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Are BRICS Stock Market Indices Mean Reverting? Evidence Based on Expected Lifetime Range Ratio

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Abstract

We use the Expected Lifetime Range (ELR) Ratio proposed in Shaik and Maheswaran (2018) to find evidence of mean reversion in the BRICS stock markets indices. We divide the sample period into pre-crisis, crisis, and post-subprime crisis data sets. We find that the BRICS stock market indices show mean reversion from 2001 to 2018. While before the subprime crisis, the indices followed a random walk, after the subprime crisis, the BRICS stock markets show mean reversion behavior and have become more predictable. We also conduct the Lo and Mackinlay variance Ratio test and find that the Expected Lifetime Range Ratio is better at detecting the presence of mean reversion.

Key words: Mean Reversion; BRICS; Lo and Mackinlay Variance Ratio; Subprime Crisis; Expected Lifetime Range ratio

JEL classifications: C58; G10; G12; G14

1. Introduction

Financial markets are considered to be efficient if the underlying stock price process follows random walk behavior. This implies that it becomes impossible to predict the future price of an asset as every step in the random walk process is independent and stochastic in nature. Due to this, both informed and uninformed investors are unable to make abnormal profits. On the contrary, if the stock price process is mean-reverting, then there can be a possibility to predict the future price based on the existing available information. Therefore, the presence of mean reversion is a significant critique of the efficient market hypothesis. Hence, much research has been focused by the academicians and practitioners to understand whether asset returns mean revert or not.

Over the last few decades, in the literature, most of the researchers have used unit root tests, serial correlation tests, and spectral analysis to test for the presence of mean reversion. Cochrane (1988), Lo-Mackinlay (1988) developed the variance ratio tests, which have been further improved and extensively used to test if the increments in the price process are uncorrelated. Researchers have also used GARCH models to test for mean reversion in stock price processes.

In this paper, we use the Expected Lifetime Range (ELR) Ratio proposed by Shaik and Maheswaran (2018) to detect the presence of mean reversion. The ELR Ratio test statistic uses the extreme values of asset prices to detect mean reversion in stock returns, unlike the standard non-parametric tests such as, variance ratio tests, which only use closing price series. The idea is that the extreme values of asset prices do provide more information and are more efficient in capturing the mean reversion when compared to the tests based on closing prices alone.

Jim O'Neill coined the acronym 'BRIC' for the four major emerging economies viz. Brazil, Russia, India, and China. In 2010, after adding South Africa, it was renamed as BRICS. As these developing countries aim for economic co-operation, it is interesting to study if the financial markets of these countries follow any common characteristics. This study concentrates on the stock market indices of BRICS countries and seeks to analyze their behavior. The study also divides the data in pre-subprime crisis, the subprime crisis, and post-subprime crisis periods to test if the crisis caused any change in the stock market index behavior. We compare our results of the ELR Ratio to the Lo-Mackinlay test statistic and see how the stock indices in BRICS economies behave.

The rest of the paper is organized as follows. Section 2 briefly reviews the literature on this topic. In Section 3, we explain the methodology of ELR Ratio and the Lo-MacKinlay (LM) variance ratio statistic. In Section 4, we describe the data set analyzed in this study. In Section 5, we show the empirical evidence based on the data on the presence of mean reversion in the selected stock markets. In Section 6, we undertake a check on the robustness of our findings by analyzing sub-samples from before, during, and after the global financial crisis of 2008. Section 7, summarizes and

discusses the results. In Section 8, we conclude the article with the implications of our main findings.

2. Literature Review

'The stock market forecasters cannot forecast' was the conclusion drawn by Cowles 3rd (1933) after analyzing the performance of investment professionals. However, in the paper Cowles 3rd and Jones (1937) they found significant evidence of serial correlation in stock indices. Granger and Morgenstern (1963) found that in the short run, the series obeyed the random walk hypothesis, but that in the long run it does not. They also concluded that business cycles were of little or no importance.

Fama and French (1988) examined the auto-correlations of the NYSE portfolio returns. They concluded that mean-reverting price component dominates in the short run but, the random walk price component dominates in the long run. Samuelson *et al*. (1965) showed that a financial time series follows a random walk if it has a unit root component and also has a martingale property. The unit root tests are used to test for the first component, and the variance ratio tests are used for testing the martingale property, i.e., for testing for uncorrelated increments.

One of the most popular variance ratio tests has been the Lo and MacKinlay (1988) Variance Ratio test. This test is based on the fact that for a stock price series following random walk, the variance of the return will be linearly proportional to the return horizon. In that paper, the US stock market data for various holding periods from 1962-1985 was analyzed, and the random walk theory was strongly rejected. Poterba and Summers (1988) used variance ratio test to analyze the market returns of 18 countries and concluded that the returns are positively serially correlated (mean trending) in the short run and they are negatively auto-correlated (mean reversion) in the long run.

With increased globalization, there has been a greater interest in the emerging stock markets. Most institutional investors have invested a significant portion of their portfolios in emerging markets. Consequently, several researchers such as, Kawakatsu

and Morey (1999), Chaudhuri and Wu (2003), Nam *et al*. (2005), Liau and Yang (2008), Zhang and Li (2008) and Wang *et al*. (2015) have tested the emerging markets for efficiency and have found evidence both for and against the Efficient Market Hypothesis. An and Brown (2010) found that all the four BRIC stock index series were non-stationary. Tiwari and Kyophilavong (2014) found evidence of mean reversion in all the BRICS stock markets except Russia. Nalın and G¨uler (2015) conducted tested the behavior of BRIC-T countries from 1997-2013 found evidence that except China, all the countries showed non-stationary behavior. Hamid *et al*. (2017) performed variance ratio tests on 14 Asia-Pacific countries and found that for the period 2004-2009 none of the stock markets showed random walk behavior during that period. Shaik and Maheswaran (2017b) studied the emerging Asian stock markets based on unit root tests, which revealed that the stock prices followed a random walk for the period of study from 2001 to 2015. However, the random walk hypothesis was rejected in the post-subprime crisis period from 2008-2015.

In this paper, we extend the work done by Shaik and Maheswaran (2018) that uses the ELR Ratio test statistic to detect the presence of mean reversion. The ELR Ratio is based on the information of extreme values of asset prices in contrast to the other variance ratio tests available in the literature, which are based on only the closing prices. The paper theoretically demonstrates the superiority of the ELR Ratio over LM variance ratio test in detecting the presence of mean reversion. In this paper, we empirically test the results on BRICS stock market indices. We also perform a robustness check by conducting our empirical analysis in pre, crisis, and post-subprime crisis subsample periods. This also helps us to determine the impact of the global financial crisis of 2008 on the behavior of BRICS stock market indices.

3. Methodology

In this section, we discuss the two test statistics that were used in this paper to detect the presence of mean reversion in the global stock indices. The test statistics are expressed in terms of the Moving Average (MA) parameter ‘θ’ proposed by Shaik

and Maheswaran (2018). Please refer to Shaik and Maheswaran (2018) for detailed derivations of the methodology.

We first discuss the data generating process that has been specified to come up with the test statistics.

Let us consider a simple random walk process for 'N' steps as follows,

$$X_0=0$$
$$X_1=x_1$$
$$X_2=x_1+x_2$$
$$\vdots$$
$$X_N= x_1+x_2+\ldots.+x_n \quad (1)$$

Where, x_1,x_2, …., x_n are iid random variables.

We further assume that each x_i: i=1, 2, …, n follow as moving average MA(1) model with parameter 'θ' as follows

$$x_i= Z_i + \theta Z_{i-1} \ : i \geq 1 \text{ and } |\theta| \leq 1 \quad (2)$$

each Z_i is i.i.d ~ N(0,1).Under this specification, as the number of random walk steps 'N' tend to infinity, the classical Lo-Mackinlay variance ratio test statistic can be defined as

$$LM = \frac{(1+\theta)^2}{(1+\theta^2)} \quad (3)$$

Where θ = MA (1) parameter. The ELR Ratio can be expressed as

$$ELR = \frac{2(1+\theta)}{\sqrt{(1+\theta^2)}} \quad (4)$$

After conducting the bootstrap analysis, Shaik and Maheswaran (2018) found that the bootstrap mean values of LM and ELR test statistics are 1 and 2, respectively. Theoretically, the paper showed that if we consider the MA (1) parameter 'θ' to be fixed, then both LM and ELR risk measures can detect mean reversion. However, when we allow the MA (1) parameter 'θ' to be stochastic, then the ELR Ratio can detect mean reversion even when LM statistic cannot find the same.

We further discuss on how to use the test statistics empirically in a data set. Suppose {O, H, L, C} represent the open, high, low, and close prices of an asset. We compute the normalized returns using {O, H, L, C} prices as follows,

$$p_t = \ln(\frac{C_t}{O_t}) \tag{5}$$

$$q_t = \ln(\frac{H_t}{O_t}) \tag{6}$$

$$r_t = \ln(\frac{L_t}{O_t}) \tag{7}$$

To compute the LM statistic, we use the $\{p_t\}$ series which is based on opening and closing price series of an asset as follows,

$$LM = \left\{\frac{1}{N}\right\}\{\frac{variance\ (N-day)}{variance\ (1-day)}\} \tag{8}$$

Where,

$$variance|_{N-day} = \frac{1}{N}\sum_{t=1}^{N}(p_t - \mu)^2 \tag{9}$$

We calculate the ELR Ratio by using the $\{q_t, r_t\}$ series, which is based on opening, high and low price series of an asset.

$$ELR = \left\{\frac{1}{N}\right\}\{\frac{ELR|_{N-day}}{ELR|_{1-day}}\} \tag{10}$$

Where,

$$ELR|_{N-day} = E[q-r]|_{N-day} \tag{11}$$

We use the bootstrap technique as given in Efron and Tibshirani (1986) to calculate the bootstrap mean (bootmean) and bootstrap standard error (bootstd) for ELR Ratio and LM Ratio. To account for varying parameters, we use the *k*-day

horizon method. We calculate the ELR and LM variance ratios for *k*= 1 to 10-day horizons. Shaik and Maheswaran (2018) follow a similar technique.

We calculate the t-stat of both ELR and LM Ratios as

$$t - stat = \frac{Actual\ Ratio - Bootmean\ Ratio}{Boot\ standard\ error} \quad (12)$$

If the test statistic is negative and significant, the series is *mean reverting*. If the test statistic is positive and significant, it is *mean trending*. If the t-stat is not significant, then the series is exhibiting *random walk behavior*.

4. Data Description

The data set for this study consists of the daily opening, high, low, and closing prices of five emerging BRICS stock market indices viz. Brazil (IBOV), Russia (MOEX), India (NIFTY), China (SHCOMP) and South Africa (FTSE/JSE). The data period for this study is from January 01, 2001 to June 30, 2018. We obtained the data from the Bloomberg database.

We also divided the period into three subsamples in order to study if the global financial crisis of 2008 affected the efficiency of stock markets. Therefore, the first subsample is from January 01, 2001 to December 31, 2007, i.e., it is the pre-crisis period. The period from January 01, 2008 to May 31, 2009, was defined as 'crisis period' by the National Bureau of Economic Research. Hence, we consider it the crisis period and consider the post-crisis period from June 01, 2009 to June 30, 2018.

Table 1 reports the summary statistics of the data. We report the mean, median, standard deviation, skewness, and kurtosis of the daily close-to-close logarithmic returns of the BRICS stock indices for the period January 2001 to June 2018. All the stock indices are negatively skewed. The kurtosis is high for all the BRICS indices. The p-values reject the null hypothesis of the Jarque and Bera (1980) Test. Hence, all the stock indices have a non-normal distribution.

Table 1. Descriptive Statistics of Stock Market Index Returns for Period from Jan 2001 to June 2018.

	IBOV	MOEX	NIFTY	SHCOMP	FTSE/JSE
Mean	0.0004	0.0006	0.0005	0.0001	0.0004
Median	0.0007	0.0009	0.0009	0.0006	0.0007
Std. Dev.	0.0176	0.0199	0.0143	0.0159	0.0119
Skewness	-0.118	-0.259	-0.2921	-0.3809	-0.121
Kurtosis	7.2804	21.563	13.1433	7.7884	6.4553
Jarque-Bera Test	3323	61168	18749	4162	2189
Observations	4339	4257	4359	4249	4378

Source: Developed by authors

5. Empirical Works

We conducted an empirical analysis using the ELR Ratio and the LM Ratio on five emerging stock indices for the period January 2001 to June 2018. We also conducted a robustness check by dividing the sample into the pre-subprime crisis, the subprime crisis, and the post-subprime crisis sub-samples. Tables 2 to 9 report the results of the analysis.

5.1 Overall Sample Period

5.1.1 Expected Lifetime Range (ELR) Ratio

Table 2 reports the ELR Ratio statistics for the five stock indices for the overall sample period from January 01, 2001 to June 30, 2018. It is observed clearly from Figure 1 that the Actual ELR Ratio increases as the *k*-day horizon increases. We can see that the t-stats for all the stock market indices are significant at 5% level of significance. The statistics are also negative, which indicates that the mean of the actual ELR Ratio (Actual) is much less than its bootstrap mean (Boot) across all *k*-day horizons implying the presence of mean reversion. Hence, we observe that all five stock market indices reject the random walk hypothesis for all ten *k*-day horizons and that their prices are mean-reverting.

5.1.2 LM Ratio

Table 3 reports the LM Ratio statistics for the stock indices for the overall sample period from January 01, 2001 to June 30, 2018. Figure 2 shows that the LM Ratio decreases below one as *k*-day increases for all the stocks except for SHCOMP and NIFTY index. The IBOV had significant LM Ratio test statistics and hence rejected the random walk hypothesis. However, the t-stats for the other four stock indices, namely, MOEX, NIFTY, SHCOMP, and FTSE/JSE were not significant at 5% level of significance. Therefore, these four stock indices failed to reject the random walk hypothesis.

Table 2. Empirical Analysis of ELR Ratio Using Bootstrap Sampling for the Period: Jan 2001-Jun 2018

IBOV

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.06	1.07	0.00	-4.54**
3	1.08	1.11	0.01	-4.35**
4	1.09	1.13	0.01	-4.51**
5	1.10	1.15	0.01	-4.65**
6	1.11	1.16	0.01	-4.34**
7	1.11	1.17	0.01	-4.40**
8	1.12	1.17	0.01	-4.30**
9	1.12	1.18	0.01	-4.25**
10	1.13	1.19	0.01	-4.18**

MOEX

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.08	1.12	0.00	-7.90**
3	1.12	1.17	0.01	-8.19**
4	1.14	1.21	0.01	-7.60**
5	1.16	1.24	0.01	-7.14**
6	1.17	1.26	0.01	-6.92**
7	1.18	1.27	0.01	-6.60**
8	1.19	1.28	0.01	-6.40**
9	1.20	1.29	0.02	-6.19**
10	1.20	1.30	0.02	-6.05**

NIFTY

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.07	1.10	0.00	-7.57**
3	1.10	1.14	0.01	-6.44**
4	1.13	1.17	0.01	-5.92**
5	1.14	1.19	0.01	-4.99**
6	1.16	1.21	0.01	-4.73**
7	1.17	1.22	0.01	-4.19**
8	1.18	1.23	0.01	-3.96**
9	1.18	1.24	0.02	-3.52**
10	1.19	1.24	0.02	-3.27**

FTSE/JSE

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.000	NaN
2	1.12	1.15	0.01	-6.33**
3	1.17	1.21	0.01	-5.39**
4	1.20	1.24	0.01	-4.92**
5	1.22	1.27	0.01	-4.75**
6	1.24	1.29	0.01	-4.20**
7	1.25	1.31	0.01	-4.11**
8	1.26	1.32	0.02	-4.11**
9	1.26	1.33	0.02	-3.82**
10	1.27	1.34	0.02	-3.72**

SHCOMP

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.09	1.11	0.00	-5.76**
3	1.13	1.17	0.01	-6.06**
4	1.15	1.20	0.01	-5.58**
5	1.17	1.23	0.01	-5.58**
6	1.18	1.24	0.01	-5.21**
7	1.19	1.26	0.01	-4.91**
8	1.20	1.26	0.01	-4.49**
9	1.21	1.27	0.02	-4.01**
10	1.22	1.28	0.02	-3.86**

** indicates the level of significance at 5%.

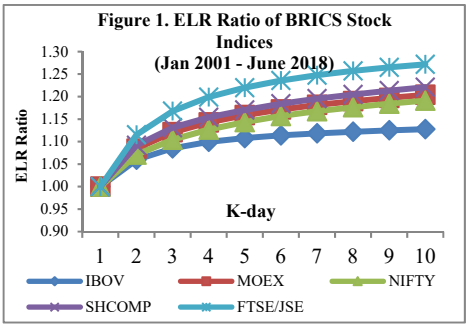


Table 3. Empirical Analysis of LM Ratio Using Bootstrap Sampling for the Period: Jan 2001-Jun 2018

IBOV

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.00	1.00	0.01	-0.01
3	0.98	1.00	0.02	-0.72
4	0.95	1.00	0.03	-1.59
5	0.93	1.00	0.03	-2.10**
6	0.91	1.00	0.04	-2.21**
7	0.90	1.00	0.04	-2.48**
8	0.88	1.00	0.04	-2.80**
9	0.87	1.00	0.05	-2.76**
10	0.86	1.00	0.05	-2.74**

MOEX

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.02	1.00	0.02	1.20
3	1.00	1.00	0.02	0.11
4	0.98	1.00	0.03	-0.72
5	0.97	1.00	0.03	-0.84
6	0.96	1.00	0.04	-1.05
7	0.95	1.00	0.04	-1.11
8	0.95	1.00	0.05	-1.14
9	0.94	1.00	0.05	-1.24
10	0.93	1.00	0.05	-1.29

NIFTY

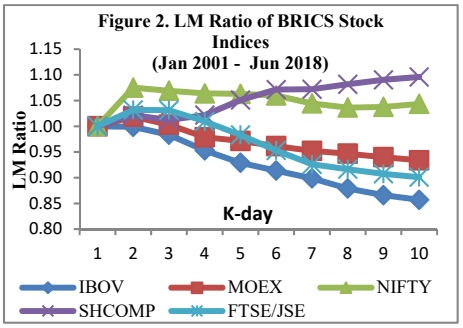
k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.08	1.00	0.01	5.15**
3	1.07	1.00	0.02	3.09**
4	1.06	1.00	0.03	2.17**
5	1.06	1.00	0.03	1.81
6	1.06	1.00	0.04	1.52
7	1.04	1.00	0.04	1.01
8	1.04	1.00	0.04	0.81
9	1.04	1.00	0.05	0.79
10	1.04	1.00	0.05	0.83

FTSE/JSE

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.03	1.00	0.02	2.01**
3	1.03	1.00	0.02	1.42
4	1.01	1.00	0.03	0.30
5	0.98	1.00	0.03	-0.59
6	0.95	1.00	0.04	-1.26
7	0.93	1.00	0.04	-1.84
8	0.92	1.00	0.04	-1.93
9	0.91	1.00	0.05	-1.93
10	0.90	1.00	0.05	-1.92

SHCOMP

k	Actual	Boot	Bootstd	t-stat
1	1.00	1.00	0.00	NaN
2	1.02	1.00	0.02	1.42
3	1.01	1.00	0.02	0.55
4	1.02	1.00	0.03	0.72
5	1.05	1.00	0.03	1.56
6	1.07	1.00	0.04	1.85
7	1.07	1.00	0.04	1.78
8	1.08	1.00	0.05	1.81
9	1.09	1.00	0.05	1.85
10	1.10	1.00	0.05	1.83



** indicates the level of significance at 5%.

5.1.3 Comparative Analysis

We observe that the ELR Ratio can reject the null hypothesis of random walk behavior even when the LM Ratio cannot. Therefore, the ELR Ratio is better at detecting non-random walk behavior than the LM Ratio.

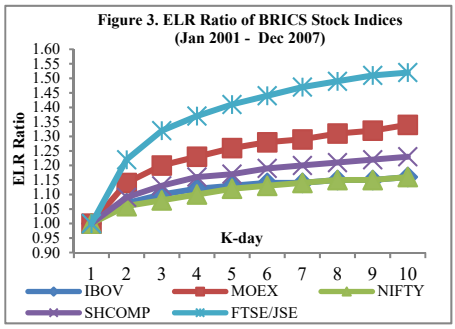
6. Robustness Check

In this section, we check the robustness of our findings by analyzing the subsamples. We divide our total sample into pre-crisis[1] (January 01, 2001 to December 31, 2007), crisis[2] (January 01, 2008 to May 31, 2009) and post-subprime crisis[3] (June 01, 2009 to June 30, 2018) periods.

6.1 Pre-crisis Period

6.1.1 Expected Lifetime Range (ELR) Ratio

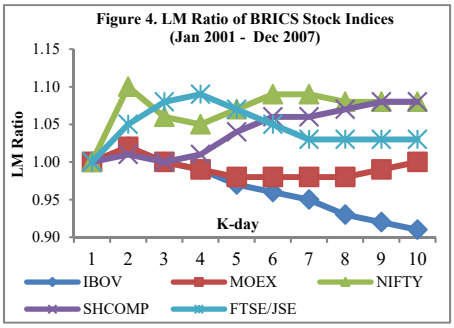
The t-stats of all the BRICS stock indices are not significant at 5% level of significance for any *k*-day horizon. Therefore, all the indices show random walk behavior in the pre-crisis period. Figure 3 shows that the ELR Ratio increases as *k*-day horizon increases.



Note: [1,2,3] The Tables for the empirical analysis of ELR and LM statistics based on the bootstrap methods for pre-crisis period, crisis and post-subprime crisis periods will be provided upon request to the authors. We have removed from the original paper due to the space constraints.

6.1.2 LM Ratio

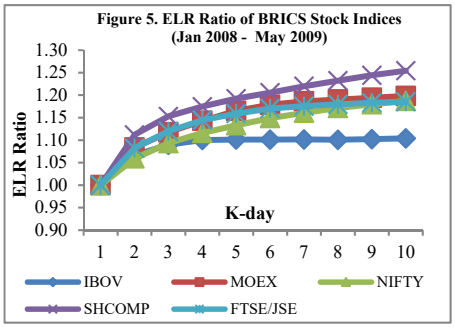
LM Ratio too indicates that the BRICS indices show random walk behavior in the pre-crisis period. Figure 4 shows the movement of LM Ratio over the *k*-day horizon.



6.2 Crisis Period

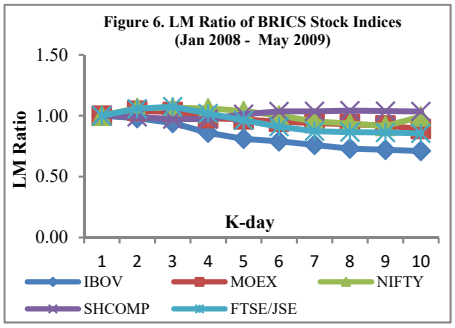
6.2.1 Expected Lifetime Range (ELR) Ratio

During the crisis period, IBOV and MOEX show presence of mean reversion and remaining indices show random walk behavior. Figure 5 shows the movement of the ELR Ratio over the *k*-day horizons.



6.2.2 LM Ratio

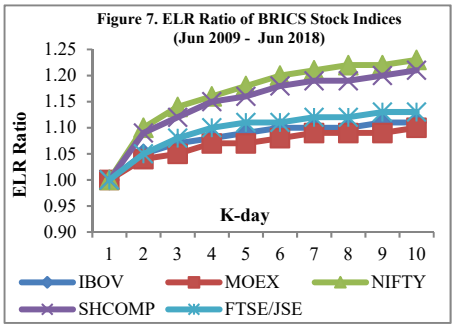
None of the five BRICS stock indices reject the random walk hypothesis during this period. Figure 6 shows the movement of LM Ratio over the *k*-day horizon.



6.3 Post-crisis Period

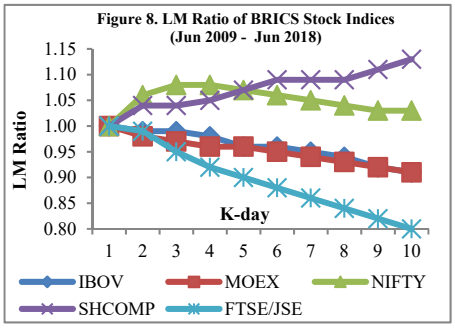
6.3.1 Expected Lifetime Range (ELR) Ratio

Figure 7 shows that the ELR Ratio remains more than one over the *k*-day horizon for all the BRICS stock indices. The random walk hypothesis cannot be rejected only for the NIFTY index as the t-stats are not significant at 5% level. Hence, the NIFTY index shows random walk behavior while the other four indices show the presence of mean reversion.



6.3.2 LM Ratio

In this period, only the FTSE/JSE index rejects the null hypothesis of random walk, while the other four indices show random walk behavior. Figure 8 displays the LM Ratio over the *k*-day horizon for all the BRICS stock market indices.



7. Summary and Discussion

Table 4. Summary Table

	Overall Sample	Pre-Crisis	Crisis	Post-Crisis
ELR Ratio	Mean Reversion	Random Walk	Random Walk#	Mean Reversion*
LM Ratio	Random Walk +	Random Walk	Random Walk	Random Walk ^

Except for IBOV and MOEX stock indices as they follow mean reversion
* Except NIFTY stock index as it follows random walk behavior after k=4 day horizon.
+ Except IBOV stock index as it follows mean reversion behavior after k=5 day horizon
^ Except for FTSE/JSE stock index as it follows mean reversion after k=4 day horizon

We have used the ELR Ratio statistic to detect mean reversion in stock prices using high and low prices. We also compare the results with that of the LM variance ratio, which is based on the closing prices of stocks. We analyze five emerging BRICS stock indices for the period from January 01, 2001 to June 30, 2018. The results indicate that all the five stock indices showed mean reversion in this period based on the ELR Ratio even though LM Ratio is not able to detect the same. The results of the ELR Ratio test statistic concurred with the findings of Tiwari and Kyophilavong (2014), Hamid *et al.* (2017) and Shaik and Maheswaran (2017b).

To check for the robustness of our findings, we divided our sample period into pre, crisis, and post-subprime crisis subsamples. In the pre-subprime crisis period, both, the ELR Ratio and the LM Ratio test statistics have found that stock indices follow random walk behavior based on the *k*-day analysis. However, in the crisis period, the ELR Ratio test statistic found that IBOV and MOEX show mean reversion while the LM Ratio indicated that all indices show random walk behavior. Similarly, in the post-crisis period, the ELR Ratio has found evidence of mean reversion in all the BRICS stock indices except for NIFTY, whereas, the LM Ratio statistic has failed to detect mean reversion in all the five stock indices. Therefore, based on our empirical study on BRICS stock indices, we can see that the ELR Ratio is better than the LM Ratio at detecting the presence of mean reversion in a data series. We observe that after the subprime crisis of 2008, most stock indices show the presence of mean reversion, which implies that the stock index prices have become more predictable. Therefore, these results indicate that contrary to Granger and Morgenstern (1963), the business cycle does affect the behavior of stock prices.

8. Conclusion

This study proposes a new test statistic to detect the presence of mean reversion using high and low prices. We plan to study the properties of this test statistic and to test its asymptotic distribution as a part of future research. The results of this study indicate that the stock prices can be predicted and hence that technical trading can be profitable. The study is relevant to the practitioners and the policymakers who would like to understand the market efficiency of the BRICS stock market indices. Further research can be conducted to understand the spillover effect between the developed nations and the emerging markets.

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