Revisiting the Weak Form Efficiency with Structural Breaks : Evidence from the Indian Stock Market

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Abstract

This study investigated the weak form efficiency in the Indian stock market after accounting for structural breaks. The parametric and non - parametric Wright (2000) sign variance ratio test and its multiple variance ratio extensions, after accounting for structural breaks based on Bai and Perron (2003), were used in this study. This study found that the large, middle, and small capitalization indices were not weak form efficient based on the variance ratio tests on daily data for the 2000 - 2017 period. However, once the structural breaks were accounted for, this study found the large capitalization indices to be weak form efficient. However, the middle and small capitalization indices were not weak form efficient, even after accounting for structural breaks. The notion of adaptive or evolving market efficiency was also supported in this study. The traders will not get abnormal economic profits by trading in the large capitalization space. However, outside the large capitalization space, there is potential for abnormal economic profits. This study supports the assertion that if the structural breaks were not considered, weak form of market efficiency tests might give misleading results. The present study is different from most other studies in the Indian market by accounting for the structural breaks in the weak form of efficiency tests.

Keywords : weak form market efficiency, variance ratio, structural breaks, India

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The Martingale test has received enormous attention in financial economics because of the efficient market hypothesis (EMH). EMH is one of the most debated concepts, which has dominated economics and finance in the past decades and is central to both theoretical and empirical finance. Though the concept was around in some form or the other since 1900 (Bachelier), it was Fama (1970) who formalized and operationalized the concept in his seminal survey and defined an efficient market [1] as one in which any new information is quickly and fully reflected in the security prices. According to Bekaert and Harvey (2000), informational efficiency is important to the relationship uniting the stock markets and economic growth in the emerging markets like India. According to the weak form of EMH, the current asset prices already reflect past prices. The interpretation of this efficient price signals by the rational market agents leads to optimal allocation of savings. A well-functioning market plays a critical role in allocation of the nation's resources and savings between various industries and companies for investment in productive assets, thereby improving and sustaining the

[1] Though there are other efficiencies like the operational efficiency and the allocational efficiencies, the object of interest is the informational efficiency.

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growth prospects of a company. Further, it has implications on the market structure, cost of capital, portfolio management, etc.

According to Fama (1970), in an efficient market, the past prices cannot be used to forecast future prices. The empirical investigation from that time focused upon this aspect of forecasting and Campbell, Lo, and MacKinlay (1997) stated that the random walk and the Martingale model grew directly out of the idea that past prices cannot be used to forecast future prices. They also outlined the three versions of the random walk hypothesis. The random wall 1 model (IID increments) is the independently and identically distributed version, where :

$$P_t = \mu + P_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim IID\,(0\,,\sigma^2) \qquad (1)$$

where, μ is the expected price change and $IID\,(0, \sigma^2)$ means that ε_t is independent and identically distributed with mean 0 and variance σ^2. Not only the increments are linearly uncorrelated, but also any non - linear functions of the increments are uncorrelated.

The random walk 2 model (independent increments) relaxes the assumption of identical distribution and allows for unconditional heteroskedasticity in the asset prices. The random walk 3 model (uncorrelated increments) is the least restrictive of the three versions relaxing the independence assumption also and includes asset prices with dependent but uncorrelated increments. In this study, only the random walk 3 model or the 'Martingale model' (Martingale difference series - MDS) is tested and the only assumption that needs to be satisfied is covariance Cov $\{\varepsilon_t , \varepsilon_{t-k}\} = 0$ for all $k \neq 0$ (uncorrelatedness) but not Cov $\{\varepsilon^2_t , \varepsilon^2_{t-k}\} \neq 0$ for some $k \neq 0$. The basic premise of the Lo and MacKinlay (1988) 'variance ratio test' (VR test) is that under random walk, the variance of the *n*th period return is equal to *'n'* times the variance of the one period return. The later innovations in the VR test are the more powerful non - parametric Wright (2000) rank and signs VR tests and the multiple variance ratio tests.

The focus has shifted from the developed markets to the emerging markets in the recent years. In the Asian markets, Hoque, Kim, and Pyun (2007) examined the random walk hypothesis for eight emerging equity markets in Asia using the Wright's rank and sign and Whang - Kim sub - sampling tests as well as the conventional Lo - MacKinlay and the multiple variance ratio Chow - Denning tests and evidenced that except for Taiwan and Korea, the random walk assumption was rejected for all the stock market indices of the other six countries. Kim and Shamsuddin (2008) tested the Asian markets using the variance ratio test based on the non - parametric wild bootstrap and signs as they are finite sample tests, which do not rely on large sample theories for statistical inference. They found that the Hong Kong, Japanese, Korean, and Taiwanese markets were efficient in the weak-form compared to the markets of Indonesia, Malaysia, and Philippines. Charles and Darne (2009) examined the random walk hypothesis for the Shanghai and Shenzhen stock markets for both A and B shares using daily data over the period from 1992 - 2007 using the multiple variance ratio tests, including the conventional multiple Chow- Denning test. They evidenced that while the Class B shares for Chinese stock exchanges did not follow the random walk hypothesis, the Class A shares seemed more efficient. Al - Khazhali, Ding, and Pyun (2007) studied the Middle East and North African stock markets using Wright's (2000) rank and sign test and evidenced mixed results, but most importantly suggested that the non-parametric rank and sign tests were more suited for the emerging markets. Bley (2011) analyzed the Gulf stock markets using daily, weekly, and monthly index data for the 10-year period between 2000 and 2009 with both homoskedastic and heteroskedastic assumptions and rejected the random walk for the daily data, but not for the weekly and monthly data. Smith (2009) tested the Martingale hypothesis in the European emerging stock markets using joint variance ratio tests based on signs and the wild bootstrap for the period from 1998 - 2007 and opined that size, liquidity, and the quality of the market were important for MDS returns.

In the Indian stock market, Hiremath and Kamiah (2010) studied the weak form efficiency of the major stock indices using the conventional Lo - MacKinlay and the multiple variance ratio Chow - Denning extension and concluded that generally, the large cap indices were efficient compared to the mid-cap and small-cap indices. Hiremath and Kumari (2014) studied the linear and non - linear dependence between 1991 and 2013 in the Indian stock market and found support for evolving market efficiency in the Indian stock market.

Charles and Darne (2009) observed that the possible presence of structural breaks might affect the variance ratio tests. Narayan and Smyth (2007) examined the stock price data of the developed countries, namely, the G-7 countries using unit root tests accounting for structural breaks and found that the weak form efficiency was supported for all the countries except for Japan. Mishra, Mishra, and Smyth (2015) studied the high frequency data in the Indian stock market using unit root tests with structural breaks and contended that such studies, without considering a structural break, will be prone to errors. Structural breaks happen due to policy changes, war, depression, shifts in trade patterns, etc.

The aim of this paper is to examine the weak form EMH of the major stock indices in the Indian stock market during the 2000 - 2017 period with daily data using the parametric and non-parametric Wright (2000) sign variance ratio test and its multiple variance ratio extensions after accounting for structural breaks.

There are several motivations for this study. The Indian equity market became the fifth largest in the world by the end of 2018 in terms of both traded value and market capitalization and is one of the fastest growing economies in the world. The increasing international portfolio investment and participation provides a perfect platform for gathering information about the market structure, efficiency, and evidence of the integration mechanism with the developed markets.

Mishra et al. (2015), Parthasarathy (2013), and Mangala and Lohia (2017), using different methodologies, found evidence for rejection of weak form of market efficiency in the Indian stock market. Ryaly, Kumar, and Urlankula (2014) and Ryaly, Raju, and Urlankula (2017) proved the existence of weak form of market efficiency in the Indian stock market. The findings based on prior studies have been mixed, and so, based upon empirical evidence, the issue of weak form of efficiency has not been decided conclusively. Most of these tests employed either the unit root tests with or without structural breaks or the variance ratio tests without structural breaks. Most studies use long periods of data without accounting for structural breaks. The failure to account for structural breaks might be the reason for such mixed results.

This study attempts to bridge this gap by examining the weak form of market efficiency in the Indian stock market using daily data and by using the parametric and non - parametric Wright (2000) sign variance ratio test and its multiple variance ratio extensions after accounting for structural breaks. This methodology not only has better size and power properties than other tests, but also addresses the issue of heteroskedasticity. Further, I distinguish my study from all the other studies in the Indian market by accounting for the structural breaks in the weak form efficiency or the Martingale tests, with daily data, using the Bai and Perron (2003) generalized structure for analyzing the structural breaks. I also form sub - samples based on break points and apply the variance ratio tests on the sub - samples and compare the results with full sample to ascertain the impact of considering such structural breaks on the results.

This study also extends the literature to the studies of market efficiency in the emerging markets in a general way as prior studies in emerging markets have also evidenced mixed results. The evidences in developed markets generally support market efficiency ; whereas, the evidences in emerging markets are mixed. This study also extends the literature by analyzing the most recent data.

Methodology

X_t is a martingale if,

$$E\,[X_{t+1}|\ \{X_t, X_{t-1},..\}] = X_t \qquad (2)$$

The behavior of the major indices in the Indian stock market is examined by the parametric Lo and MacKinlay (1988) tests, non - parametric Wright (2000) rank and sign tests, and the Chow - Denning (1993) multiple variance ratio (VR) tests. The basic premise of the VR test is that under random walk, the variance of the n^{th} period return is equal to 'n' times the variance of the one period return.

The hypotheses statements are :

- **H_0 :** The index series is not a martingale difference series (MDS).
- **H_1 :** The index series is a martingale difference series.

Let $\{y_1\}$ denote a time series consisting of T observations $y_1, \ldots, y_t$ of asset returns. The variance ratio of the k-th difference is defined as :

$$V\,R(k) = \frac{\sigma^2(k)}{\sigma^2(1)} \qquad (3)$$

$VR(k)$: is the variance ratio of the index k-th difference.

$\sigma^2(k)$: is the unbiased estimator of $1/k$ of the variance of the index k-th difference under the alternate hypothesis.

$\sigma^2(1)$: is the variance of the first-differenced index series.

k : is the number of days of base observations interval or the difference interval.

Following Lo and MacKinlay (1988), the estimator of the k-period difference, $\sigma^2(k)$, is calculated as :

$$\sigma^2(k) = \frac{1}{k(T - k + 1)\,(1 - k/T)} \sum_{t=k}^{T} (y_t + \ldots + y_{t-k+1} - k\hat{\mu})^2 \qquad (4)$$

where,

$$\hat{\mu} = \frac{1}{T} \sum_{t=1}^{T} y_t\,,$$

The unbiased estimator of the variance of the first difference, $\sigma^2(1)$, is computed as follows :

$$\sigma^2(1) = \frac{1}{T} \sum_{t=1}^{T} (y_t - \hat{\mu})^2 \qquad (5)$$

Lo and MacKinlay (1988) showed that under IID assumptions :

$$M_1(k) = \frac{VR(k) - 1}{\phi(k)^{1/2}} \text{ (asymptotically distributed as } N\,(0,1)) \qquad (6)$$

The asymptotic variance, $\varphi(k)$, is given by:

$$\phi(k) = \frac{2(2k-1)\,(k-1)}{3kT} \qquad (7)$$

Lo and MacKinlay (1988), in order to account for asset returns' empirical departures from normality, developed a statistic robust to many forms of heteroskedasticity :

$$M_2(k) = \frac{VR(k)\text{-}1}{\phi^*(k)^{1/2}} \text{(asymptotically distributed as } N\,(0,1)) \tag{8}$$

where,

$$\phi^*(k) = \sum_{j=1}^{k-1}\left[\frac{2(k\text{-}j)}{k}\right]^2 \partial(j) \tag{9}$$

$$\delta(j) = \sum_{t=j+1}^{T} \frac{(y\text{-}\hat{\mu})^2\,(y_{t-j}\text{-}\hat{\mu})^2}{[\left(\sum_{t-1}^{T}(y_t\text{-}\hat{\mu})^2\right)^2} \tag{10}$$

Charles and Darne (2009) noted that the Lo - MacKinlay tests being asymptotic tests, whose sampling distribution is approximated, based on its limiting distribution, were biased and right skewed in finite samples. Wright (2000) proposed the use of signs and ranks where ranks and signs are substituted in place of the differences in the Lo and MacKinlay tests and have an exact distribution. Wright showed that his non - parametric variance ratio tests, based on ranks (R_1 and R_2) and signs (S_1 and S_2), have better size and power properties to examine the random walk / martingale hypothesis than the tests suggested by Lo and MacKinlay for many processes. Wright's proposed R_1 and R_2 are defined as:

$$R_1 = \left(\frac{\frac{1}{Tk}\sum_{t=kj}^{T}(r_{1,t} + ... + r_{1,t\text{-}k+1})^2}{\frac{1}{T}\sum_{t=1}^{T} r_{1,t}^2} \text{-}1\right) \times \phi(k)^{\text{-}1/2} \tag{11}$$

$$R_2 = \left(\frac{\frac{1}{Tk}\sum_{t=kj}^{T}(r_{2t} + ... + r_{2,t\text{-}k+1})^2}{\frac{1}{T}\sum_{t=1}^{T} r_{2,t}^2} \text{-}1\right) \times \phi(k)^{\text{-}1/2} \tag{12}$$

where, $r_{1t} = \left(r\left(y_t - \frac{T+1}{2}\right)\right) \Big/ \sqrt{\frac{(T\text{-}1)\,(T+1)}{12}}$

$r_{2t} = \Phi^{\text{-}1}(r(y_t) \,/\, (T+1)).$

$\varphi(k)$ is defined in (5), $r\,(y_t)$ is the rank of y_t among $y_1, \ldots, y_T$, and Φ^{-1} is inverse of the standard normal cumulative distribution function. The test based on the signs of returns rather than ranks is given by :

$$S_1 = \left(\frac{\frac{1}{Tk}\sum_{t=k}^{T}(S_t + ... + S_{t\text{-}k+1})^2}{\frac{1}{T}\sum_{t=1}^{T} S_t^2} \text{-}1\right) \times \phi(k)^{\text{-}1/2} \tag{13}$$

where, $\varphi(k)$ is defined in (5), $st = 2u(yt, 0)$, $s_t(\overline{u}) = 2\overline{u}(y_{t,.}(\overline{u}))$, and

$$\mu(x_t, q) = \begin{cases} 0.5 \text{ if } x_1 > q, \\ \text{-}0.5 \text{ otherwise} \end{cases}$$

Thus, S_1 assumes a zero drift value.

According to Chow and Denning (1993), failing to control the joint test size for these estimates results in very large Type I errors. They extended the Lo and MacKinlay (1988) methodology and provided a simple modification for testing multiple variance ratios. Collatez (2005) and Kim and Shamsuddin (2008) proposed their extension of the Chow - Denning (1993) multiple variance ratio test to Wright (2000) rank and sign based tests. Luger (2003) suggested the application of Chow - Denning multiple variance ratio modification to Wright (2000) individual rank and sign variance ratio tests, and Hung, Lee, and Pai (2009) applied and asserted that this methodology provided unambiguous conclusion regarding weak market efficiency.

Chow and Denning (1993) (CD) proposed the multiple VR test incorporated with studentized maximum modulus (SMM) critical values to control overall test size for the VR test statistics under different time period q. Under the alternate hypothesis, for a single VR test, VR (q) =1, and $M_r(q)$ = VR (q) -1 = 0. Now consider a set of m VR tests $\{M_r(q_i) \mid I = 1,\ldots, m\}$, where $\{q_i \mid {}_i =1,\ldots, m\}$ and $\{q_i \geq 1, q_i \neq q_j \mid q_i \in N\}, \forall_i \neq j$. Under the specification, the random walk alternate hypothesis consists of m sub-hypotheses:

$$H_{oi} : M_r(q_i) = 0 \text{ for } i = 1,\ldots, m$$

$$H_{oi} : M_r(q_i) \neq 0 \text{ for any } i = 1,\ldots, m \qquad (14)$$

Rejection of any sub-hypothesis H_{oi} will lead to the turndown of RWH. Consider five sets of above mentioned test statistics, $\{Zj(q_i) \mid i = 1, \ldots , m), \{R_j /q_i) \mid i = 1,\ldots , m\}$ for j=1,2 and $\{S_1(q_i) \mid i = 1,\ldots m\}$.. Since the RWH is rejected if any of the estimated VR ratios is significantly different from one, Chow and Denning (1993) reconstructed the test statistics under the multiple specifications. The multiple VR test is based on the following inequality :

$$P_r[\max(\mid z_1 \mid, \ldots , \mid z_m \mid) \leq SMM(\alpha ; m ; N)] \geq (1 - \alpha) \qquad (15)$$

where, $\{z_i \mid i = 1, \ldots, m\}$ is a set of m standard normal variates, SMM (α ; m ; N) is the upper α point of the SMM distribution with parameter m and N (sample size) degrees of freedom. Asymptotically, when N goes infinite, SMM $(\alpha ; m ; \infty) = Z_{\alpha+/2}$, where $\alpha + = 1 - (1 - \alpha)^{1/m}$.

The modified VR test statistics, based on Lo and MacKinlay (1988), Chow and Denning (1993), and Wright (2000) are given below :

$$Z_j^*(q) = \max_{1\leq i\leq m} \mid Z_j(q_j) \mid \text{, for } j = 2 \qquad (16)$$

$$R_j^*(q) = \max_{1\leq i\leq m} \mid R_j(q_j) \mid \text{, for } j = 1, 2 \qquad (17)$$

$$S_j^*(q) = \max_{1\leq i\leq m} \mid S_j(q_j) \mid \text{, for } j = 1 \qquad (18)$$

where the critical values of $Z_j^*(q)$ are based on the above mentioned SMM distribution. Under the *iid* assumption 0 (i.i.d. first differences) in Wright (2000), the test statistics of $R_j^*(q)$ are distributed as :

$$\max \mid R_j^{\dagger}(q_1) \mid, \mid R_j^{\dagger}(q_2) \mid, \ldots, \mid R_j^{\dagger}(q_m) \mid \qquad (19)$$

where, $R_j^{\dagger}(q_1)$ is the ranks - based test computed with any random permutation of the elements $\{y_t\}_{t=1,}^{T}$, each element is 1 with probability ½ and -1 otherwise. Therefore, the exact sampling distribution of $R_j^{\dagger}(q)$ and $S_j^*(q)$ (j = 1, 2) can be simulated with any arbitrary degree of accuracy. The CD modified VR statistics under multiple specifications are $M^{cd}{}_2$, $R^{cd}{}_1$, $R^{cd}{}_2$, and $S^{cd}{}_1$ for M_2, R_1, R_2, and S_1, respectively. Only the M_2 and S_1 are reported because of the MDS hypothesis.

Many studies including Lo (2004) showed that financial return predictability varies over time and other studies like Charles, Darne, and Kim (2011) and Lazar, Todea, and Filip (2012) also showed the importance of structural changes in analyzing the weak form efficiency. Many tests for structural changes have been proposed in the econometrics literature and can be divided into (a) single structural change and (b) multiple structural change tests. In this study, I analyze the weak form efficiency of the major indices in the Indian stock market based on multiple structural changes determined endogenously. Bai and Perron (2003) developed three steps or tests to estimate the multiple structural breaks in a time series. At first, the 'sup' F type test of structural stability against the alternate hypothesis of no structural breaks is tested. Once the null is rejected, Bai and Perron (2003) suggest robustness check using the statistical significance at the 5% level of the 'double maximum tests' 'UDmax' and 'WDmax' statistic to see if atleast one break is present. Once the presence of break is corroborated, the number of breaks and the dates are ascertained from the sequential procedure (at the 5% level of significance).

Results and Discussion

(1) Data Description and Descriptive Statistics : The NIFTY and SENSEX indices of the NSE (National Stock Exchange) and the BSE (Bombay Stock Exchange) are chosen as the large cap indices. The BSE (Bombay Stock Exchange) S&P BSE Midcap index and S&P BSE Smallcap index are chosen as the mid-cap and small-cap indices, respectively. The large capitalization indices, Nifty and Sensex, represent the 50 large, liquid stocks and 30 fifty large, liquid stocks in the Indian stock market, respectively. The S&P BSE Midcap index and the Smallcap index represent the middle capitalization stocks and the S&P BSE Smallcap index represents the smaller capitalization stocks. The sample period for the Nifty and Sensex indices runs from 01 January 2000 to 31 December 2017 (daily data). While the sample period for the S&P BSE Midcap and S&P BSE Smallcap indices runs from April 1, 2003 to December 31, 2017 (daily data). The publicly available daily data from the NSE and BSE websites are used in this study.

The Table 1 reports the descriptive statistics of all the return series. The large-cap indices exhibit the least skewness and kurtosis. Though all the return series are negatively skewed and leptokurtic, the skewness is more negative for the mid and small cap indices compared to the large cap index. However, the Jarque - Bera statistics indicate that none of the tested return series follow normal distribution. Though the Ljung - Box tests suggest that all the tested indices are characterized by serial correlation, Lo and MacKinlay (1988) showed that VR tests are more powerful and robust tests.

Table 1. Basic Statistics

INDEX	CNX Nifty	BSE Sensex	BSE Mid-Cap	BSE Small-Cap
		Panel A - Daily Data		
Observations	4482	4482	3667	3667
Mean	0.000421	0.000412	0.000814	0.000856
Median	0.000904	0.000945	0.002198	0.002403
Std. Deviation	0.014799	0.014833	0.014225	0.014997
Skewness	-0.28914	-0.20421	-1.05752	-1.00266
Kurtosis	11.77206	10.633	11.44598	8.643506
Jarque Bera	14432.7**	10911.7**	11582.84**	5480.70**
Ljung Box $Q(10)$	880.72**	858.91**	650.66**	610.92**
Ljung Box $Q(20)$	925.19**	890.68**	674.95**	632.2**

Note. Returns are computed as log return of closing prices. ** represents significance at the 5% level. Under normal distribution, skewness = 0 and kurtosis = 3.

(2) Single and Multiple VR Test - Daily Data for the Complete Period : The Table 2 reports the results of the single VR statistics namely, M_2, and S_1 using daily data. The time intervals representing day, week, fortnight, and month (q = 2, 5, 10, and 20) are studied as in many other similar studies. The parametric Lo and MacKinlay (1988) M_2 is reported as it is robust to conditional heteroskedasticity. The alternate hypothesis is that the time series is a martingale difference series (MDS), which is a necessary condition for weak form efficiency. If the null hypothesis is accepted, the tested series is not weak form efficient. The results in Panel A indicate that based on M_2 and S_1, the null of 'not a *MDS*'[2] is accepted for both the large cap indices Nifty and Sensex. There is much stronger acceptance in the case of the midcap and smallcap indices. Wright (2000) also showed that sign based S_1 is exact and robust to many forms of conditional heteroskedasticity.

The variance ratio is calculated at various intervals, namely q = 2,5,10, and 20. The null of 'not a martingale series' is accepted for q = 2 for the Nifty index and q = 2 and 5 for Sensex and Midcap index at the 5% level of significance. For the Smallcap index, M_2 accepts the null of 'not a MDS' at the 5% level for q = 2, 5, 10, and 20. The sign based test S_1 accepts the null of 'not a MDS'at the 5% level for q = 2, 5, 10, and 20 for all the tested indices. The acceptance by the heteroskedasticity robust M_2 and the sign based test S_1 confirm that the acceptances are not due to conditional heteroskedasticity. Though the acceptance is stronger in the case of midcap and smallcap indices than the large-cap indices, the single VR tests accept the null of 'not a MDS' for all the indices using daily data. The results imply that all the tested indices namely, Nifty, Sensex, Midcap, and Smallcap indices are not weak form efficient.

Chow and Denning (1993) and others have argued that single VR tests lead to over-rejection of the alternate hypothesis when the joint test size is not controlled. Chow and Denning (1993) showed that failing to control the joint test size for these estimates results in very large Type I errors and suggested the multiple VR test incorporated with studentized maximum modulus (SMM) critical values to control overall test size for the VR test statistics.

Table 2. Individual VR and CD Multiple Variance Ratio Tests Using Daily Data for the Major Stock Indices in the Indian Stock Market (Full Period - 2000 - 2017)

Panel A. Individual VR Tests Using Daily Data								
	Large Capitalization Indices				Secondary Indices			
	NIFTY		SENSEX		MIDCAP		SMALLCAP	
q	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1
2	2.773**	5.380**	5.116**	4.857**	2.645**	5.800**	5.557**	5.938**
5	1.358	3.925**	3.157**	4.574**	2.063**	5.218**	4.668**	5.997**
10	0.521	2.728**	1.775	3.926**	1.358	4.364**	3.553**	5.640**
20	0.783	2.083**	1.374	3.944**	1.623	3.832**	3.199**	5.422**

Panel B. CD Multiple VR Tests Using Daily Data							
NIFTY		SENSEX		MIDCAP		SMALLCAP	
M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1
2.773**	5.380**	5.116**	4.857**	2.645**	5.800**	5.557**	5.997**

Note. The VR statistic is based on Lo - MacKinlay M_2 and Wright's (2000) sign S_1 using daily data of the major indices of the Indian stock market for the period from 2000-2015. The data for the BSE Midcap and Smallcap indices are from 2003 to 2017. Panel A reports the individual VR statistics and Panel B reports the Chow - Denning multiple VR statistics. The statistics M^{cd}_2 and S^{cd}_1 represent the CD extension to M_2 and S_1, respectively. The significance at the 5% level is indicated by **.

[2] The Wright (2000) rank based tests also (not shown in the table) accept the null of 'no' random walk.

Colletaz (2006) and Kim and Shamsuddin (2008) proposed their extension of the Chow-Denning (1993) multiple variance ratio test to Wright (2000) rank and sign based tests. I also use the multiple variance - ratio extension to the Wright (2000) rank and sign based tests as the existing literature has shown that these tests are more powerful and robust for testing the weak form of market efficiency. The statistics M^{cd}_2 and S^{cd}_1 represent the CD extension to M_2 and S_1, respectively.

The Table 2, Panel B reports the multiple VR statistics for large-cap indices in the Indian stock market. The CD multiple VR statistics M^{cd}_2 and S^{cd}_1 accept the null of 'not a MDS' for all the tested indices at the 5% level. The multiple VR results support the individual VR results that all the tested indices, including large capitalization indices, are not weak form efficient.

The complete 18 year sample is divided into four equal periods [3] and the Table 3 reports the results of the individual VR tests and the multiple VR tests of the Periods I and IV only for brevity. The null of 'not a MDS' is accepted for both the NIFTY and SENSEX at the 5% level for Periods I, II, and IV. The null of 'not a MDS' is accepted for both the midcap and smallcap indices at the 5% level for all the periods. The interesting part is the stronger acceptance in the last period compared to the first period for all the indices.

Table 3. Individual VR and CD Multiple Variance Ratio Tests Using Daily Data Divided into Four Equal Periods for the Major Stock Indices in the Indian Stock Market

	NIFTY				SENSEX			
	Period 1		Period 4		Period 1		Period 4	
q	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1
2	1.409	3.783**	0.153	2.550**	0.848	3.664**	3.069**	2.970**
5	0.568	3.524**	-0.393	1.972**	0.511	3.133**	1.102	2.673**
10	0.389	3.210**	-0.509	1.324	0.210	2.821**	0.233	1.633
20	0.575	3.216**	-0.900	0.728	0.390	2.300**	-0.481	1.023
	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1
CD	1.409	3.783**	0.900	2.550**	0.848	3.664**	3.069**	2.970**
	MIDCAP				**SMALLCAP**			
	Period 1		**Period 4**		**Period 1**		**Period 4**	
Period	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1
2	1.510	5.175**	2.752**	4.538**	2.036**	4.275**	4.325**	6.101**
5	0.757	5.156**	1.817	5.641**	1.495	4.293**	3.308**	6.870**
10	0.650	5.658**	0.862	5.645**	1.728	4.845**	2.266**	7.319**
20	0.982	6.158**	0.184	5.850**	2.581**	5.646**	1.048	7.824**
	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1
CD	1.510	6.158**	2.752**	4.538**	2.581**	5.646**	4.325**	7.824**

Note. The VR statistic is based on Lo - MacKinlay M_2 and Wright's (2000) sign S_1 using daily data of the major indices of the Indian stock market for the period from 2000 - 2017 in the Indian stock market. The data for the BSE Midcap and Smallcap indices are from 2003 to 2017. This table reports the individual VR statistics and Chow-Denning (CD) multiple VR statistics based on four equal periods namely, Jan 2000 to Jun 2004, July 2004 to Dec 2008, Jan 2009 to Jun 2013, and July 2013 to Dec 2017. For the Midcap and Smallcap indices, the first period is between Apr 2003 to Jun 2004. Only the Periods I and IV are reported here for brevity. The statistics M^{cd}_2 and S^{cd}_1 represent the CD extension to M_2 and S_1, respectively. Significance at the 5% level is indicated by **.

[3]. As the start date for Midcap and Smallcap indices is 1-Apr-2003, the first period will be shorter for those indices.

Though the null of 'not a MDS' is accepted for all the tested daily index time series, the results are consistent with the conclusions of Lo and MacKinlay (1988) in that the large cap indices are more efficient than the midcap and smallcap indices. However, the result that the large cap indices are not weak form efficient is different from that of the results in the developed markets. The results, without accounting for structural breaks, are evidence that the Indian stock market is not weak form efficient. These findings are similar to the findings of Mangala and Lohia (2017) but different from that of Ryaly et al. (2014) and Ryaly et al. (2017) in the Indian stock market.

(3) Structural Break Points Using Bai and Perron (2003) Methodology : The Table 4 reports the Bai and Perron multiple structural break test results for all the tested indices using daily data for the tested complete period. The test 1 is the 'sup' F type test of structural stability against the alternate hypothesis of no structural breaks. The rejection of the null of 'no structural breaks' at the 5% level suggests the presence of multiple breaks in the tested time series. The multiple breakpoint test - 2 is only a confirmatory test for the presence of multiple structural breaks. A non-zero UDmax and WDmax test statistic would confirm the presence of structural breaks in the time series. The UDmax test statistic of 3, 3, 2, and 2 is the number of break points for Nifty, Sensex, Midcap, and Smallcap indices, respectively. The actual number of break points is determined based on the Bai - Perron tests of $L + 1$ vs. L sequentially determined breaks. The sequential F - statistic determined breaks third test suggests four break points for the Nifty and Sensex. The structural break points occur in the years 2003, 2005, 2009, and 2014 for Nifty and Sensex. Similarly, the structural break points occur in the years 2005, 2009, and 2014 for the BSE Midcap and Smallcap indices. The year 2003 is the year after the 'Internet Bust' of 2001-2002. The General Elections in 2009, contrary to expectation, resulted in the formation of a stable government in India. The General Elections in 2009 brought about a full majority government after nearly three decades.

Table 4. Bai & Perron (2003) Methodology : Structural Break Point Results

Dependent Variable:		NIFTY	SENSEX	MIDCAP	SMALLCAP
	Test 1 - Null Hypothesis : No structural breaks				
C		4465.4**	14728.**	6876.38**	7613.61**
	Multiple Breakpoint Test - 2				
Bai-Perron tests of 1 to *M* globally determined breaks		To check for the presence of at least one break			
Udmax determined breaks:		3	3	2	2
WDmax determined breaks:		4	4	2	2
	Multiple Breakpoint Test - 3				
Bai-Perron tests of *L*+1 vs. *L* sequentially determined breaks		2000-2017		2003-2017	
Sequential *F*-statistic determined breaks:		4	4	3	3
			Break dates - Sequential		
Break Test	**Critical Value****	**NIFTY**	**SENSEX**	**MIDCAP**	**SMALLCAP**
0 vs. 1 *	8.58	24-08-09	30-10-05	27-05-14	28-05-14
1 vs. 2 *	10.13	13-05-14	28-03-14	05-12-05	07-07-05
2 vs. 3 *	11.14	06-12-05	15-09-09	10-09-09	09-01-09
3 vs. 4 *	11.83	15-04-03	29-12-03		
4 vs. 5	12.25				

Note. * Significant at the 0.05 level. ** Bai-Perron (Econometric Journal, 2003) critical values.

(4) Single and Multiple VR Tests After Accounting for Structural Breaks : The sample was divided into periods as recommended by Bai and Perron (2003) results in Table 4. Nifty index was divided into five periods with breakpoints on 15-04-2013, 06-12-05, 24-08-09, and 13-05-14 and similarly for other tested indices. The Table 5 reports the individual VR and CD multiple variance ratio tests using daily data for the tested large capitalization stock indices after accounting for the structural breaks. The individual S_1 statistic accepts the null of 'not a MDS' only for the first at $q = 2$, 5, and 10 and at $q = 10$ and 20 for the second period for the Nifty index.

In the case of the Sensex, the sign based S_1 accepts the null of 'not a MDS' at $q = 2$, 5, and 10 in the first period and the M_2 statistic accepts the null of 'not a MDS' in the fifth period at $q = 2$. The multiple VR $S^{cd}{}_1$ accepts the null of 'not a MDS' for the Nifty at the 5% level in the first period only. The null of 'not a MDS' is rejected for all the other four periods for both the large capitalization indices at any level of significance by the $S^{cd}{}_1$ statistic. The results of the individual VR tests are generally supported by the multiple VR tests except in the case of Sensex in the fifth period, suggesting that the individual VR M_2 result may be due to over acceptance. The results are different from the findings of Mishra et al. (2015) in case of the Indian stock market. However, the results are similar to the findings of Narayan and Smyth (2007) in case of the developed markets.

Further, when the actual variance ratio is analyzed (z - stat is shown in the table) for the NIFTY index, M_2 - VR (2) is 1.06, 1.12, 1.06, 1.04, and 0.98 for Periods 1 to 5, respectively. This seems to support the adaptive hypothesis or the evolving hypothesis where the markets become increasingly informationally efficient over time. This result is consistent with the conclusions of Hiremath and Kumari (2014).

Table 5. Individual VR and CD Multiple Variance Ratio Tests Using Daily Data for the Large Capitalization Stock Indices After Accounting for Structural Breaks

NIFTY	Period 1		Period 2		Period 3		Period 4		Period 5	
Obs.	811		614		866		853		864	
q	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1
2	1.247	3.021**	1.262	1.979	1.318	0.578	1.098	0.342	-0.424	1.463
5	0.459	2.732**	0.574	1.887	0.758	0.695	1.264	0.531	-0.462	1.193
10	0.276	2.193**	0.507	2.890**	0.136	0.586	0.719	0.469	-0.661	0.695
20	0.383	1.430	0.205	3.598**	0.799	1.279	0.459	-0.147	-0.988	0.006
CD	$M^{cd}{}_2$	$S^{cd}{}_1$	$M^{cd}{}_2$	$S^{cd}{}_1$	$M^{cd}{}_2$	$S^{cd}{}_1$	$M^{cd}{}_2$	$S^{cd}{}_1$	$M^{cd}{}_2$	$S^{cd}{}_1$
	1.247	3.021**	1.262	3.598	1.318	1.279	1.264	0.531	0.988	1.463
SENSEX	Period 1		Period 2		Period 3		Period 4		Period 5	
Obs.	981		629		678		834		864	
q	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1
2	0.840	3.641**	0.709	1.675	1.908	1.652	1.055	0.311	2.388**	1.940
5	0.807	3.230**	0.239	1.646	0.997	1.599	1.109	0.075	1.234	1.765
10	0.431	2.929**	0.339	1.768	0.039	1.573	0.661	-0.047	0.174	0.901
20	0.470	2.193**	0.654	1.589	0.675	1.531	0.439	-0.101	-0.478	0.141
CD	$M^{cd}{}_2$	$S^{cd}{}_1$	$M^{cd}{}_2$	$S^{cd}{}_1$	$M^{cd}{}_2$	$S^{cd}{}_1$	$M^{cd}{}_2$	$S^{cd}{}_1$	$M^{cd}{}_2$	$S^{cd}{}_1$
	0.840	3.641**	0.709	1.768	1.908	1.652	1.109	0.311	2.388	1.940

Note. The VR statistic is based on Lo - MacKinlay M_2 and Wright's (2000) sign S_1 using daily data of the major indices of the Indian stock market for the period from 2000 - 2015 in the Indian stock market. The data for the BSE Midcap and Smallcap indices are from 2003 to 2017. Panel A reports the individual VR statistics and Panel B reports the Chow-Denning multiple VR statistics. The periods are based on Bai & Perron's (2003) structural break points in Table 4. The statistics $M^{cd}{}_2$ and $S^{cd}{}_1$ represent the CD extension to M_2 and S_1, respectively. Significance at the 5% level is indicated by **.

Table 6. Individual VR and CD Multiple Variance Ratio Tests Using Daily Data for the BSE Midcap and Smallcap Indices After Accounting for the Structural Breaks Based on Bai and Perron's (2003) Methodology

BSE MIDCAP INDEX								
	Period 1		Period 2		Period 3		Period 4	
Obs.	549		969		1206		797	
q	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1
2	1.987**	6.065**	2.456**	5.840**	5.728**	5.963**	2.145**	4.324**
5	1.221	7.066**	2.706**	6.302**	5.753**	6.669**	1.217	5.008**
10	1.061	8.375**	2.681**	6.442**	3.874**	5.032**	0.442	4.694**
20	0.910	8.858**	3.337**	7.575**	3.848**	4.973**	-0.267	4.270**
	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1
CD	1.987	8.858**	3.337**	7.575**	5.753**	6.669**	2.145**	5.008**
BSE SMALLCAP INDEX								
	Period 1		Period 2		Period 3		Period 4	
Obs.	549		969		1142		859	
q	M_2	S_1	M_2	S_1	M_2	S_1	M_2	S_1
2	2.781**	5.040**	3.574**	7.263**	5.665**	10.035**	4.033**	4.978**
5	2.350**	6.130**	4.692**	8.579**	5.887**	10.420**	3.230**	5.217**
10	2.076**	6.948**	4.983**	8.868**	4.505**	8.222**	1.983	5.021**
20	1.829**	7.864**	5.542**	9.673**	4.106**	8.196**	0.705	4.959**
	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1	M^{cd}_2	S^{cd}_1
CD	2.781**	7.864**	5.542**	9.673**	5.887**	10.42**	4.033**	5.217

The Nifty and the Sensex indexes exhibiting negative serial correlation in the last period is another interesting feature. Lo and MacKinlay (1988), by analyzing the weekly index data in the U.S., contended that portfolios will generally exhibit positive serial correlation and individual stocks will have a tendency to exhibit negative serial correlation.

The Table 6 reports the individual VR and CD multiple variance ratio tests using daily data for the BSE Midcap and Smallcap indices and it is seen that the null of 'not a MDS' is accepted for all the periods and in most of the tested holding periods at the 5% level of significance. The results evidence that, once the structural breaks are accounted, the large capitalization indices are weak form efficient in the Indian stock market. The midcap and smallcap indices are not weak form efficient, even after accounting for structural breaks.

Conclusion

This study examines the weak form of market efficiency in the Indian stock market using the daily data for the 2000 - 2018 period. The large capitalization NSE index Nifty and BSE Sensex along with BSE Midcap and BSE Smallcap indices are examined using parametric and non - parametric variance ratio tests. Further, in order to increase the power of the single VR tests, Chow and Denning's (1993) multiple ratio tests extension to Wright (2000) rank and sign test was also used. This study is distinguished from most other studies in the Indian market by accounting for the structural breaks in the weak form of efficiency or the martingale tests. Without accounting for structural breaks, the results that the Indian stock market is not weak form efficient is a finding similar to many other studies for the complete 18 year period and regular periods. However, once the structural breaks are accounted for, this study finds that the large capitalization indices are weak form efficient. This study proves the assertion of many researchers that market efficiency tests might give misleading results if the structural breaks are not considered. The Indian stock market is weak form efficient based on the evidence in this study with regard to large capitalization indices. The notion of adaptive or evolving market efficiency is also supported in this study. The results show that the Midcap and Smallcap indices are not weak form efficient, even after accounting for structural breaks. This result is similar to the findings of many other studies in the developed markets. This study has not only attempted to set to rest the question of market efficiency in the Indian stock market, but also shows the importance of considering structural breaks in such studies.

Research Implications, Limitations of the Study, and Scope for Future Research

The major finding that emerges from this study is that the large capitalization indices are weak form efficient once the structural breaks are accounted for in the Indian stock market. The reason for existing studies not finding support for weak form of efficiency for large capitalization indices may be due to the presence of structural breaks. The implication for researchers is that they should consider the structural breaks in market efficiency studies. Traders cannot expect to earn economic profits by trading in the large capitalization indices. However, there is potential for economic profits in the midcap and smallcap space. The support for evolving market efficiency seems to support the initiatives taken by the policy makers to improve corporate governance, liquidity, etc. in the past two decades. However, they might have to focus on the reasons for the lack of weak form of market efficiency in the midcap and smallcap space. In this study, only the major indices are considered. Neither the industry specific indices nor the individual stocks are considered in this study. These may be avenues for future research. Furthermore, future research can focus on other methods to identify structural breaks. Future research can also study the reasons for the portfolios containing large, liquid, and blue chip stocks in the Indian stock market exhibiting negative serial correlation in the recent period.

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