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# The past, the present and the prospective future of efficient market hypothesis: a theoretical and empirical investigation of international stock markets

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**Abstract.** *This article discusses the documentary evidence on the Efficient Market Hypothesis (EMH) generated in the middle of 20th century and 21st century so far to have a crystal clear understanding of whether the destiny of EMH has met an end or it will continue to play a crucial role in the modern finance. The debate that is ongoing between the conflicting ideologies of EMH and the behavioral finance is presented here. Further, to have a comprehensive understanding of the concept, this article empirically tests the validity of the weak-form of market efficiency by implementing various tests such as unit root test (Augmented Dickey-Fuller, Phillips-Perron test), variance ratio test, runs test, serial correlation LM test, GARCH model, etc. We study the data of eleven indices pertaining to nine developed and emerging nations of the world. The study then concludes with a futuristic view that the concept of EMH will continue to be one of the most and widely accepted theories by academicians despite the availability of a pile of literature that discards or goes against the hypothesis, until and unless the behavioral theorists come up with a concrete theory guiding stock pricing and return behavior.*

**Keywords:** efficient market hypothesis, random walk, behavioral finance, market anomalies, stock market.

**JEL Classification:** G14, G15, G40.

## 1. Introduction

The capital market is one of the pillars on which the edifice of the economy stands. It provides funds for the smooth sailing of the economy. Thus, it is of utmost importance that stock markets be efficient in their operations and information processing. The capability of a capital market to absorb information has attracted the attention of academicians, scholars, traders, and regulatory bodies. However, there are two contrasting views. One view states that the market fully absorbs the information with immediate effect, whereas the other states quite the opposite suggesting only limited information efficiency. Informational efficiency of the stock market is of prime concern in this article. The notion of stock market efficiency states that the prices of the stock quickly and fully absorb any new information that comes into the market. It helps in understanding whether the stock market is capable enough to process the newly arrived information systematically as far as movements of stock prices are concerned. The Efficient Market Hypothesis (EMH) claims that the prices of the stocks absorb all the pieces of information quickly, thus, making it impossible for the investors to earn more than normal returns from the market consistently. EMH is understood in three forms: weak, semi-strong and strong forms that differ from each other based on the information they process. Each subsequent form engulfs within it the set of information of the previous form. Weak form efficiency states that historical data can't help in predicting the future course of prices as historical or past information has already been accounted for in the stock prices. Similarly, semi-strong and strong forms suggest that publicly available information and private information respectively can't be used to beat the market consistently. As a result, neither there is any undervalued security in the stock market nor is overvalued. The market, therefore, will always trade at fair prices, which behaves randomly.

Discussion on another branch of economics namely behavioral economics had taken momentum in early 1980s. Behavioral finance, a sub-branch of behavioral economics discards the rationality of the investors (one of the basic assumption of EMH) as investors do get swayed by psychological and emotional biases while taking investment decision. There are patterns in the stock returns that can be identified and be used to predict future returns. Parallel literature on market anomalies was also being produced. Market anomalies are the distortions that go against the accepted paradigm of EMH. These are the patterns that help investors earn above average returns which should not be the case as per theory of market efficiency. Faith in the theory of market efficiency has been shaken with the advent of market anomalies such as size effect, contrarian/reversal effect, day of the week effect, January effect, and momentum effect etc. While on one hand, literature on these anomalies started appearing and rigorous discussions were being made among academicians and practitioners regarding behavioral finance and on the other hand, parallelly, the theory of EMH was being subjected to several statistical tests.

EMH is indeed a widely discussed concept in the financial literature and has often been subjected to several empirical investigations by scholars and academicians worldwide. If a stock market possesses information efficiency, it implies that the return behavior of the stocks of that market manifest attributes of a random walk. Thus, one can infer that the markets where returns don't follow random walk cannot be considered weak-form efficient. The objective of the article is to put forth the literature concerning the empirical and theoretical investigation of the weak form of EMH. The study then puts the hypothesis to the empirical analysis taking the stock market data of nine developed and emerging economies from 2005-2018. The article seeks out the answer of several questions such as:

- How the concept of EMH has evolved in the last few decades.
- What kind of supportive and challenging evidence has the literature provided to us?
- What does empirical investigation tells about the theory of market efficiency?
- Can EMH be entirely replaced by a new behavioristic finance theory, or will this new theory only be used to support EMH. What would be the future of EMH given continuously evolving literature on behavioral finance?

The organization of this article is as follows: Section 2 deals with the literature surveyed chronologically pertaining to different periods (20th and 21st century) to understand the evolvement of the concept of market efficiency. Section 3 discusses about the data taken and the methodology that has been applied in the article. Section 4 deals with the empirical investigation of the weak form efficiency of nine selected markets. Section 5 discusses how behavioral finance has challenged the existence of EMH. Section 6 finally concludes with a futuristic view of EMH.

## 2. Literature review

### 2.1. Understanding the soul of EMH through earlier studies (20th Century)

Bachelier (1900) speculated that stock prices move in "Brownian motion", which is nothing but random erratic movements that imply that stock prices can't be forecasted and are largely unpredictable. Kendall and Hill (1953) also specified that stock and commodity prices do follow a random walk. Fama (1965) asserted that there are mainly two approaches for studying if successive price changes are independent or not. The first approach uses essential statistical techniques such as coefficients of correlation or analysis of runs of same and opposite signs. In contrast, the second approach tests different trading rules and observes if they provide a return over and above a simple buy-hold strategy. Most of the empirical researches have heavily relied on the first approach. Fama (1965) stated that technical analysts are just like an astrologer and have no significant role in the analysis of the stock market. It also said that unless the fundamentalists have some new insights or new information, they also serve no purpose as stocks are already priced at their fair or intrinsic values. Until this time, there was no significant evidence against the three forms of market efficiency. Gradually, EMH was put to the test in stock market of several emerging, underdeveloped, and developed nations. Solnik (1973) tested the random walk model in European nations, where slight deviations from the random walk were observed. Sharma and Kennedy (1977) compared the theory of random walk in the markets USA, UK, and India, which were observed to be following the random walk. Ambrosio (1980) on the other hand, rejected the random walk hypothesis in the Singapore stock market. Lo and MacKinlay (1988) devised the new variance ratio test in order to test the weak level market efficiency. The study rejected the hypothesis as significant departures from a random walk were observed in the returns. Urrutia (1995) found the inefficiency in the four emerging nations of Latin America, whereas on opposite Ojah and Karemera (1999) discovered the efficiency in emerging nations of Latin America. Inefficiencies were found by Poshakwale (1996), Loughani and Chappell (1997), and Mookerjee and Yu (1999) in the Indian, London, and Chinese stock markets, respectively. Chan et al. (1997) tested weak-form market efficiency in eighteen nations and found them efficient. Thus, the evidences which strongly favored EMH by the 1960s-1970s were gradually getting weaker.

Emerging of parallel literature on behavioral finance was also casting serious doubts on the future of EMH. Some evidences inconsistent with the well-established hypothesis of market efficiency started appearing in the literature, though these pieces of evidences were not being viewed together as they were vastly scattered and incoherent. These anomalous pieces of evidence in the form of momentum and contrarian effect, day of the week effect, small-firm effect, turn of the year effect, price-earnings ratio anomaly started emerging by the 1980s and 1990s. Results contrary to EMH were being discussed by various researchers, which raised a question as to how long the EMH will continue if it remained unrevised in light of new evidence being drawn. Cross (1973) analyzed the behavior of stock prices on Mondays and Fridays and observed that prices had shown rise more often on Fridays and least often on Mondays. Jensen (1978) pointed towards the inadequacies observed in asset pricing literature by several noted academicians and stated that one could not simply ignore this anomalous evidence. French (1980) examined behavior of stock returns on different week days to study weekend effect and observed that returns on Mondays were significantly negative while returns were observed to be positive on other days. Bondt and Thaler (1985) observed that the losers outperformed winners by 19.6 % after 36 months/3 years of portfolio formation, while the winners were earning 5% less than the market. Jegadeesh and Titman (1993) reported that buying winner stocks (stocks that performed well in past) and selling loser stocks (stocks that performed poor) would generate significantly positive returns in 3-12 months as markets display continuation pattern for at least 3-12 months. These anomalous evidences showed that markets provide more than normal return which goes against EMH. Several academicians put forth several other such pieces of evidence challenging the efficient market hypothesis.

### 2.2. Summary findings of literature on efficient market hypothesis in last 20 years (21st century)

In the past two decades, the hypothesis of market efficiency has been put on several tests in different stock markets to know if it is still valid in those markets or not. Cheung and Coutts (2001) confirmed the existence of weak form market efficiency hypothesis in the Hong Kong stock market as stock returns followed random walk model. Smith et al. (2002) investigated the random walk hypothesis in eight African nations, including South Africa. They found that seven markets reject random walk as these markets showed autocorrelation in stock returns, with the only exception of South Africa. Similarly, Abraham et al. (2002) and Buguk and Brorsen (2003) found mixed results for stock markets of gulf nations and Istanbul, respectively. Smith and Ryo (2003) tested weak form efficiency in five emerging countries of Europe and observed that four of the five markets rejected the random walk hypothesis. The study found liquidity to be an essential factor affecting market efficiency. Moustafa (2004) showed efficiency in the stock market of UAE, although their market was newly developed at that time. Lima and Tabak (2004) found efficiency in the Hong Kong stock market and inefficiency in the Singapore market, while mixed evidence was reported for the market of China and asserted that market efficiency is largely affected by liquidity and market capitalization. Mollah (2007) and Balsara et al. (2007) found evidence of market inefficiency in Botswana and the Chinese stock market, respectively implying predictability of the stock prices. Awad and Daraghma (2009) reported market inefficiency in the Palestinian stock market, indicating that probability of earning excess returns exist in this market. Mishra (2009) found the Indian market to be having inefficiencies. Mehla and Goel (2012) analyzed the market efficiency of India. They found the presence of inefficiency implying predictability of returns and probability of earning more than what the market offers on average. Mobarek and Fiorante (2014) did sub-period analysis of weak-form efficiency of BRIC nations. They found inefficiencies in the earlier sub-period, while the markets were observed to approach the state of market efficiency in the later sub-period. Shiller and Radikoko (2014) found inefficiency in the Canadian stock market, and Hawaldar et al. (2017) presented mixed results relating to market efficiency in the Bahrain stock market. Lekovic (2018) reported that even after decades of continuous research, the literature is still not able to reach to a consensus about the validity of the efficient market hypothesis and the presence or absence of market anomalies. Awiagah and Choi (2018) reported inefficiency in the Ghana stock exchange, which was observed to be insensitive to return frequency. Kiran (2019) also rejected the random walk hypothesis in BRICS nations due to dependencies being found in the stock returns. Agwu et al. (2020) found inefficiency in the Nigerian stock exchange as prices were found to have a significant relationship with their lag values, which violates the basic assumption of the efficient market hypothesis.

It is clear from the above discussion that the literature has not reached a consensus as there are both supporting as well as conflicting evidence regarding the validity of the efficient market hypothesis. These contradictory observations reported in the literature, for one market or even for different markets, could probably arise due to various factors such as the techniques used, considered time window, or the data frequency. It is also argued that the inefficiencies are mostly reported in developing markets whereas developed markets display efficient behavior. To gain a clearer view of these conflicting observations, the present study analyses nine developed and developing nations for the period 2005-2018 for all the countries using unit root testing, run test, serial correlation test, variance ratio test, and GARCH model. The experiments allow us to arrive at precise results and drive us to understand the hypothesis better.

## 3. Data description and methodology

The details of the indices and methodology being used in the article for empirically investigating the weak form of market efficiency have been explained in this section.

### 3.1. Sample data description

The article considers eleven global indices of nine countries for the empirical analysis. These indices were selected to include developing as well as developed nations. SP Global

100 has also been used in the study to capture the efficiency of the world stock market as this index is a barometer of the performance of 100 global companies selected from 29 stock markets. The selection of indices allows to investigate the efficacy and robustness of the methodology used extensively. Table 1 provides the list of the indices used for the purpose of analysis. We collected the data of daily closing prices from the Thomson Reuters EIKON data stream for the period January 2005 to November 2018 (3623 observations). The software used for the analysis includes E-Views, MS-Excel, and R.

**Table 1.** *List of sample countries and their respective indices*

| No. | Country | Index used |
|---|---|---|
| 1 | Brazil | Bovespa |
| 2 | India | Nifty, Sensex |
| 3 | Germany | DAX 30 |
| 4 | United States of America | Dow Jones |
| 5 | United Kingdom | FTSE 100 |
| 6 | Greece | Athex |
| 7 | Hong Kong | Hang Seng |
| 8 | China | Shenzhen |
| 9 | Japan | Topix |
| 10 | World | SP Global 100 |

The article follows the convention of working with log returns in financial literature. The daily log returns have been calculated as follows:

$$R_t = \ln\left(\frac{S_t}{S_{t-1}}\right), t = 1, 2, 3, \ldots, \mathrm{T}$$

where:
$S_t$ and $S_{t-1}$ represent the closing prices of the stock on *t*-th and *(t-1)*-th day respectively.

### 3.2. Methodology and techniques used

The tests undertaken in the study for purpose of empirical investigation are as follows-

a) Unit Root Test – Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Test have been used to test the stationarity in the data as non-stationarity in the data implies random walk.
b) Runs Test helps in detecting statistical dependencies in the time series data. When expected number of runs varies significantly from the observed number of runs, null hypothesis (no randomness) gets rejected.
c) Lo and MacKinlay's Heteroskedasticity – robust standard error estimates have been used to calculate variance ratio. Variance ratio of q-period difference (returns) should be q times the variance of one period difference for the series to be called a random walk as according to random walk theory, VR (q) must approach unity.
d) Breusch-Godfrey serial correlation LM Test has been applied in order to test the data for the presence of serial correlation. The presence of it implies violation of weak form efficiency hypothesis. Autocorrelation and Partial autocorrelation have also been calculated to see if returns have lagged relationship with itself.
e) GARCH (1, 1) model has also been applied to test weak form of market efficiency. The model would capture the presence of volatility clustering in stock returns that implies market inefficiency.

## 4. Data analysis and empirical results

### 4.1. Descriptive statistics

Table 2 summarises the descriptive statistics of daily return of the indices studied.

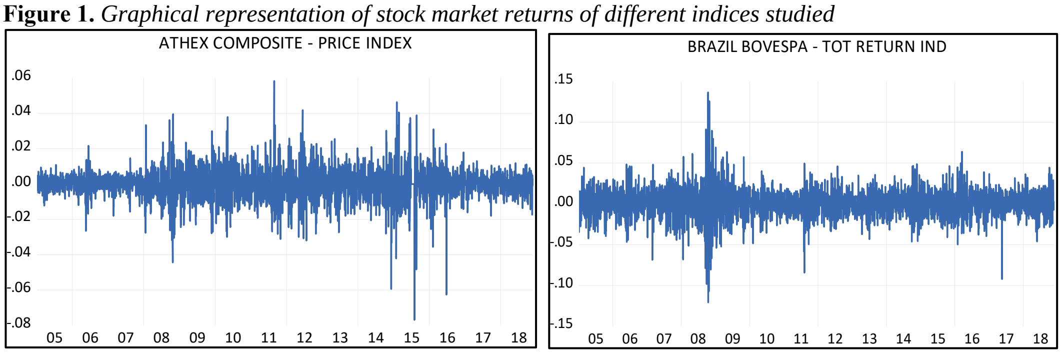
**Table 2.** *Descriptive statistics*

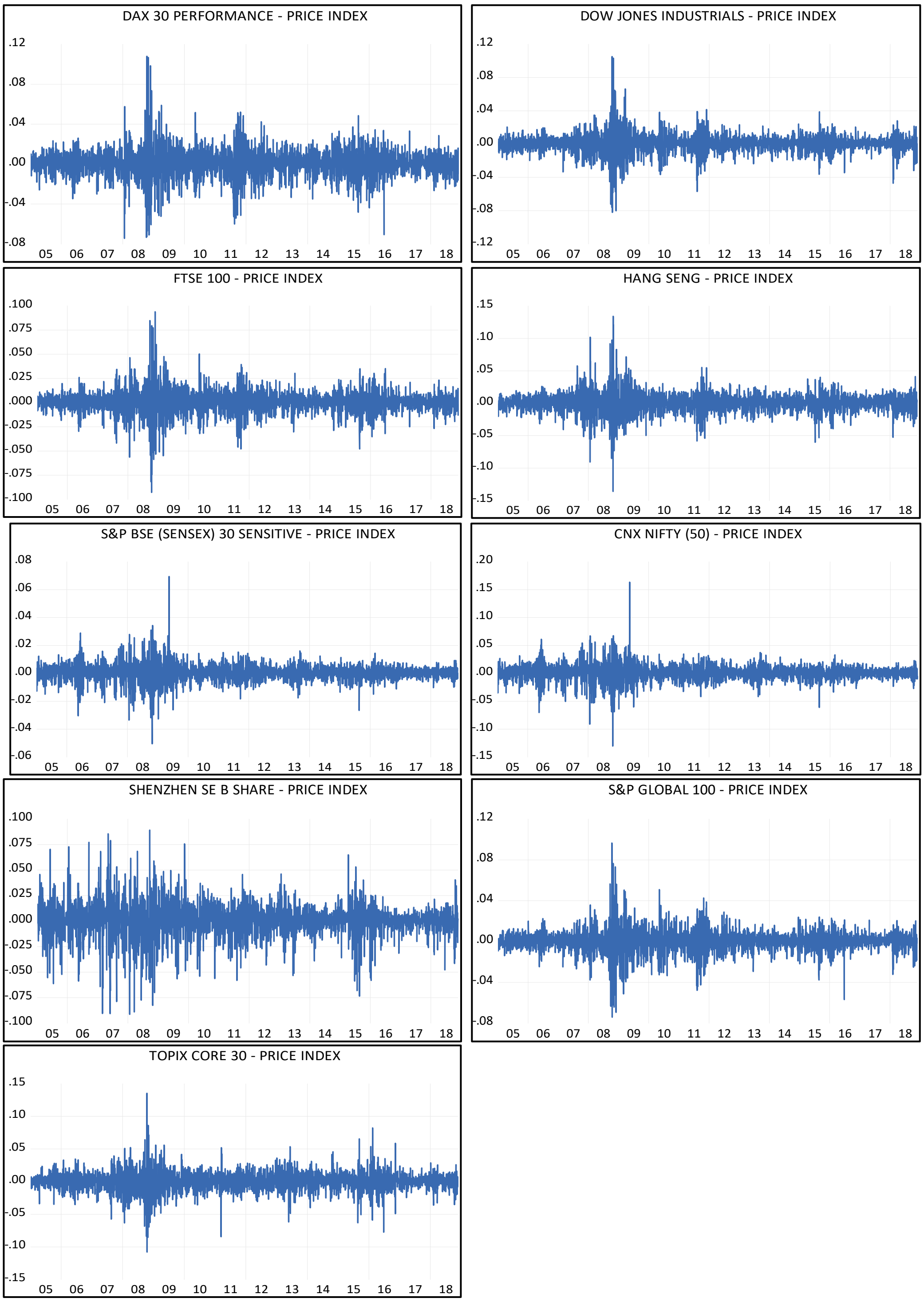
| Index | Mean | Maximum | Minimum | Standard Deviation | Skewness | Kurtosis | Jarque-Bera | JB p-value |
|---|---|---|---|---|---|---|---|---|
| Athex | -0.00018 | 0.0583 | -0.0769 | 0.0083 | -0.3764 | 9.8284 | 7124.3 | 0.00* |
| Bovespa | 0.00033 | 0.1367 | -0.1209 | 0.0167 | -0.0490 | 8.9010 | 5258.2 | 0.00* |
| DAX 30 | 0.00026 | 0.1079 | -0.0743 | 0.0131 | -0.0364 | 9.7075 | 6792.6 | 0.00* |
| Dow Jones | 0.00022 | 0.1050 | -0.0820 | 0.0107 | -0.1608 | 14.81704 | 21095.8 | 0.00* |
| FTSE 100 | 0.00010 | 0.0938 | -0.0926 | 0.0111 | -0.1529 | 11.89864 | 11967.87 | 0.00* |
| HangSeng | 0.00016 | 0.1340 | -0.1358 | 0.0144 | -0.0079 | 13.32343 | 16088.14 | 0.00* |
| Nifty | 0.00044 | 0.1633 | -0.1301 | 0.0137 | -0.0398 | 14.20090 | 18940.21 | 0.00* |
| Sensex | 0.00019 | 0.0694 | -0.0503 | 0.0059 | 0.0776 | 13.28948 | 15986.13 | 0.00* |
| Shenzhen | 0.00038 | 0.0890 | -0.0913 | 0.0156 | -0.5036 | 8.218779 | 4264.5 | 0.00* |
| S&P Global 100 | 0.00010 | 0.0964 | -0.0740 | 0.0103 | -0.3055 | 12.63174 | 14060.8 | 0.00* |
| Topix | -0.000002 | 0.1352 | -0.1078 | 0.0143 | -0.2596 | 10.435 | 8388.4 | 0.00* |

*significant at 5% level.

As evident from Table 2, the mean return of all the indices except Athex and Topix is positive; the highest is for Nifty. Standard deviation tells about the volatility of the series. The highest volatility is present in the case of Bovespa whereas Sensex is the least volatile. Skewness and Kurtosis measure the symmetry and peakedness of the data respectively. The observed statistics of Skewness are negative for all the indices except Sensex. The observed value of kurtosis hints towards the non-normal distribution as all the values are significantly greater than zero (leptokurtic distribution), the highest being in the case of US and Indian stock market indices i.e. Dow Jones and Nifty. The results of the Jarque-Bera test for normality also confirm non-normal distribution as the p-value is less than 0.05, thereby rejecting the null hypothesis that states that distribution is normal. The highest value of Jarque-Bera statistics is again in the case of Dow Jones and Nifty.

**Figure 1.** *Graphical representation of stock market returns of different indices studied*






The returns of all the indices have been presented in the form of graphs.

## 4.2. Methodology and findings

### 4.2.1. Unit root test – ADF and PP test

To test whether the unit root is present in the data or not, the two most famous and widely used unit root tests, the Augmented Dickey-Fuller (ADF) test (1979) and Phillips-Perron (PP) test (1988), have been applied. The presence of unit root implies non-stationarity in the data, which further implies that the data does follow a random walk. A time series having a unit root is said to be non-stationary and thus follows a random walk (Ahmad et al., 2006, pp. 49-56). The results of the ADF test are obtained using intercept and no trend as well as using both intercept and trend, equations for which are presented below as equation 1 and 2 respectively.

$$\Delta y_t = \alpha_0 + \lambda y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + u_t \quad (1)$$

$$\Delta y_t = \alpha_0 + \beta_0 t + \lambda y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + u_t \quad (2)$$

The results of the ADF test are obtained using both intercept as well as intercept and trend equations. PP test is a non-parametric method that controls higher-order serial correlation present in series. The test is robust with respect to unspecified autocorrelation and heteroskedasticity, if present any, in error terms in the test equation. The results of the ADF test using both an intercept and a trend and with only an intercept are presented in Tables 3 and 4, respectively. Since the value of t-statistics is less than the Mackinnon critical values for all the indices at 1%, 5%, and 10% significance level, the null hypothesis (series contains unit root) gets rejected. Thus, the data of all the indices don't have a unit root, and that the data is stationary. Based on the results of the ADF test for both equations, we conclude that the selected markets are not following the random walk hypothesis and thus are weak-form inefficient.

**Table 3.** *ADF results using trend and intercept*

| Index | T-statistics | p-value | Critical values | | |
|---|---|---|---|---|---|
| | | | At 1% level | At 5% Level | At 10% Level |
| Athex | -56.11613 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Bovespa | -61.72224 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| DAX 30 | -60.07145 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Dow Jones | -47.26427 | 0.00* | -3.960574 | -3.411047 | -3.127341 |
| FTSE 100 | -28.81088 | 0.00* | -3.960576 | -3.411048 | -3.127342 |
| Hang Seng | -61.8163 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| NIFTY | -57.62205 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Sensex | -57.08752 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Shenzhen | -56.59314 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| S&P Global 100 | -44.35029 | 0.00* | -3.431974 | -3.862147 | -3.567141 |
| Topix | -59.72579 | 0.00* | -3.960573 | -3.411046 | -3.127341 |

*significant at 5% level.

**Table 4.** *ADF results using intercept and no trend*

| Index | T-statistics | p-value | Critical values | | |
|---|---|---|---|---|---|
| | | | At 1% level | At 5% Level | At 10% Level |
| Athex | -56.12267 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| Bovespa | -61.72719 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| DAX 30 | -60.07668 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| Dow Jones | -47.25676 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| FTSE 100 | -28.81384 | 0.00* | -3.431971 | -2.862141 | -2.567134 |

| Index | T-statistics | p-value | Critical values | | |
|---|---|---|---|---|---|
| | | | At 1% level | At 5% Level | At 10% Level |
| Hang Seng | -61.82185 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| NIFTY | -57.62308 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| Sensex | -57.08489 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| Shenzhen | -56.57106 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| S&P Global 100 | -44.35373 | 0.00* | -3.431969 | -2.862141 | -2.567133 |
| Topix | -59.73094 | 0.00* | -3.431969 | -2.862141 | -2.567133 |

*significant at 5% level.

**Table 5.** *PP test results using both trend and intercept*

| Index | T-statistics | p-value | Critical values | | |
|---|---|---|---|---|---|
| | | | At 1% level | At 5% Level | At 10% Level |
| Athex | -55.99747 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Bovespa | -62.03045 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| DAX 30 | -60.19023 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Dow Jones | -66.66126 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| FTSE 100 | -62.65178 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Hang Seng | -61.81111 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| NIFTY | -57.57739 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Sensex | -57.02539 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Shenzhen | -56.86381 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| S&P Global 100 | -56.10661 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Topix | -59.83460 | 0.00* | -3.960573 | -3.411046 | -3.127341 |

*significant at 5% level.

**Table 6.** *PP test results using intercept and no trend*

| Index | T-statistics | p-value | Critical values | | |
|---|---|---|---|---|---|
| | | | At 1% level | At 5% Level | At 10% Level |
| Athex | -56.00441 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Bovespa | -62.03116 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| DAX 30 | -60.19461 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Dow Jones | -66.64450 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| FTSE 100 | -62.66005 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Hang Seng | -61.81659 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| NIFTY | -57.57917 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Sensex | -57.02447 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Shenzhen | -56.86159 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| S&P Global 100 | -56.11209 | 0.00* | -3.960573 | -3.411046 | -3.127341 |
| Topix | -59.83830 | 0.00* | -3.960573 | -3.411046 | -3.127341 |

*significant at 5% level.

Next, we present the results of the Phillips-Perron test in Tables 5 and 6, respectively, with two different specifications, one with both trend and intercept and the other one with an intercept only. Results similar to that of ADF are observed for the Phillips-Perron test, which serves as confirmatory analysis. The test statistics computed are less than Mackinnon's critical values, thereby rejecting the null hypothesis (the data contains unit root) at all the three levels of significance, i.e., 1%, 5%, and 10%. Thus, all the indices undertaken in the study do not follow a random walk, and hence these stock markets are inefficient. In case of both the ADF and PP test, null hypothesis has been rejected for the SP Global 100, thus signifying the inefficiency in behavior of world market index.

### 4.2.2. Runs Test

Runs test detects the statistical dependencies or randomness. The number of runs is calculated as a sequence of changes in prices with the same sign, and it rejects the null hypothesis (no randomness) if the expected number of runs significantly varies from the observed number. If observed number of runs is less than the expected, it indicates overreaction to the information by the market participants. In contrast, presence of more than the expected number of runs hints towards the lagged response to the information. In both scenarios, there exists the probability of earning excess returns. (Poshakwale, 1996, pp. 605-616)

Let n(0) and n(1) be the number of positive runs and negative runs respectively and N be the total no. of observations. The z-statistics is calculated by:

$$z = \frac{\omega - \mu_\omega}{\sigma_\omega} \quad N \approx (0,1)$$

where, $\mu_\omega = \frac{2 \times n\,(0) \times n(1)}{N} + 1$ and $\sigma_w^2 = \frac{2 \times n(0) \times n(1)[2 \times n(0) \times n(1) - N]}{N^2(N-1)}$

**Table 7.** *Results of Runs Test*

| Index | No. of observations | Actual number of runs | Expected number of runs | Number of positive runs [n(0)] | Number of negative runs [n(1)] | Z-statistics | P-value |
|---|---|---|---|---|---|---|---|
| Athex | 3623 | 1610 | 1792.467 | 1621 | 2002 | -6.132 | 0.000* |
| Bovespa | 3623 | 1854 | 1809.985 | 1879 | 1744 | 1.465 | 0.143 |
| DAX 30 | 3623 | 1869 | 1810.675 | 1754 | 1869 | 1.940 | 0.052 |
| DowJones | 3623 | 1883 | 1812.112 | 1785 | 1838 | 2.356 | 0.018* |
| FTSE100 | 3623 | 1822 | 1812.999 | 1810 | 1813 | 0.316 | 0.752 |
| HangSeng | 3623 | 1818 | 1812.020 | 1841 | 1782 | 0.199 | 0.842 |
| Nifty | 3623 | 1791 | 1810.978 | 1864 | 1759 | -0.664 | 0.506 |
| Sensex | 3623 | 1773 | 1811.407 | 1856 | 1767 | -1.277 | 0.202 |
| Shenzhen | 3623 | 1677 | 1812.141 | 1837 | 1786 | -4.492 | 0.000* |
| SP Global 100 | 3623 | 1761 | 1812.470 | 1783 | 1840 | -1.697 | 0.090 |
| Topix | 3623 | 1761 | 1804.748 | 1693 | 1930 | -1.460 | 0.144 |

*significant at 5% level.

Empirical results related to the runs test is presented in Table 7. It can be observed from the table that the p-value is less than the threshold value of 0.05 for Athex, Dow Jones, and Shenzhen indices, thus rejecting the null hypothesis of no randomness, which means that these markets follow a random walk. The markets indices other than Athex, Dow Jones, and Shenzhen do not follow a random walk as the observed p-value is more than zero. Therefore, we conclude that these markets are inefficient.

### 4.2.3. Autocorrelation, partial autocorrelation and Ljung-Box Q-Statistics

Autocorrelation and partial autocorrelation measure the association between stock returns at two different time points. In other words, it measures the correlation between a series' present values with its lagged value(s) and indicates if the past values (lags) can be used to predict the future values. Autocorrelation is the relation of the data series with its historical values. The results of autocorrelation and partial correlation are reported in Table 8.

**Table 8.** *Autocorrelation and partial autocorrelation coefficients up to 10 lags*

| Index | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Athex | AC | 0.069 | -0.012 | -0.016 | -0.044 | -0.020 | -0.013 | 0.041 | 0.040 | 0.000 | 0.013 |
| | PAC | 0.069 | -0.017 | -0.014 | -0.043 | -0.015 | -0.013 | 0.042 | 0.032 | -0.006 | 0.014 |
| | Q-Stat | 17.493 | 18.029 | 18.970 | 26.107 | 27.590 | 28.251 | 34.441 | 40.279 | 40.279 | 40.878 |
| | Prob. | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |

| Index | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bovespa | AC | -0.025 | -0.012 | -0.049 | -0.017 | 0.005 | -0.013 | -0.033 | 0.008 | -0.001 | 0.016 |
| | PAC | -0.025 | -0.013 | -0.050 | -0.020 | 0.002 | -0.016 | -0.036 | 0.006 | -0.003 | 0.012 |
| | Q-Stat | 2.2670 | 2.7988 | 11.488 | 12.592 | 12.673 | 13.299 | 17.288 | 17.511 | 17.515 | 18.412 |
| | Prob. | 0.132 | 0.247 | 0.009* | 0.013* | 0.027* | 0.039* | 0.016* | 0.025* | 0.041* | 0.048* |
| DAX30 | AC | 0.001 | -0.032 | -0.021 | 0.013 | -0.047 | 0.022 | -0.003 | -0.012 | -0.012 | 0.010 |
| | PAC | 0.001 | -0.032 | -0.021 | 0.012 | -0.09 | 0.022 | -0.005 | -0.013 | -0.010 | 0.006 |
| | Q-Stat | 0.0073 | 3.7995 | 5.3713 | 6.0154 | 14.112 | 15.806 | 15.830 | 16.345 | 16.835 | 17.219 |
| | Prob. | 0.932 | 0.150 | 0.147 | 0.198 | 0.015* | 0.015* | 0.027* | 0.038* | 0.051 | 0.070 |
| DowJones | AC | -0.093 | -0.051 | 0.038 | -0.007 | -0.039 | -0.005 | -0.030 | 0.041 | -0.030 | 0.017 |
| | PAC | -0.093 | -0.060 | 0.028 | -0.004 | -0.037 | -0.015 | -0.036 | 0.037 | -0.026 | 0.017 |
| | Q-Stat | 31.663 | 41.158 | 46.517 | 46.708 | 52.319 | 52.428 | 55.597 | 61.717 | 64.966 | 66.068 |
| | Prob. | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |
| FTSE100 | AC | -0.034 | -0.051 | -0.047 | 0.053 | -0.050 | -0.021 | 0.020 | 0.008 | -0.012 | 0.004 |
| | PAC | -0.034 | -0.052 | -0.051 | 0.047 | -0.052 | -0.022 | 0.018 | 0.000 | -0.007 | 0.005 |
| | Q-Stat | 4.1867 | 13.524 | 21.458 | 31.736 | 40.780 | 42.390 | 43.812 | 44.069 | 44.625 | 44.680 |
| | Prob. | 0.041* | 0.001* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |
| HangSeng | AC | -0.027 | 0.012 | -0.025 | -0.022 | -0.013 | -0.022 | 0.025 | 0.025 | -0.006 | -0.033 |
| | PAC | -0.027 | 0.011 | -0.025 | -0.023 | -0.014 | -0.023 | 0.023 | 0.025 | -0.007 | -0.034 |
| | Q-Stat | 2.6458 | 3.1464 | 5.4852 | 7.2355 | 7.8549 | 9.6083 | 11.849 | 14.070 | 14.200 | 18.257 |
| | Prob. | 0.104 | 0.207 | 0.140 | 0.124 | 0.164 | 0.142 | 0.106 | 0.080 | 0.115 | 0.051 |
| Nifty | AC | 0.043 | -0.006 | -0.025 | 0.013 | -0.008 | -0.046 | -0.019 | 0.031 | 0.061 | 0.042 |
| | PAC | 0.043 | -0.008 | -0.025 | 0.015 | -0.009 | -0.046 | -0.014 | 0.031 | 0.056 | 0.038 |
| | Q-Stat | 6.7500 | 6.8667 | 9.1645 | 9.8058 | 10.017 | 17.691 | 18.987 | 22.426 | 35.768 | 42.263 |
| | Prob. | 0.009* | 0.032* | 0.027 | 0.044* | 0.075 | 0.007* | 0.008* | 0.004* | 0.00* | 0.00* |
| Sensex | AC | 0.053 | -0.014 | -0.023 | 0.004 | -0.012 | -0.043 | -0.028 | 0.030 | 0.070 | 0.051 |
| | PAC | 0.053 | -0.017 | -0.022 | 0.006 | -0.014 | -0.042 | -0.023 | 0.031 | 0.064 | 0.044 |
| | Q-Stat | 10.255 | 11.005 | 12.946 | 13.008 | 13.572 | 20.248 | 23.019 | 26.253 | 43.955 | 53.357 |
| | Prob. | 0.001* | 0.004* | 0.005* | 0.011* | 0.019* | 0.003* | 0.002* | 0.001* | 0.00* | 0.00* |
| Shenzhen | AC | 0.062 | -0.014 | 0.024 | 0.022 | 0.008 | 0.002 | 0.031 | 0.023 | -0.010 | 0.014 |
| | PAC | 0.062 | -0.018 | 0.026 | 0.018 | 0.007 | 0.001 | 0.031 | 0.019 | -0.012 | 0.015 |
| | Q-Stat | 13.767 | 14.512 | 16.601 | 18.320 | 18.566 | 18.578 | 22.130 | 24.078 | 24.433 | 25.168 |
| | Prob. | 0.00* | 0.001* | 0.001* | 0.001* | 0.002* | 0.005* | 0.002* | 0.002* | 0.004* | 0.005* |
| SP Global 100 | AC | 0.068 | -0.072 | -0.008 | 0.019 | -0.045 | -0.018 | 0.002 | 0.007 | -0.034 | 0.003 |
| | PAC | 0.068 | -0.077 | 0.002 | 0.015 | -0.048 | -0.009 | 0.003 | 0.004 | -0.034 | 0.007 |
| | Q-Stat | 16.729 | 35.424 | 35.677 | 37.055 | 44.381 | 45.573 | 45.595 | 45.773 | 49.943 | 49.981 |
| | Prob. | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |
| Topix | AC | 0.007 | -0.014 | -0.035 | 0.002 | -0.002 | -0.037 | -0.009 | -0.008 | -0.017 | 0.009 |
| | PAC | 0.007 | -0.014 | -0.035 | 0.002 | -0.003 | -0.038 | -0.008 | -0.009 | -0.019 | 0.008 |
| | Q-Stat | 0.1900 | 0.9035 | 5.4429 | 5.4523 | 5.4704 | 10.344 | 10.618 | 10.838 | 11.833 | 12.109 |
| | Prob. | 0.663 | 0.637 | 0.142 | 0.244 | 0.361 | 0.111 | 0.156 | 0.211 | 0.223 | 0.278 |

*significant at 5% level.

The null hypothesis states that there is no autocorrelation. We reject the null hypothesis for Greece, USA, UK, India, China, and the global index (SP Global 100), which means that returns in these markets are autocorrelated with their previous returns, which further implies that information doesn't get reflected in the stock prices immediately. More specifically, there is a lag in the absorption of information. Thus, these markets are not weak-form efficient. The null hypothesis is accepted for the stock market of Brazil, Germany, Hong Kong, and Japan as the p-value is more than 0.05. Thus, these markets are weak-form efficient as far as autocorrelation and partial autocorrelation suggests.

The last two rows of the table report the Ljung-Box Q-statistics (null hypothesis of the test suggests no autocorrelation up to specified lags) and their p-values. From the Q-statistics values, results similar to that of auto-correlation can be observed. The null hypothesis is rejected in the case of Greece, the USA, the UK, India, China, and the global index (SP Global 100), thereby suggesting that these markets display autocorrelation and are inefficient. On the other hand, Brazil, Germany, Hong Kong, and Japan have no autocorrelation and thus are weak-form efficient.

### 4.2.4. Variance Ratio Test

This test helps in testing for random walk that assumes homoscedastic increments as well as the random walk where increments are assumed to be heteroskedastic (Campbell et al., 1998, pp. 559-562). If we assume that a series follows random walk, then it simply implies that the variance of q-period difference (returns) should be q times the variance of one period difference.

Suppose $y_t$ is the return at any time t where t is equal to 1,…, T. According to variance ratio test, VR (q) is the ratio of variance of $q^{th}$ difference to variance of first difference.

$$VR(q) = \frac{\sigma^2(q)}{\sigma^2(1)}$$

where:
$\sigma^2(q)$ denotes 1/q the variance of the q-differences and $\sigma^2(1)$ is variance of the first differences.

According to random walk theory, VR (q) must approach unity. If it is less than 1 or more than 1, it indicates towards presence of negative serial correlation and positive serial correlation respectively (Borges, 2010, pp. 711-726). Since the data series of the selected indices are volatile as seen in the graphs (also confirmed by results of GARCH model), Lo and MacKinlay's heteroskedasticity-robust standard error estimates have been calculated in this study. Variance ratio test for the selected indices for sampling intervals of 2, 4, 8 and 16 days has been performed.

**Table 9.** *Variance Ratio test: Heteroskedasticity robust standard error estimates*

| Index | | q=2 | q=4 | q=8 | q=16 |
|---|---|---|---|---|---|
| Athex | VR (q) | 0.5441 | 0.2808 | 0.1293 | 0.0674 |
| | Z (q) | -13.91 | -12.94 | -11.06 | -8.60 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| Bovespa | VR (q) | 0.4939 | 0.2484 | 0.1213 | 0.0601 |
| | Z (q) | -15.42 | -12.93 | -10.25 | -7.61 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| DAX 30 | VR (q) | 0.5170 | 0.2472 | 0.1270 | 0.0603 |
| | Z (q) | -14-54 | -12.83 | -9.97 | -7.52 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| DowJones | VR (q) | 0.4809 | 0.2304 | 0.1098 | 0.0563 |
| | Z (q) | -11.29 | -9.436 | -7.34 | -5.39 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| FTSE100 | VR (q) | 0.5082 | 0.2291 | 0.1202 | 0.0588 |
| | Z (q) | -13.09 | -11.27 | -8.29 | -6.19 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| HangSeng | VR (q) | 0.4812 | 0.2490 | 0.1190 | 0.0606 |
| | Z (q) | -11.55 | -9.258 | -7.37 | -5.70 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| Nifty | VR (q) | 0.5253 | 0.2578 | 0.1267 | 0.0657 |
| | Z (q) | -28.58 | -23.886 | -17.77 | -12.78 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |

| Index | | q=2 | q=4 | q=8 | q=16 |
|---|---|---|---|---|---|
| Sensex | VR (q) | 0.5358 | 0.2632 | 0.1283 | 0.0667 |
| | Z (q) | -12.71 | -11.71 | -9.42 | -7.14 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| Shenzhen | VR (q) | 0.5406 | 0.2609 | 0.1305 | 0.0647 |
| | Z (q) | -15.14 | -14.10 | -11.28 | -8.72 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| SP Global 100 | VR (q) | 0.5752 | 0.2632 | 0.1335 | 0.0537 |
| | Z (q) | -10.90 | -10.46 | -8.19 | -6.05 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |
| Topix | VR (q) | 0.5109 | 0.2517 | 0.1273 | 0.0608 |
| | Z (q) | -13.90 | -11.77 | -8.99 | -6.86 |
| | p-value | 0.00* | 0.00* | 0.00* | 0.00* |

*significant at 5% level.

Variance ratio i.e. VR (q) and test statistic of heteroskedastic standard error estimates have been reported in the Table 9 along with their associated p-values. For all the indices, similar results were found. The null hypothesis that the data series follow random walk is rejected. Since it is suggested that variance ratio should be close to 1 in order to call a data series random walk, all the variance ratios in the table are significantly less than 1. This implies that the returns of all these markets are autocorrelated and there is reversion to the mean. The data series of all the selected indices are found to be having negative serial correlation as the observed values of variance ratio are less than 1 for all the values of q (Borges, 2010, pp. 711-726). It signifies that the investors have the tendency to overreact to the information (whether positive or negative) which eventually gets corrected in the days to come.

### 4.2.5. Breusch-Godfrey Serial Correlation LM Test

This test tests for the presence of serial correlation in the residual series of the data by finding regression of the series with its lagged values. The null hypothesis states that there is no serial correlation up to specific lags taken while the alternate suggests the presence of serial correlation. The results presented in Table 10 show that with the exception of Bovespa, DAX, Hang Seng and Topix, null hypothesis is rejected in all other markets taken for the study as p-value is less than 5% significance level. Thus as per the results of this test, only markets of Brazil, Germany, Hong Kong and Japan are weak form efficient as their indices are not serially correlated. Rest of the markets possess significant serial correlation in their stock market data thus signifying inefficiency.

**Table 10.** *Breusch-Godfrey Serial Correlation LM test results*

| Index | Athex | Bovespa | DAX 30 | Dow Jones | FTSE 100 | Hang Seng | Nifty | Sensex | Shenzhen | SP Global 100 | Topix |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LM test statistic | 18.529 | 2.8529 | 3.7979 | 44.750 | 13.954 | 3.0837 | 6.9508 | 11.322 | 14.950 | 37.966 | 0.9080 |
| p-value | 0.000* | 0.240 | 0.149 | 0.000* | 0.000* | 0.214 | 0.031* | 0.003* | 0.000* | 0.000* | 0.635 |

Null Hypothesis – No serial correlation up to 2 lags.

### 4.2.6. Garch (1, 1) Model

The sum of ARCH and GARCH coefficient measures the persistence of volatility clustering. The persistence of volatility clustering means the inefficiency of the capital market (Mishra, 2011, pp. 26-34; Seth and Sharma, 2015, pp. 88-106). GARCH (1, 1) model has been used in the study to capture the existence of volatility clustering in the data series. According to model, if sum of ARCH (1) and GARCH (1) coefficients is close to unity, it indicates the persistence of volatility clustering and thus signifies the inefficiency of the stock market. The results of GARCH (1, 1) model indicate that sum of ARCH (1) i.e. α and GARCH (1) i.e. β is close to unity in case of all the selected indices and all the values are significant. It signifies the persistence of volatility indicating the inefficiency of the stock markets selected.

**Table 11.** *GARCH (1, 1) model results*

| Index | α | | | β | | | α+β |
|---|---|---|---|---|---|---|---|
| | Coefficient | Z-statistics | p-value | Coefficient | Z-statistics | p-value | |
| Athex | 0.0588 | 24.598 | 0.00* | 0.9430 | 759.43 | 0.00* | 1.0018 |
| Bovespa | 0.0665 | 11.181 | 0.00* | 0.9086 | 117.34 | 0.00* | 0.9752 |
| DAX 30 | 0.0864 | 13.355 | 0.00* | 0.8987 | 116.24 | 0.00* | 0.9851 |
| DowJones | 0.1163 | 14.806 | 0.00* | 0.8630 | 98.227 | 0.00* | 0.9793 |
| FTSE100 | 0.1077 | 13.335 | 0.00* | 0.8773 | 100.17 | 0.00* | 0.9851 |
| HangSeng | 0.0608 | 12.827 | 0.00* | 0.9304 | 164.80 | 0.00* | 0.9912 |
| Nifty | 0.0849 | 14.992 | 0.00* | 0.9086 | 154.11 | 0.00* | 0.9936 |
| Sensex | 0.0783 | 14.588 | 0.00* | 0.9154 | 164.37 | 0.00* | 0.9937 |
| Shenzhen | 0.0351 | 19.548 | 0.00* | 0.9633 | 633.91 | 0.00* | 0.9985 |
| SP Global 100 | 0.0992 | 14.927 | 0.00* | 0.8916 | 122.29 | 0.00* | 0.9909 |
| Topix | 0.0975 | 15.964 | 0.00* | 0.8893 | 125.57 | 0.00* | 0.9868 |

*significant at 5% level.

**Table 11.** *Summary results of all the tests*

| | ADF Test | PP Test | Runs Test | AC, PAC and Q-statistics | Variance Ratio Test | B-G LM Test | GARCH |
|---|---|---|---|---|---|---|---|
| Athex | WFMI | WFMI | WFME | WFMI | WFMI | WFMI | WFMI |
| Bovespa | WFMI | WFMI | WFMI | WFME | WFMI | WFME | WFMI |
| DAX 30 | WFMI | WFMI | WFMI | WFME | WFMI | WFME | WFMI |
| Dow Jones | WFMI | WFMI | WFME | WFMI | WFMI | WFMI | WFMI |
| FTSE 100 | WFMI | WFMI | WFMI | WFMI | WFMI | WFMI | WFMI |
| Hang Seng | WFMI | WFMI | WFMI | WFME | WFMI | WFME | WFMI |
| Nifty | WFMI | WFMI | WFMI | WFMI | WFMI | WFMI | WFMI |
| Sensex | WFMI | WFMI | WFMI | WFMI | WFMI | WFMI | WFMI |
| Shenzhen | WFMI | WFMI | WFME | WFMI | WFMI | WFMI | WFMI |
| SP Global 100 | WFMI | WFMI | WFMI | WFMI | WFMI | WFMI | WFMI |
| Topix | WFMI | WFMI | WFMI | WFME | WFMI | WFME | WFMI |

Table 11 presents the summary of results derived from applying various tests and techniques of analysis. WFMI here represents weak-form market inefficiency whereas WFME represents weak-form market efficiency. Majority of the tests in majority of the markets have provided evidence that goes against the accepted paradigm of efficient market hypothesis and random walk theory.

## 5. Behavioral finance: a challenge to existence of EMH. An opinion

The recent empirical evidences (presented in section 2.2) have shown that the dominance of the theory of market efficiency has become far less acceptable than it was before. Academic finance has evolved a long way from the accepted paradigm of EMH to the behavioral finance. Where the EMH had strong evidences and literature that favoured the hypothesis, the evidences in support of behavioral finance are not much strong. The pieces of literature on behavioral finance, behavioral biases, market anomalies etc. are widely scattered and are not viewed in unison. EMH assumed that investors are always rational which is not possible in the real world at all the times. The behavioral finance is indeed the new future of academic finance as it is based on realities of real world as it assumes that investors get swayed by emotions and biases of their own and that of the others. However, it is also the matter of fact that behavioral finance has not yet come up with any concrete theory guiding asset pricing or return behavior as the discipline is still in its infancy stage where lot of research is being done. Though the literature has also provided evidences of stock market anomalies that go against the accepted paradigm of EMH, debates on their persistency and causes are still going on. Thus, it can be asserted that behavioral finance is indeed emerging as the basis of future academic finance. However, lot of new research based on strong evidences favouring behavioral finance is required to challenge the traditional finance and EMH that has strong and wide acceptance among academicians.

## 6. Conclusion

The present study discussed how the Efficient Market Hypothesis has evolved since its origin. The literature in the early 20th century presented substantial evidence in favor of market efficiency. However, the recent literature showed strong evidence of market inefficiency when the hypothesis was examined through several statistical tests. The results in this study have shown strong evidence of market inefficiency in the majority of the markets except for the results from one or two tests which suggest efficiency in the case of Shenzhen, Bovespa, DAX 30, Topix, and Hang Seng. Thus these markets didn’t show any substantial evidence of market efficiency. However, despite the vast amount of conflicting literature, the hypothesis is still regarded as one of the most accepted paradigms in financial literature. Most probably because even though behavioral economists have given some behavioral explanation of market inefficiency, they have not come out with any concrete theory explaining behavior or movements of stock prices yet. Thus, the efficient market hypothesis will continue to be accepted as one of the finest theories in the literature of finance till behavioral economists present any such concrete theory.

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