear behaviour of stock returns as an alternative to random walk and found non-linearity in the underlying returns. Similar results were also reported for the UK [Newell *et al,* 1997; Abhyankar *et al,* 1995; Opong *et al,* 1999]. While examining the presence of non-linearity in Malaysian stock returns, Mahamood and Asimakopoulas (2001) observed conditional heteroscedasticity as responsible for observed non-linearity in returns. The study employed three tests namely, McLeod and Li (1983) test, Engel (1982) ARCH test and third momentum test due to (Hsieh, 1989). Solibakke (2005) distinguished between 'models that are non-linear in mean and hence depart from the martingale hypothesis and models that are non-linear in variance and hence depart from assumption of independence but not from the martingale hypothesis. In the empirical work, Solibakke (2005) found strong non-linearity in variance and weak dependence in mean of Norwegian stock returns.

It may be noted that most of the studies cited above are confined to the well developed markets. Given the fact, it is interesting to see whether stock returns exhibit the same patterns in emerging markets as well. Sewell *et al* (1993) provided evidence of non-linearity in the emerging markets. Similarly, Cinko (2002) for Turkey, Scheicher (1996) for Vienna, Afonso and Teixeira (1998) for Portugal, Seddighi and Nian (2004) for China, Panagiotidis (2005) for Greece and Dorina and Simina (2008) for 8 emerging economies (Romania, Hungary, Czech Republic, Lithuania, Poland, Slovakia, Slovenia, Turkey), and Hassan *et al* (2003) for Kuwait provided evidence of non-linearity in stock returns. Recently, Lim and Brooks (2009) who used a set of non-linearity tests reported non-linear structure in stock returns of China.

The overwhelming empirical evidence of non-linear structure in stock returns since late 1980s, both from developed and emerging economies, indicates possible predictability of future returns. However, non-linear dependence present throughout sample period or confined to a certain period within a sample period is important enough to explore. Such possibilities cannot be denied given changes in institutional arrangements and regulatory norms. Further, events occurring during a particular period might induce non-linearity in stock returns during that period and non-linear dependency might disappear later. In case underlying returns are non-linear for a few episodes, then it is difficult to make any forecast of future returns. To examine such possibilities, Hinich and Patterson (1995) suggest windowed test procedure. Under this procedure, whole sample should be divided into windows and then apply Hinich (1996) bicorrelation test.

The studies by Ammermann and Patterson (2003), Bonilla *et al* (2006), Lim (2008), Lim *et al* (2003a), Lim *et al* (2008) employed this windowed test procedure in empirical studies. Ammermann and Patterson (2003) reported brief periods of linear and non-linear dependence and disappearance of such dependencies before they could be exploited by investors. Similar episodic transient non-linear dependencies were reported by Bonilla *et al* (2006) for Latin America, Lim *et al* (2003a) for four ASEAN countries. Several of non-linear tests were performed by Lim *et al* (2008) on non-overlapping sample for the period 1992-2005 for 10 Asian emerging markets, and documented dependencies in returns. The windowed bicorrelation test, in contrast, provides evidence of non-linear dependencies only in a few periods. The other periods seem to follow pure noise process. The existence of dependency in a few periods indicates co-existence

of weak form efficiency and non-random walk behaviour which is explained by market sentiments (Lim *et al,* 2003b). Strong evidence of non-linear dependence is also found in Egypt, Israel, Jordon, Morocco and South Africa and thus rejecting earlier evidences of weak form efficiency in these markets. However, bispectrum test employed could not reject null of linearity (Lim, 2009). Lim (2008**)** using bicorrelation test examined sectoral efficiency of Malaysian stock market. It was observed that the tin and mining sector were relatively more efficient compared to the property sectors which exhibited wide deviations from random walk. The study concluded that the inefficiency had been the highest during the period of Asian financial crisis. Using the same test on 50 countries, Lim and Brooks (2008) found that deviation from random walk was more persistent in low income economies. The variations might be due to low GDP and variations in property rights protection in low income countries. Conditional heteroscedasticity has been cited as one of the responsible factor for observed non-linear dependence in returns (Mahamood and Asimakopoulas, 2001; Poshakwale, 2002). Extensive application of BDS test to examine the issue of non-linearity is seen.

For India, Amanulla and Kamaiah (1998) reported independence of returns, whereas Mitra (2000), Chaudhuri and Wu (2004), Ahmad *et al* (2006)*,* concluded that stock returns in India do not follow a random walk.[2] These studies have employed conventional tests which are not capable of detecting non-linear structure in the data. However, an exception is the study by Poshakwale (2000) which employed BDS test on a sample of 100 actively traded stocks on BSE for the period 1990-1998 to detect non-linear dependence. The study found evidence of non-linear dependence and concluded that RWH could not hold in case of 100 stocks traded on BSE.

The issue of non-linear dependence in stock returns has not been addressed in the Indian context, with the exception of the study by Poshakwale (2002). In the light of the fact that the stock market in India has witnessed several changes since the mid 1990's, the present study assumes relevance, and seeks to examine non-linear behavior of stock returns in two premier stock exchanges namely, NSE and BSE. The study relates to the period June 1997 to March 2009 and uses a wider set of data. To investigate the issue, a set of non-linearity tests is applied. Also, to examine persistence of dependence, windowed test procedure of Hinich (1995) is followed. Further, an attempt is made to identify events that occurred during the periods for which Hinich (1996) test detects significant presence of non-linear dependence.

The remainder of the paper is organized in the following sections. Section 2 briefly describes data and methodology (non-linearity tests). Section 3 discusses empirical results and concluding remarks are given in the last section.

2. Data and Methodology

2.1 Data

Data of daily stock returns of eight indices namely from the NSE and six indices from the BSE for the period June 1997 to March 2009 are considered for the present study. The data

[2] For a comprehensive survey of literature on market efficiency hypothesis for India, see Amanulla and Kamaiah (1996).

coverage, however, is different for different indices which are as follows: From NSE: CNX Nifty, CNX Nifty Junior, CNX Defty, and CNX IT from 02/06/1997 to 31/03/2009, CNX 500 from 07/06/1999 to 31/03/2009, CNX 100 from 01/01/2003 – 31/03/2009 and data range for CNX Infrastructure is from 01/01/2004 to 31/03/2009. From BSE: BSE Sensex, BSE 100 and BSE 200 from 01/01/1998 to 31/03/2009, BSE 500 from 03/01/2000 to 31/03/2009, and data range for BSE Midcap and BSE Small cap is from 01/01/2004 to 31/01/2009. The index values of the NSE and the BSE are collected from the official website of NSE and CMIE Prowess respectively. This study has the advantage of covering the period during which major market micro structure changes have taken place. The data set of fourteen indices has another advantage as it helps to measure relative efficiency of markets represented by different indices traded at the same exchange. Besides, most of the indices considered have the track record of at least five years

2.2 Methodology

A set of non-linear tests namely, Hinich bispectrum (1989), McLeod and Li (1983), Tsay (1986), Brock *et al* (1996), and Hinich bicorrelation (1996) tests are employed to examine the non-linear structure in stock index returns of the NSE and the BSE. Further, to examine whether presence of non-linear dependence is pertinent during whole sample period or a few sub-periods, Hinich (1995) windowed test procedure is followed. The tests are implemented after removing linear dependence in daily returns by fitting an AR (ρ) model. A brief description of these tests is given in present section.

Hinich bispectrum test is a test of linearity and Gaussianity as described in Hinich and Patterson (1989). The Hinich bispectrum test is a frequency domain test. It estimates bispectrum of stationary time series and provides a direct test for non-linearity in returns series. The flatness of the skewness function in this frequency domain test indicates third order non-linear dependence. The McLeod and Li (1983) portmanteau test of non-linearity seeks to test whether squared autocorrelation function of returns is non-zero. The Tsay (1986) test of non-linearity seeks to detect quadratic serial dependence in the data. It tests the null that all coefficients are zero.

The Brock *et al* (1996) proposed a portmanteau test (BDS test) for time based dependence in a series. It has power against a variety of possible deviations from independence including linear dependence, non-linear dependence, or chaos. In this test, *m* denotes the embedded dimension (period histories), and ε is a distance that is used to decide if returns are near each other. The estimate of the correlation integral value is the proportion of pairs of *m* period histories that are near to each other. The BDS statistic is estimated at different *m*, and ε values.

The portmanteau bicorrelation test of Hinich (1996) is a third order extension of the standard correlation tests for white noise. The null hypothesis for each window is that the transformed data are realizations of a stationary pure white noise process that has zero correlation (C) and bicorrelation (H). Thus, under the null hypothesis, the correlation (C) and bicorrelation (H) are expected to be equal to zero. The alternative hypothesis is that the process in window has some non-zero correlation (second order linear) or bicorrelations (third order non-linear dependence). The linear dependence in returns is removed using an AR (ρ) model. An appropriate lag is selected so that there is no significant (C) statistics. Hence, rejection of null of pure noise implies non-linear dependence. Further, the Hinich and Patterson (1995) test

procedure involves dividing the full sample period into equal-length non-overlapped windows to capture episodic dependencies in stock returns. The present study divides whole sample into a set of non-overlapped window of 50 observations in equal length.[3] Then, Hinich (1996) bicorrelation test is applied to detect episodic non-linear dependencies in returns

3.3 Empirical Results

The present section presents non-linearity tests results. The non-linear dependence in stock returns is examined through applying the set of non-linear tests mentioned in the above section. Before performing these tests, linear dependence is removed by fitting AR (ρ) model so that any remaining dependence would be non-linear. The results for McLeod-Li and Tsay tests are reported in table 1. The former tests the null of i.i.d while the latter tests that all coefficients are zero. Rejection of null suggests that the underlying returns series are non-linearly dependent. The McLeod-Li test strongly rejects the null of i.i.d as probability values for all index returns are zero. CNX IT and CNX 500 are however exceptions to this (see table 1). The Tsay test results support the presence of non-linear dependence as evidenced by the McLeod-Li test. Tsay test results suggest that with sole exception of CNX IT, all other index returns are characterized by non-linear dependence (see table 1).

Further, the Hinich bispectrum tests the null of absence of third order non-linear dependence (flat skewness function). Rejection of null suggests a non-linear process. Unlike other non-linear tests, the bispectrum directly tests for linearity. Hence, filtering of data is not necessary before performing the test. In other words, the test is invariant to linear filtering. In the present study, the bispectrum though performed both on raw data and residuals, the results are reported only for raw returns as results for both the series are the same. It is evident from last column of table 1 that the bispectrum test rejects the null of absence of third order non-linear dependence for all the index returns.[4]

The BDS test is performed at various embedded dimensions (m) like 2, 4, and 8 and 10 at various distances (ε) like 0.75s, 1.0s, 1.25s, and 1.50s where s denotes standard deviations of the return. The BDS test statistics are furnished in table 2. In the table, the value in each cell represents BDS test statistic followed by probability value in parenthesis. The BDS tests the null hypothesis that returns series are i.i.d. Rejection of the null implies that random walk hypothesis does not hold good. It is clear from the statistics reported in table 2 that null of i.i.d is rejected for all indices. The rejection of i.i.d for residuals from AR (ρ) models indicates presence of non-linear structure in returns series. This implies possible predictability of future returns based on past information.

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[3] Hinich and Patterson (1995) suggest that the window length should be sufficiently large to validly apply bicorrelation test and yet short enough for the data generating process to have remained roughly constant.

[4] The bispectrum test could not be calculated for CNX IT, BSE 200 and CNX 500.

Table 1. McLeod-Li, Tsay and Bispectrum Test Statistics

Index Returns	*Mc Leod-Li Test Statistics (probability)*	*Tsay Test Statistic*		*Bispectrum Test Statistic*
		Lag 4	Lag 6	
CNX Nifty	0.0000	6.25 (0.0000)	4.41 (0.0000)	3.75 (0.0000)
Nifty Junior	0.0000	6.97 (0.0000)	4.16 (0.0000)	13.03 (0.0000)
CNX Defty	0.0000	6.97 (0.0000)	4.81 (0.0000)	16.64 (0.0000)
CNX IT	1.0000	1.12 (0.3414)	13.60(0.000)	-
BSE Sensex	0.0000	5.76 (0.0000)	3.73 (0.0000)	7.00 (0.000)
BSE100	0.0000	75.11 (0.0000)	36.66 (0.000)	31.26 (0.0000)
BSE 200	0.0000	91.83 (0.0000)	44.04 (0.000)	-
CNX 500	1.0000	2.42 (0.0070)	1.71 (0.0219)	-
CNX Bank Nifty	0.0000	4.05 (0.0000)	2.99 (0.0000)	13.36 (0.0000)
BSE 500	0.0000	5.72 (0.0000)	3.80 (0.0000)	18.08 (0.0000)
CNX 100	0.0000	6.53 (0.0000)	4.58 (0.0000)	17.88 (0.0000)
CNX Infrastructure	0.0000	5.89 (0.0000)	4.56 (0.0000)	20.3 (0.0000)
BSE Midcap	0.0000	8.17 (0.0000)	4.59 (0.0000)	30.26 (0.0000)
BSE Smallcap	0.0000	6.37 (0.0000)	3.70 (0.0000)	10.19 (0.0000)

Note: The McLeod-Li statistics tests the null hypothesis that the increments are independently and identically distributed, and the corresponding p values are given in second column. Tsay statistics tests that all coefficients are zero. Alternative hypothesis is that returns series are characterized by non-linear dependence. Tsay statistics is calculated at lag 4 and 6 and respective statistic followed by p values in parentheses is given. The bispectrum statistics test the null of absence of third order non-linear dependence. The bispectrum statistic is given in last column along with p values in parentheses. The bispectrum test could not be calculated for CNX IT, BSE 200 and CNX 500.

Table 2. BDS Test Statistics

Index Returns	m=2, ε = 0.75s	m=4, ε = 1.0s	m=8, ε =1.25 *S*	m=10, ε=1.50s
CNX Nifty	12.94 (0.0000)	20.53 (0.0000)	31.25 (0.0000)	32.07 (0.0000)
Nifty Junior	15.81 (0.0000)	23.77 (0.0000)	35.49 (0.0000)	37.08 (0.0000)
CNX Defty	13.15 (0.0000)	20.56 (0.0000)	31.04 (0.0000)	32.18 (0.0000)
CNX IT	19.32 (0.0000)	23.39 (0.0000)	25.53 (0.0000)	24.60 (0.0000)
BSE Sensex	13.71 (0.0000)	22.00 (0.0000)	34.67 (0.0000)	35.94 (0.0000)
BSE100	18.99 (0.0000)	25.78 (0.0000)	32.72 (0.0000)	31.41 (0.0000)
BSE 200	28.16 (0.0000)	27.04 (0.0000)	21.87 (0.0000)	18.91 (0.0000)
CNX 500	16.89 (0.0000)	21.78 (0.0000)	23.97 (0.0000)	22.08 (0.0000)
CNX Bank Nifty	12.37 (0.0000)	17.75 (0.0000)	24.94 (0.0000)	25.81 (0.0000)
BSE 500	15.03 (0.0000)	23.10 (0.0000)	34.02 (0.0000)	33.57 (0.0000)
CNX 100	11.98 (0.0000)	18.26 (0.0000)	28.44 (0.0000)	28.63 (0.0000)
CNX Infrastructure	10.27 (0.0000)	16.93 (0.0000)	26.21 (0.0000)	26.13 (0.0000)
BSE Midcap	11.96 (0.0000)	16.63 (0.0000)	22.94 (0.0000)	22.16 (0.0000)
BSE Smallcap	10.20 (0.0000)	13.68 (0.0000)	18.63 (0.0000)	19.12 (0.0000)

Note: The table reports the BDS test results. Here, 'm' and 'ε' denote the dimension and distance, respectively and 'ε' equal to various multiples (0.75, 1, 1.25 and 1.5) of standard deviation (*s)* of the data. The value in the first row of each cell is BDS test statistic followed by the corresponding p-value in parentheses. The asymptotic null distribution of test statistics is N (0.1). The BDS statistic tests the null hypothesis that the increments are independently and identically distributed, where the alternative hypothesis assumes a variety of possible deviations from independence including non-linear dependence.

The Hinich (1996) bicorrelation (H) test statistics covering the full sample period are presented in table 3. The null of pure noise is tested. The total number of bicorrelations and corresponding probability values are provided in columns 2 and 3 of table 3. It is evident from the probability values that, with exception of CNX IT and CNX 500 as in case of McLeod-Li and Tsay

tests, the null of pure noise is clearly rejected by all other index returns both from NSE and BSE. It may be inferred that returns series are characterized by non-linear dependencies as the bicorrelation test applied to residuals extracted after fitting AR (ρ) model. The null of pure noise could not be rejected for CNX IT and CNX 500, as the probability value is almost close to 1(see table 3).

Table 3. Hinich Bicorrelation (H) Statistics for Full Sample

Index Returns	*Number of Lags*	*Number of Bicorrelations*	*Probability (p) Value for (H) Statistic*
CNX Nifty	24	276	0.0000*
CNX Nifty Junior	24	276	0.0000*
CNX Defty	24	276	0.0000*
CNX IT	24	276	1.0000
BSE Sensex	23	253	0.0000*
BSE 100	23	253	0.0000*
BSE 200	23	253	0.00008
CNX 500	23	231	0.9999
CNX Bank Nifty	22	231	0.0000*
BSE 500	22	231	0.0000*
CNX 100	18	153	0.0000*
CNX Infrastructure	17	136	0.0000*
BSE Mid Cap	17	136	0.0000*
BSE Small Cap	17	136	0.00008

Note: The table reports Hinich bicorrelation test statistics. Under the null of pure noise, the bicorrelations are expected to be zero. Rejection of null hypothesis suggests presence of non-linear dependence. * indicates rejection of null hypothesis of zero bicorrelation at 1 % level of significance.

Whether non-linear dependence is present throughout the sample period or confined to a certain sub-period within the sample is an interesting issue to explore. This helps to understand nature of market efficiency over a period of time. To examine the episodic dependence in returns series, Hinich and Patterson (1995) suggested dividing the sample into different windows and then testing the null of pure noise. To remove linear dependence from the data, an AR (ρ) model is fitted and then following Lim *et al* (2008), the residuals are divided into a set of non-overlapped window of 50 observations in equal length and then H statistics of Hinich (1996) are computed to detect non-linear dependencies in each window. The lag is selected so that there are no significant (C) windows at 5 percent probability value.

Table 4 presents total number of significant (H) windows in column 3, and the percentage of significant windows to total number of windows is given in column 4 of table 4. The results show that the number of significant (H) windows on an average is low. These significant windows reject the null of pure noise indicating presence of non-linearity confined to these windows. The BSE Midcap and BSE Smallcap index returns are characterized by highest percentage of non-linear dependence (38.4 %) followed by CNX Nifty Junior (32.2 %) and CNX 500 (26.5 %). While the BDS test rejects the null of i.i.d for CNX IT and CNX 500, the other non-linear tests including Hinich (1996) test suggest that these two index returns validate weak form efficiency. However, it

is not unsurprising that CNX IT and CNX 500 possess pockets of non-linear dependencies as is evident from table 4. The events occurred during these windows do not seem to influence the overall performance of CNX IT and CNX 500 index returns. This view is suggestive and not determinative.

Table 4. Windowed Test Results of Hinich H Statistic

Index Returns	*Total Number of Windows*	*Total Number of Significant H Windows*	*Percentage of Significant Windows*	*Windows Period*
CNX Nifty	59	10	16.9	01/12/98 – 03/26/98, 06/10/98 – 08/18/98, 01/04/01 – 03/19/01, 08/09/01 – 10/22/01, 10/24/02 – 01/06/03, 03/16/04 – 05/26/04, 12/28/04 – 03/10/05, 03/09/06 – 05/23/06, 12/22/06 – 03/08/07, 12/26/07 – 03/04/08.
CNX Nifty Junior	59	19	32.2	08/16/99 – 10/25/99, 01/01/00 – 03/16/00, 03/21/00 – 06/01/00, 10/25/00 – 01/03/01, 08/09/01 – 10/22/01, 10/23/01 – 01/07/02, 03/19/02 – 05/30/02, 05/31/02 – 08/08/02, 06/03/03 – 08/11/03, 01/01/04 – 03/15/04, 03/16/04 – 05/26/04, 12/28/04 – 03/09/05, 05/23/05 - 08/01/05, 03/09/06 – 05/23/06, 05/24/06 – 07/31/06, 10/12/06 – 12/21/06, 12/26/07 – 03/04/08, 08/01/08 – 10/15/08, 10/16/08 – 01/01/09.
CNX Defty	59	10	16.9	06/02/97 – 08/11/97, 08/10/00 – 10/19/01, 10/23/02 – 01/03/03, 03/17/04 – 05/27/04, 12/29/04 – 03/10/05, 03/10/06 – 05/24/06, 05/25/06 – 08/01/06, 10/13/06 – 12/22/06, 12/26/06 – 03/09/07, 12/27/07 – 03/05/08.
CNX IT	59	9	15.2	10/24/97 – 01/07/98

				01/08/98 – 03/24/98, 11/05/99 – 01/17/00, 03/31/00 – 06/13/00, 01/16/01 – 03/28/01, 03/29/01 –06/11/01, 08/23/01 – 11/02/01, 01/10/07 – 03/23/07, 06/09/0/ - 08/18/08, 08/19/08 – 10/31/08,
BSE Sensex	56	8	14.2	10/29/98 - 01/08/99, 10/30/02 – 01/10/03, 10/28/03 – 01/06/04, 03/22/04 – 06/01/04, 12/30/05 – 03/14/06, 03/16/06 – 05/29/06, 05/30/07 – 08/07/07, 10/19/07 – 12/31/07.
BSE 100	55	13	23.6	06/04/98 – 08/12/98, 03/26/99 – 06/08/99, 01/10/01 – 03/22/01, 08/16/01 – 10/29/01, 10/30/02 – 01/10/03, 03/22/04 – 06/02/04, 01/03/05 – 03/15/05, 10/19/05 – 12/29/05, 03/16/06 – 05/29/06, 03/15/07 – 05/29/07, 01/01/08 – 03/11/08, 03/12/08 – 05/28/08, 08/07/08 – 10/22/08, 10/23/08 – 01/06/09.
BSE 200	55	12	21.8	01/01/98 - 03/18/98, 03/19/98 – 06/04/98, 06/05/98 – 08/12/98, 01/10/01 – 03/22/01, 08/16/01 – 10/29/01, 10/30/02 – 01/10/03, 03/22/04 – 06/01/04, 01/03/05 – 03/15/05, 03/16/06 – 05/29/06, 05/30/06 – 08/04/06, 10/18/06 – 12/28/06, 03/15/07 – 05/29/07, 01/01/08 – 03/11/08, 03/12/08 – 05/28/08, 08/07/0/ - 10/21/08, 10/22/08 – 01/06/09.
CNX 500	49	13	26.5	10/26/99 – 01/05/00, 01/04/01 – 03/16/01,

				08/09/01 – 10/22/01, 10/24/02 – 01/06/03, 06/03/03 – 08/11/03, 03/19/04 – 05/31/04, 12/31/04 – 03/14/05, 10/18/05 – 12/28/05, 03/14/06 – 05/26/06, 05/29/06 – 08/03/06, 05/29/07 – 08/06/07, 12/31/07 – 03/10/03, 08/06/08 – 10/20/08.
CNX Bank Nifty	45	7	15.5	10/19/00 – 12/28/00, 08/03/01 – 10/16/01, 05/27/02 – 08/02/02, 03/10/04 – 05/20/04, 12/22/04 – 03/03/05, 10/09/07 – 12/17/07, 12/18/07 – 02/27/08
BSE 500	47	8	17.0	03/14/00 – 05/29/00, 01/01/01 – 03/13/01, 08/06/01 – 10/17/01, 10/21/02 – 01/01/03, 03/11/04 – 05/21/04, 12/23/04 – 03/04/05, 10/09/06 – 12/18/06, 12/19/07 – 02/28/08.
CNX 100	31	7	22.5	05/28/03 – 08/05/03, 03/10/04 – 05/20/04, 12/22/04 – 03/03/05, 10/06/05 – 12/20/05, 03/06/06 – 05/18/06, 12/19/06 – 03/06/07, 02/29/08 – 05/16/08.
CNX Infrastructure	31	7	22.5	05/27/04 - 08/05/04, 03/10/05 – 05/23/05, 12/26/05 – 03/09/06, 10/12/06 – 12/21/06, 03/09/07 – 05/23/07, 12/26/07 – 03/04/08, 01/01/09 – 03/18/09
BSE Midcap	26	10	38.4	12/28/04 – 03/09/05, 05/23/05 – 07/29/05, 08/01/05 – 10/11/05, 10/13/05 – 12/23/05, 03/09/06 – 05/23/06, 05/24/06 - 07/31/06, 12/22/06 – 03/08/07, 12/24/07 – 03/04/08, 08/01/08 – 10/15/08, 10/16/08 – 12/31/08.

BSE Smallcap	26	10		01/01/04 – 03/15/04, 03/16/04 – 05/26/04, 12/28/04 – 03/09/05, 08/01/05 – 10/11/05, 03/09/06 – 05/23/06, 05/24/06 – 07/31/06, 10/12/06 – 12/21/06, 12/26/07 – 03/04/08, 08/01/08 – 10/15/08, 10/16/08 – 12/31/08.

Note: Total number of significant H windows and the percentage to total number of windows is furnished in the table. A window is significant if the H statistic rejects the null hypothesis at a 5 % probability value. Last column of the table presents significant window dates.

The evidences from non-linear tests, namely McLeod-Li, Tsay, Hinich bispectrum, BDS and Hinich bicorrelation tests employed in the study provide strong evidences of non-linear dependence in both NSE and BSE across all index returns considered. The windowed Hinich test results document that the reported dependence is confined to a few brief episodes. This implies that the events during the small number of significant window periods are responsible for rejection of null of pure noise for the whole sample period. Given the fact, events occurred during these periods of significant windows provide further insight into issue of non-linearity in returns.

Theoretically, the non-linear structure in data is explained by different factors. The characteristics of market microstructure, restrictions on short sale (Antoniou *et al,* 1997), noise trading (McMillan, 2003), market imperfections (Dwyer *et al*, 1996; Anderson and Vahid, 2001), heterogeneous beliefs (Sarantis, 2001) are factors cited in literature, responsible for non-linear dependency structure in stock returns. In the context of heterogeneous behaviour of investors, Lim and Hinich (2005), and Lim *et al* (2006), examined whether non-linear burst is associated with major economic and political events. Instead of hypothesizing prior event as in case of event study methodology, Lim and Hinich (2005), and Lim *et al* (2006) propose an alternative approach where the non-linear dependency is first detected through Hinich (1996) bicorrelation with windowed procedure and identifying major events occurred during the significant window period which exhibited non-linear dependency. Following the framework, attempt is made here to identify those events which probably induced non-linear dependency in those window periods which are found to be significant by Hinich (1996) test.

The period of significant windows of respective indices are given in the last column of table 4. The major political and economic events occurred during the year January 1997 to March 2009 are identified. These events are associated with those periods of significant windows reported in table 4 based on Hinich (1996) test with windowed procedure. The major events are identified through news reports and events cited as important by various issues of annual reports of RBI and SEBI. These are discussed in the Appendix at the end of this paper.

The different indices reacted to different events differently. One possible reason may be due to different market capitalization and liquidity. For instance, BSE Midcap and BSE Smallcap immediately responded to crisis and they are more vulnerable. Both positive and negative events are found to be associated with existence of non-linearity. However, negative events have

greater and persistence impact. The sub-prime crisis, uncertainties in international oil prices, global financial crisis have impact on a longer period and it was for almost all indices. The presence of non-linearity confounds EMH in Indian equity market.

3.4 Concluding Remarks

The issue of non-linear dependence though gained importance in recent time, is seldom discussed in India. Motivated by this concern, the present paper attempted to test non-linear dependence in stock returns of indices at two premier Indian stock exchanges namely, NSE and BSE. A set of non-linear tests are applied to examine the behavior of stock returns. Strong evidences of non-linear dependences for almost all index returns of NSE and BSE are found in the study. The results from windowed Hinich test showed that the reported non-linear dependencies are not consistent during the whole period suggesting presence of episodic non-linear dependencies in returns series surrounded by long periods of pure noise. The events occurred during the episodes of presence of non-linearity are identified. Both positive and negative events though identified, but negative events have larger impact. The major events identified are uncertainties in international oil prices, turbulent world markets, sub-prime crisis, global economic meltdown and political uncertainties importantly border tensions. The investigation into intraday and tick-by-tick data would provide further insights regarding existence of non-linearity and associated events. The presence of non-linear structure in returns data during 1997-2009 is consistent with earlier findings of Poshakwale (2002) for BSE.

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Appendix

1997-1998

The financial year 1997-98 witnessed a higher level of volatility. The market-friendly budget of 1997-98 had favourable impact as there was spurt in stock returns up to middle of August. The significant window period for CNX IT falls in October '97 to January'98 (see table 3.4). This period was associated with events such as currency crisis in South East Asia which generated panic in the market resulting in negative net Foreign Institutional Investors (FIIs) inflows.

1998-99

The performance of market in general was gloomy during the year. The significant windows period during this financial year are associated with the events such as impending sanctions following nuclear test, instability in exchange rate and turmoil in international market and the bad news of US-64 scheme of UTI scam.

1999-00

The massive inflow of FIIs and mutual funds in both NSE and BSE created upward pressure in stock returns during the months August'99 – October'99 and late October'99 – February'00. The new Government was formed at the Centre. The new government passed several reform bills[5] and RBI in its annual report pointed that the market positively responded to the news of rating India as stable market by international credit rating agencies. However, the uncertainty about international oil price and hike in interest rate by US Fed, dot.com bubble burst on March 10, 2000 and on political front, the hijack of Air India followed by war hysteria between India and Pakistan during January'00 – March'00 generated nervousness in the market. Annual report of SEBI reported that behaviour of stock returns was not linear during the year.

2000-01

The significant windows indicating non-linearity in the financial year 2000-01 were for the months March-June, October-December and January'00 – March'00 (see table 3.4). The events such as increase in international oil prices and, panic in international equity market are associated with these periods. Generally, the Indian equity market witnessed sharp decline in all indices during the year 2000-01. The last quarter of the year, January'00-March'00 witnessed high volatility. The RBI's annual report 2000-01 indicated the Union budget, expectations of strong earnings, growth of new economy as responsible factors for sharp rise. Besides, the fall was due to liquidity /solvency of some co-operative banks.

2001-02

During the year especially August-October'01, bearish sentiment prevailed in the market. The US stock market crashed following terrorist attack on World Trade Centre on September 11, 2001. The slowdown in major international stock market aggravated depression and resulted in heavy selling by FIIs in Indian stock market.

2002-03

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[5] The bills passed during the year were Insurance Regulatory Authority (IRA) Bill, Foreign Exchange Management Act (FEMA) Securities Laws (Amendment) Bill.

The events associated with the period identified as period of significant windows (see table 3.4) were India-Pakistan border tension, slip in consumer spending and bad monsoon, tension in Middle East and rise in international oil prices. The Bank Nifty responded to new information of profitability of banks and relaxation of Foreign Direct Investment (FDI) norms for private sector banks.

2003-04

The Indian equity market witnessed 83 per cent returns which are highest in any emerging markets. The RBI annual report of the year pointed that the improved fundamentals, strong corporate results and initiatives on disinvestment and active derivative trading were responsible for the spurt in returns. SEBI allowed brokers to extend margin trading facility. The period of January-March'04 was period of political uncertainties leading to depression in market.

2004-05

The turbulent political conditions of March'04 continued up to May'04 and resulted in lackluster returns. The major indices such as BSE Sensex reached lowest on May 17, 2004 due to political uncertainties. These uncertainties made the market nervous. During the period May – July – August and October – December'04, due to strong economic outlook, high and sustained portfolio investment, market responded quickly and rally of returns continued.

2005-06

The first quarter of the financial year March'04/April – May'05 was marked by prevalence of bearish sentiment in the market and associated events during the period were uncertainty relating to the global crude oil prices, rise in interest rates and turmoil in international stock markets. The corrections during the period October – December'05 were because of response of market to the news of rise in domestic inflation rate, uncertainty regarding crude oil prices. The proposals of Union Budget 2006-07 including raising FIIs investment limit and improving fundamentals, sound business outlook were met by rally in stock returns during the last quarter, January'-Marh'06.

2006-07

The period of significant windows during the financial year March'05 – May'06 were associated with the sharp fall in metal prices, uncertainty in global interest rate and inflationary pressure in the economy. Hike in Cash Reserve Ratio (CRR) and Bank rate by RBI are associated with significant window period, October-December'06. The impending recession in US and deterioration in sub-prime mortgage banking in US adversely affected the Indian equity market.

2007-08

The financial year 2007-08 was highly volatile as BSE crossed 20,000 mark and in the same year reached lowest ever in Indian equity market. The first and second quarter (continued with corrections) witnessed buoyant trend (May-August'07). The disarray because of US sub-prime crisis, surge in international oil prices, political uncertainties, policy cap on external commercial borrowings (ECBs) generated panic during October-December'07 though sharp increases were also observed (This period was highly volatile). The period of December'07 – March'08 associated with decline in developed equity markets following sub-prime crisis, global recession, fear of credit squeeze and hike in short term capital gains tax, increase in domestic inflation rate etc.

The year 2008 was year of financial crisis and global economic meltdown. The periods of significant windows during this financial year fell in March'07-May'08, June-August-October'08 and October'08 to January'09. As RBI noted in its annual report, the turbulence in global financial market began deepening in July 2008. Fannie Mac and Freddie Mac reported drop in fair value assets. On September 15, 2008, major US investment bank, Lehman Brother declared bankrupt while Merill Lynch, another major investment bank in US saved by merger with Bank of America. During January 08, Northern Rock bank crisis aggravated and JP Morgan and Citibank profits dived deep. The situation was further aggravated by Satyam scam.

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