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Non-Linearity Behavior of the Nepalese Stock Market

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Abstract

The objective of this study is to examine the Non-Linearity Behavior of the Nepalese Stock Market based on the NEPSE index, Float index, Sensitive float index & Sensitive index. By using recent statistical tools to control some of the limitations of financial data. This study aims to detect low deterministic chaos in the Nepalese Stock Market. Using the powerful BDS test and Variance Ratio Test, the empirical results suggest that the Nepalese stock market indicates the existence of non-linearity in raw and filtered returns. Furthermore, the findings point to a strong dependence in the stock returns and chaotic behavior and stock prices can be predicted using past data.

Keywords: Non-Linear, BDS test, NEPSE index, Float index, Sensitive float index, Sensitive index

Introduction

A number of econometric models have become insufficient to capture the nature of stock markets behavior. It is not easy to capture the chaotic and non-linear behavior of stock markets using econometric models, for instance, in markets were traders are always exposed to risks, speculation and volatility. Non-linear dynamics have become a critical part of research in a number of fields from econometrics, physics, mathematics, and economics. Previous research have been made by different researchers (Brooks & Hinich, 1998), (Lim & Hinich, 20005),(Espinosa, 2010) have been describing conformation of nonlinear behavior in time series financial assets worldwide. Nevertheless, the current global financial crisis that was instigated by the United States subprime mortgage in 2007 has brought other features of the capital markets under scrutiny, because it is through these periods that inflows and outflows of speculative capitals show variability (Calvo, 2006). The Nepal Stock Exchange (NEPSE) which contains 370 Scrips. The study covers other indices like Float index, Sensitive float index & Sensitive index. Therefore, high variability in the capital or stock markets could destabilize the local currency leading to serious disturbances in the economy. In light of the above, evidence of nonlinear behavior of the Nepalese stock market indices may provide us with information on whether this period of volatility is permanent or temporary. This is necessary in enabling the government to make structural long-term decisions that would avoid the entrance of speculative inflows or short-term decisions that may lead to interventions on the exchange rates.

Bulk of research work in finance has depend on linear shaping in trying to detect linearity in time series. So the methodology designed to detect nonlinearity deterministic patterns in a time series, this study aims to broaden or add into the limited literature on previous research on the topic. The Nepalese stock market indices are used to examine if the time series generates some form of chaos or non-linearity. The indexes exhibiting low deterministic chaos may contain vital information on inefficiencies, hence, it may help in predicting future stock returns.

Literature Review

A number of studies examining disorganize movements in stock markets have resurfaced in the past years. (Mendez-Mercado & Willey, 1992) set down evidence of disordered movement in the Japanese Nikkei Index. But they failed to identify any chaotic process in the Dow Jones Industrial average and the Financial Times of London Industrial Index. (Sewell, Stansell, Lee, & Pan, 1993) put down proof of linear dependencies in the stock markets of Japan, Korea, and Hong Kong. (Errunza, Hogan, Kini, & Padmanabhan, 1994) famed non-linearity behavior in the different stock markets like India, Japan, Brazil, Chile, Mexico, and Germany. The conformation on non-linearity has been recorded in literature, it has been inconclusive. (Scheikman & LeBaron, 1989) judged the U.S stock market index returns and found linear independence. On the other hand, the same authors found evidence of linear dependence in the University of Chicago index. The decision was drawn, variations in weekly returns come from non-linearity as opposed to randomness. (Lim & Hinich, 2005) examined fourteen stock market indices from Asian countries , they found non-linearity, and they decided that the behavior of indices is essential in financial time series irrespective of location. The time series model the economy is seen as in equilibrium even though it is constantly affected by external shocks. Accordingly non-linear models disclose a lot of information such as stock markets crash and large movements that are not easily explained by linear models. Financial data is generally faced with limitations of sample size and non-stationary. After considering these limitations, this study utilizes recent statistical methodologies to identify low dimensional deterministic chaos in one of the major stock exchange in Africa.

Hypotheses, Data and Methodology

The objective of this paper is to examine the Non-Linearity Behavior of the Nepalese Stock Market by BDS independent test of the Nepal stock market. Therefore, the hypothesis to be tested is:
H0: The return of Nepalese stock market is independent and identically distributed /linearly dependent.
H1: The return of Nepalese stock market is not independent and not identically distributed /non-linearly dependent.

For empirical analysis, NEPSE Index, float index, sensitive float index, and sensitive index at daily frequency. The sample includes 1168 observations for the period of February 2015 to February 2020. The data was provided by the official website of NEPSE. The use of the BDS Test (Brock, Dechert, & Scheinkman, 1987) is very common in studying non-linearity. The BDS test is a luggage test statistic that can be used to notice non-linearity dependencies of a series. Hence, the null hypothesis states that the series are independently and identically distributed. The BDS test was previously applied by (Liu, Granger, & Heller, 1992); (Kanzler, 1998); (Panagiotidis, 2005); (Winker & Jeleskovic, 2007).EViews is used to analyze data in the study.

BDS Test

A BDS test is a powerful test which employs a concept of spatial correlation in chaos theory. Chaos theory is based on assumption that the underlying time series system is non-linear and deterministic. BDS test is powerful in detecting serial dependence in time series by testing the null hypothesis of independent and identically distributed (I.I.D) against unspecified alternative. The non-linearity test of BDS tests which gives any linear dependence has been removed from the data by taking out the first difference of natural logarithms. For the full steps on the BDS test (Brock, Dechert, Scheinkman, & LeBaron, 1996). The model of the BDS is as follows: If a time series has N observations that should be differenced of natural logarithms of raw data in time series

$$\{\chi i\} = [\chi 1{,}2, \chi 3, \dots \dots . .] \dots \dots \dots \dots \dots \dots (1)$$

Select a value of $\boldsymbol{m}$ (embedding dimension and embed the time series into $\boldsymbol{m}$ dimensional vectors by taking $\boldsymbol{m}$ successive points in the series. This converts the series of scalars into series of vectors with overlapping entries:

$\{\chi 1\ m\} = [\chi 1{,}2,\ \chi 3,\ \dots\ \dots\ .\ .\ ]\ \{\chi 2\ m\} = [\chi 2{,}3,\ \chi 4,\ \dots\ \dots\ .\ .\ \chi m{+}1\ ]\ \{\chi N{-}m\ m\ \} = [\chi N{-}m, \chi N{-}m{+}1, \dots \dots . .] \dots \dots \dots \dots \dots \dots \dots \dots (2)$

Compute the correlation integral with the dimension $\boldsymbol{m}$ and distance ϵ as follows:

$$Cm\ (d) = 1\ nm\ (nm - 1) \sum \mathrm{I}\ i{\neq}j\ (\chi p\ n\ ,\ \chi p\ n\ ) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (3)$$

Where $nm = n.\ m + 1$ and I ($, \chi$) = 1 if the maximal norm $\|\chi p\ n\ ,\ \chi p\ n\|$ < distance ϵ and 0 otherwise. Therefore, the BDS test values can be obtained using this formula:

$$BDS\epsilon, = \sqrt{n}\ [(\epsilon) - C1(\epsilon)m]\ \sqrt{V\epsilon,m} \dots \dots \dots \dots \dots \dots \dots \quad (4)$$

Where $\sqrt{V\epsilon}$, is a standard deviation in equation (4). If $BDS\epsilon, > 2$ the null hypothesis is rejected with a confidence level of 95 percent, and if $BDS\epsilon, > 3$ the null hypothesis is rejected at 99 percent confidence interval. The correlation integral is a measure of proportion that any pairs of $\boldsymbol{m}$ -vectors ($, \chi p\ n$) are within distance ϵ. The BDS test is dependent on $\boldsymbol{m}$ and ϵ. Hence, no criterion to determine these two parameters. The BDS test has a lower power against certain forms of non-linearity such as self-exciting threshold AR processes. Therefore, it can be concluded that it is robust to random variables that do not possess high order moments.

Variance Ratio Tests

The (Lo & Mackinlay, 1988) overlapping variance tests, compares the variance of differences in returns calculated over intervals by examining the predictability of the time series. When the stock market returns are supposed to follow a random walk, the variance of q- period difference should be q-times the variance on a single period. The tests are as follows:

$$(Yt\ ) = (Y0, Y1, Y2\dots \dots\dots\ ) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (6)$$

$$\Delta Yt = \mu + \epsilon t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (7)$$

Where μ is a drift parameter and $(\epsilon t\ ) = 0$ for all t, and $E(\epsilon t\epsilon t{-}j) = 0$ for any positive j. Lo and Mackinlay make the strong assumption that the ϵt are I.I.D Gaussian with a variance δ 2 (the normality assumption is not strictly).Considering (Kim, 2006) the test can be used to bootstrap probability and can be improved the sample properties of variance ratio tests. This process can be computed by using the individual Lo and Mackinlay, and joint (Chow & Denning, 1993) variance ratio statistics on samples of T observation by weighting the real data by mean 0 and variance 1 random variables. In this study, the test is computed by allowing heteroscedasticity in the data and using bootstrapping to evaluate the statistical significance. The Wild bootstrap in a two-point distribution is set at 5000 replications, using the Knuth generator and a seed of the random number generator of 1000.

Results and Analysis

The Nepal stock exchange is characterized by deep structural, functional, and institutional dysfunctions like any other emerging capital/stock market. (Birau, 2011) messages that appearing stock markets are accepted high volatility, existence of bubbles, panic , speculation, high risk investments, low level of liquidity, reduced capitalization, decreased number of deals, indicate development of financial instruments, exchange rate instability, and many other challenges. A chaotic behavior can be seen in Figure 1 especially after the 2007 global financial crisis were the index has been ever increasing.

BDS test results

In order to test the non-linearity of time series, the BDS test is used. A dimension m from 2-6 and distance (ϵ) of 0.7 were selected to complete the test. The time series data is independently and identically distributed (I.I.D) is the null hypothesis. Likewise the time series data is not independently and identically distributed (I.I.D) is the alternative hypothesis. The test of the NEPSE index indicates that p- values of all dimension for the BDS test statistics are less than the 5 percent level of significance. Thus, the null hypothesis of I.I.D is strongly rejected. As well as the test statistics are higher than the critical value of all dimension, so we reject the null hypothesis. The results presented in Table 1 clearly suggests that all other indices indicate P value of all dimensions are less than alpha (5%). And Z-statistic of all dimension are higher than the table value so the null hypothesis is rejected. The result indicates that the return series of Nepalese stock market is non-linearly dependent, hence, showing indications of chaotic behavior. Minimum value of ϵ represents a stringent criteria since the m-dimensional space must be clustered close together in terms of the BDS statistics. So, ϵ=0.7 represents a stringent approach, and m=6 as the highest dimension. A higher geometric would severe limit the confidence in the BDS statistics and the interest of the study is to identify low dimensional deterministic chaos.

Index	Dimension	Z-statistic	Probability
NEPSE Index	2	11.7495	0
	3	13.2823	0
	4	14.4677	0
	5	15.1570	0
	6	15.9017	0
Float Index	2	12.2052	0
	3	13.7313	0
	4	15.0270	0
	5	15.7372	0
	6	16.3708	0
Sensitive Float Index	2	11.6412	0
	3	13.2452	0
	4	14.6624	0
	5	15.4660	0
	6	16.2479	0
Sensitive Index	2	11.3736	0
	3	12.9555	0
	4	14.2952	0
	5	15.0952	0
	6	15.8201	0

Table 1: BDS test results

Variance Ratio test results

Variance Ratio test result explored in appendix-5 to appendix-8 the individual tests for the period 2,4,8 &16 years were statistical significant at 0.05 level. The individual test statistic and joint test statistic of NEPSE return strongly accepts the null hypothesis of independent and identically distributed (I.I.D) because p value is higher than alpha(5%) as well as Z-statistic for 2,4,8&16 years are less than critical value. Contrary, the Variance Ratio test result of other indices reject the null hypothesis of independent and identically distributed (I.I.D).

Conclusions

The objective of this study is to examine the Non-Linearity Behavior of the Nepalese Stock Market based on the NEPSE index, Float index, Sensitive float index & Sensitive index. The study used the daily returns for the period of February 2015 to February 2020. The study employ the BDS test and the Variance ratio test to detect nonlinear dependence in the stock returns. Analyses from the BDS test reveals that the Nepalese stock market indicates the existence of non-linearity in raw and filtered returns. Furthermore, the findings point to a strong dependence in the stock returns and chaotic behavior. The result of the study is similar to (Pandey, Kohers, & Kohers, 1998) and (Urrutia, 1995) who explored that stock returns reveal non-linearity and chaotic tendencies. Not independently and identically distributed in stock returns means that prices of stocks can be predicted using past data. The study found amply evidence that the Nepalese stock market indices exhibit non-linearity and dependence tendencies coupled with chaos behavior. The findings from the study have a serious implication to financial market forecasting in that, it can be noted that emerging markets such as the Nepalese Stock Exchange cannot explained by the use of equilibrium models, such as, the efficient market hypothesis.

Works Citation

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Appendices

Appendix- 1

BDS Test for R1
Date: 10/17/20 Time: 14:55
Sample: 1 1168
Included observations: 1168

Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	0.033706	0.002869	11.74953	0.0000
3	0.060523	0.004557	13.28227	0.0000
4	0.078480	0.005425	14.46771	0.0000
5	0.085678	0.005653	15.15701	0.0000
6	0.086674	0.005451	15.90172	0.0000

Raw epsilon	0.014309		
Pairs within epsilon	952668.0	V-Statistic	0.703130
Triples within epsilon	8.57E+08	V-Statistic	0.543307

Dimension	C(m,n)	c(m,n)	C(1,n-(m-1))	c(1,n-(m-1))	c(1,n-(m-1))^k
2	356386.0	0.527430	474786.0	0.702655	0.493724
3	275140.0	0.407892	474175.0	0.702959	0.347369
4	217069.0	0.322357	473209.0	0.702737	0.243877
5	172823.0	0.257093	472412.0	0.702764	0.171414
6	138898.0	0.206983	471496.0	0.702613	0.120308

Appendix-2

BDS Test for R2
Date: 10/17/20 Time: 14:52
Sample: 1 1168
Included observations: 1168

Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	0.034740	0.002846	12.20515	0.0000
3	0.062107	0.004523	13.73127	0.0000
4	0.080944	0.005387	15.02698	0.0000
5	0.088371	0.005615	15.73722	0.0000
6	0.088676	0.005417	16.37077	0.0000

Raw epsilon	0.014933		
Pairs within epsilon	959686.0	V-Statistic	0.703467
Triples within epsilon	8.66E+08	V-Statistic	0.543483

Dimension	C(m,n)	c(m,n)	C(1,n-(m-1))	c(1,n-(m-1))	c(1,n-(m-1))^k
2	359850.0	0.528910	478275.0	0.702972	0.494170
3	278472.0	0.410003	477688.0	0.703315	0.347896
4	220568.0	0.325307	476714.0	0.703087	0.244363
5	176107.0	0.260180	475896.0	0.703087	0.171809
6	141433.0	0.209312	474973.0	0.702932	0.120636

Appendix-3

BDS Test for R3
Date: 10/17/20 Time: 14:53
Sample: 1 1168
Included observations: 1168

Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	0.033529	0.002880	11.64121	0.0000
3	0.060642	0.004578	13.24521	0.0000
4	0.079976	0.005454	14.66238	0.0000
5	0.087976	0.005688	15.46603	0.0000
6	0.089187	0.005489	16.24786	0.0000

Raw epsilon	0.015193		
Pairs within epsilon	959914.0	V-Statistic	0.703634
Triples within epsilon	8.67E+08	V-Statistic	0.544296

Dimension	C(m,n)	c(m,n)	C(1,n-(m-1))	c(1,n-(m-1))	c(1,n-(m-1))^k
2	359182.0	0.527929	478386.0	0.703136	0.494400
3	277750.0	0.408940	477872.0	0.703586	0.348298
4	220169.0	0.324719	476899.0	0.703360	0.244743
5	176055.0	0.260103	476072.0	0.703347	0.172127
6	141964.0	0.210098	475153.0	0.703198	0.120911

Appendix-4

BDS Test for R4
Date: 10/17/20 Time: 14:54
Sample: 1 1168
Included observations: 1168

Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	0.032591	0.002866	11.37362	0.0000
3	0.058979	0.004552	12.95550	0.0000
4	0.077486	0.005420	14.29524	0.0000
5	0.085280	0.005649	15.09521	0.0000
6	0.086195	0.005448	15.82010	0.0000

Raw epsilon	0.014447		
Pairs within epsilon	959398.0	V-Statistic	0.703255
Triples within epsilon	8.66E+08	V-Statistic	0.543513

Dimension	C(m,n)	c(m,n)	C(1,n-(m-1))	c(1,n-(m-1))	c(1,n-(m-1))^k
2	358170.0	0.526441	478120.0	0.702745	0.493850
3	276113.0	0.406530	477530.0	0.703082	0.347551
4	217987.0	0.321501	476544.0	0.702836	0.244015
5	173834.0	0.256822	475748.0	0.702869	0.171542
6	139598.0	0.206597	474819.0	0.702704	0.120402

Appendix-5

Null Hypothesis: R1 is a martingale
Date: 10/18/20 Time: 15:01
Sample: 1 1168
Included observations: 1163 (after adjustments)
Heteroskedasticity robust standard error estimates
User-specified lags: 2 4 8 16

Joint Tests		Value	df	Probability
Max |z| (at period 2)*		1.008005	1163	0.7778
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.496027	0.499971	-1.00801	0.3135
4	0.248848	0.749972	-1.00157	0.3165
8	0.125305	0.874980	-0.99968	0.3175
16	0.063495	0.937484	-0.99896	0.3178

*Probability approximation using studentized maximum modulus with parameter value 4 and infinite degrees of freedom
Test Details (Mean = 5.39670508288e-06)

Period	Variance	Var. Ratio	Obs.
1	17.7043	--	1163
2	8.78179	0.49603	1162
4	4.40567	0.24885	1160
8	2.21843	0.12530	1156
16	1.12413	0.06349	1148

Appendix- 6

Null Hypothesis: R2 is a martingale
Date: 10/17/20 Time: 14:59
Sample: 1 1168
Included observations: 1167 (after adjustments)
Heteroskedasticity robust standard error estimates
User-specified lags: 2 4 8 16

Joint Tests		Value	df	Probability
Max |z| (at period 4)*		7.400019	1167	0.0000
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.641500	0.052825	-6.786513	0.0000
4	0.320679	0.091800	-7.400019	0.0000
8	0.160574	0.129589	-6.477616	0.0000
16	0.078588	0.171991	-5.357328	0.0000

*Probability approximation using studentized maximum modulus with parameter value 4 and infinite degrees of freedom
Test Details (Mean = 5.88910687195e-06)

Period	Variance	Var. Ratio	Obs.
1	0.00021	--	1167
2	0.00014	0.64150	1166
4	6.8E-05	0.32068	1164
8	3.4E-05	0.16057	1160
16	1.7E-05	0.07859	1152

Appendix -7

Null Hypothesis: R3 is a martingale
Date: 10/17/20 Time: 15:00
Sample: 1 1168
Included observations: 1167 (after adjustments)
Heteroskedasticity robust standard error estimates
User-specified lags: 2 4 8 16

Joint Tests		Value	df	Probability
Max |z| (at period 4)*		7.422804	1167	0.0000
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.650586	0.052066	-6.71102	0.0000
4	0.325996	0.090802	-7.4228	0.0000
8	0.167263	0.129285	-6.44107	0.0000
16	0.081730	0.172657	-5.31847	0.0000

*Probability approximation using studentized maximum modulus with parameter value 4 and infinite degrees of freedom
Test Details (Mean = 6.88781670675e-06)

Period	Variance	Var. Ratio	Obs.
1	0.00022	--	1167
2	0.00014	0.65059	1166
4	7.1E-05	0.32600	1164
8	3.6E-05	0.16726	1160
16	1.8E-05	0.08173	1152

Appendix- 8

Null Hypothesis: R4 is a martingale
Date: 10/17/20 Time: 15:01
Sample: 1 1168
Included observations: 1167 (after adjustments)
Heteroskedasticity robust standard error estimates
User-specified lags: 2 4 8 16

Joint Tests		Value	df	Probability
Max |z| (at period 4)*		7.464316	1167	0.0000
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.644442	0.052156	-6.81715	0.0000
4	0.322878	0.090715	-7.46432	0.0000
8	0.165158	0.128355	-6.50417	0.0000
16	0.079424	0.170817	-5.38925	0.0000

*Probability approximation using studentized maximum modulus with parameter value 4 and infinite degrees of freedom
Test Details (Mean = 3.65933852264e-06)

Period	Variance	Var. Ratio	Obs.
1	0.00020	--	1167
2	0.00013	0.64444	1166
4	6.3E-05	0.32288	1164
8	3.2E-05	0.16516	1160
16	1.6E-05	0.07942	1152