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Testing the weak form of efficient market hypothesis in carbon efficient stock indices along with their benchmark indices in select countries

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Abstract

This paper presents the results of tests on the weak form of Efficient Market Hypothesis applied to carbon efficient stock market indices of India, the United States of America (USA), Japan, and Brazil and their corresponding market indices which are used as their benchmark indices. In this study, Kolmogrov-Smirnov and Shapiro-Wilk tests are used to test the normality of data. Run test and auto-correlation test are used to check the randomness of the data. The tests are performed using daily closing prices for the whole sample period. It is found from the statistical tests that the daily closing prices do not follow random walks in all the four countries. However, monthly returns are following random walk in case of India, USA, and Brazil, but not in case of Japan.

Keywords

Carbon Efficient Stock Index, Efficient Market Hypothesis, Green Investment, Random Walk, Stock Market.

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Introduction

Efficient Market Hypothesis is one of the most popular topics in finance literature. The concept of Efficient-Market Hypothesis (EMH) was introduced by Eugene Fama in 1960. Fama (1970) suggested that the financial markets are "informationally efficient". According to his hypothesis, an investor can only earn normal returns in the market in the long run. It is not possible for an investor to get returns in the security market more than the average market returns consistently on a risk-adjusted basis.

There are three forms of EMH: "weak", "semi-strong", and "strong". The weak form of EMH states that prices of securities in the market reflect all past information that is publicly available. The semi-strong form of EMH states that security prices reflect all publicly available information and the prices instantly modify to reveal new public information as well. The strong form of EMH indicates that prices of security in the market instantaneously reveal even hidden information.

EMH is a highly controversial and, at the same time, an often disputed theory (Islam & Watanapalachaikul, 2005). Based on this concept, many theoretical and empirical studies have been conducted to investigate the movement of stock prices in different markets. This model suggests that it is meaningless to search for undervalued or overvalued stocks in the market. It also states that it is useless to try predicting the trends in the security market either by fundamental analysis or technical analysis. It is because it assumes that stocks are always traded at their fair value on stock exchanges. Thus, it is almost impossible for investors to purchase an undervalued stock or sell an overvalued stock. It further states that it is impossible for an investor to beat the market. Therefore, the only way an investor can possibly obtain higher returns is by purchasing riskier investments.

Yen and Lee (2008) argue that once necessary reservations and precautious interpretations are taken into consideration, the EMH will continue to play an important role in modern finance for years to come. Kratz (1999) found the concept of EMH as relevant and of

interest to the portfolio manager in order to outperform a benchmark and devise adequate strategies to exploit gross market inefficiencies.

EMH has a significant role to play for the academicians, regulatory authorities, and investors for making financial and investment decisions and steering and controlling the development of a newly emerging market (Clarke, Jandik & Mandelker, 2001). Borges (2010) has tested this hypothesis in different countries' financial markets, under different economic situations (crisis period/ recovery period), under different forms (weak, strong and semi-strong), to test the efficiency of stock market. He has found that daily and weekly returns are not normally distributed because they are negatively skewed and leptokurtic. He has also found that they display conditional heteroscedasticity. The EMH was rejected on daily data for Portugal and Greece due to first-order positive autocorrelation in the returns. France and UK data rejects efficient market hypothesis due to the presence of mean reversion in weekly data and stronger in recent years. The financial market for Germany and Spain were found to be most efficient.

Efficient market hypothesis and the random walk hypothesis have been major issues for research in the financial literature for over more than four decades. Random walk hypothesis states that prices of securities in the stock market moves randomly. It also states that the return from securities in the market is also random. In this paper, the weak form of efficient market hypothesis has been tested on Carbon Efficient Equity Indices along with their benchmark indices.

Weak form market efficiency implies that it is not possible to predict the prices of securities traded in the market using historical price information because successive price changes in securities are random. It implies that prices of securities in such a market are serially uncorrelated. However, none of the studies have tested this hypothesis for Carbon efficient stock indices.

Today, business houses are focusing on green environment or reducing global warming to achieve sustainable growth and development. Chia *et al*. (2009) suggested reducing global warming to be a long-term investment theme. It is widely considered nowadays by

the investors. The investors weigh the company's efficiency in handling the climate and its share prices.

The concept of Carbon Efficient Index is based on the performance of low carbon emitting companies. It is believed that the investors are ready to pay premium for those companies' stocks. Since there is little literature on efficient market hypothesis on carbon efficient indices, it is prudent to make an attempt to investigate the same in four major countries that are the India, USA, Japan, and Brazil.

The rest of the paper is organized as follows: section 2 focuses on the concept of Carbon Efficient Index, section 3 discusses the rationale for choosing the selected countries, sections 4 and 5 discuss the statement of the problem and rationale of the study, section 6 reviews the literature and research gap, section 7 and 8 throw light on research objectives and hypotheses, section 9 discusses the research methodology adopted to carry out the study, section 10 focusses on the analysis and findings, section 11 discusses the policy implications and conclusion of the study, and the final section discuss the scope of future research.

Carbon efficient index

The concept of a sustainable and responsible investment is becoming popular in recent years. It considers Environmental, Social, and Corporate Governance criteria (ESG) to generate long-term competitive financial returns and positive societal impact.

It is believed that sustainable and socially and environmentally responsible investment can be promoted by increasing awareness about the environment and social responsibility of investors. A swift increase of awareness, in both developed and developing economies, has been observed in this respect. New policies and regulations, such as the Kyoto Protocol, the European Emissions Trading Scheme, US Environmental Protection Agency, and Clean Air Act of 1963, are consequences of growing concern for environmental protection (Amenc, Goltz & Tang, 2010).

Therefore, it is the need of the hour to promote such companies that are environment-friendly. Investors can encourage such companies by

investing in them. Therefore, it is essential to identify such companies to facilitate the investors. For this purpose, most of the leading stock exchanges in the world have developed carbon efficient indices. This index is consisted of those companies that comply with the norms set to reduce the carbon emission into the environment in their respective countries.

Carbon efficient indices have been created to recognize a company's dedication to alleviate risks that arise from climate changes. This kind of index is developed primarily to help the investors and mutual fund managers to design a suitable fund for investors who would like to invest in environmentally responsive companies. Besides, this is also recognition to the companies for their responsible behavior towards environment. The presence of a separate index to track the movement of carbon efficient companies in the stock market is useful as investors can make a better and informed investment decision (Tripathi & Bhandari, 2012).

The screening criteria for the companies to be included in such index are their compliance with carbon emission norms set by the regulators of their respective countries in this regard. The criteria may also extend to include transparent policies regarding the emission of greenhouse gases. Companies in the carbon efficient index are chosen from a parent index and, on the basis of these criteria, they become the constituent of the carbon efficient index.

The concept of carbon efficient investment has been evolved in developed countries since 1980s, but it is still in its early stage in the developing economies like Brazil, China, and India. In this study, carbon efficient indices and their comparison with the corresponding benchmark indices of four countries' stock exchange, namely India, USA, Japan, and Brazil, have been considered.

For the promotion of carbon efficient investment in India, BSE-CORBONEX was created on November 30th, 2012. It is the 100 stocks portfolio and BSE-100 is the benchmark index for this. Similarly, 50 stock's carbon efficient index ICO2 is launched in Brazil on September 30th, 2009 and IBrX-50 index is the benchmark index for it. S&P Carbon Efficient Index was launched in the USA on

December 10th, 2009 and its corresponding benchmark index is S&P 500. S&P/ TOPIX 150 Carbon Efficient Index was launched on September16th, 2011 in Japan and it is the carbon titled version of S&P/ TOPIX 150 which is considered as benchmark index for S&P/ TOPIX 150 Carbon index.

Rationale for choosing selected countries

USA and Japan are the two biggest economies of the world, whereas India and Brazil are the two emerging economies of the world. Therefore, one developed country from the west, i.e., USA and one developed country from east (Asia), i.e., Japan are considered in this study. From the emerging economies, one emerging economy from Asia, i.e., India is chosen. The GDP growth rate of India is the highest in the world next to China. China is a communist economy and, in a communist economy, most of the investment is fueled and regulated by the government. However, India is a democratic country having a mixed economic system where individual investment has a huge role to play. Moreover, from India, the stock exchange chosen is Bombay Stock Exchange which is the biggest stock exchange in the world in terms of number of companies listed. Therefore, India is given preference over China for inclusion in this study.

Brazil is also one of the emerging economies of the world and its consideration is important in the study because it is a Latin American country. So, its inclusion in the study brings inclusion of one sample from Latin America. The consideration of these four economies is also justified from the perspective of rate of gross capital formation out of total GDP. It is 31.38%, 19.35%, 21.13%, and 20.08% for India, USA, Japan, and Brazil, respectively, which is considered to be very significant for the study. Moreover, Urrutia (1995) concluded that emerging markets are less efficient than developed markets. Therefore, two indices from the two leading economies of the world, namely, the USA and Japan and two indices from the world's emerging economies, namely, India and Brazil have been considered. The overview of the selected countries is presented in Appendix A.

Statement of the problem

Considering the concept of efficient market hypothesis, it is implied that only normal return can be earned by investing in carbon efficient indices. However, Tripathi and Bhandari (2012) found that companies with better performance on ESG issues are likely to be considered as a better investment proposition as well as a safer investment destination by the investors. Eccles, Ioannou, and Serafeim (2011) observed that, in the long run, companies that adopted better environmental and social policies outperformed significantly in terms of stock performance, compared to the companies which had did not adopt any of these policies. It has been observed that the driving force behind the carbon efficient investment is the social responsibility of the investors (Amenc, Goltz & Tang, 2010). The recent report by the United Nations Environment Program (UNEP) shows that carbon efficient investment, if continued for a substantially longer period, will result in faster economic growth.

The above discussions have led to that question that is it really possible to generate more than normal return by investing in the carbon efficient indices? Or to earn more than normal return one has to resort to technical analysis.

Therefore, the present study attempts to investigate the possibility of generating more than normal return by resorting to technical analysis in carbon efficient indices as well as their corresponding benchmark indices and thereby testing the weak form of efficient market hypothesis in both indices of the select countries.

Rationality of study

World's developed countries are responsible for the increase in carbon dioxide in the atmosphere. But of late, world’s developed countries are increasingly outsourcing their carbon pollution to emerging economies like India, Brazil, and China. Carbon emission can be controlled if companies act upon its reduction in environment. In this regard, it is also the responsibility of society to encourage those companies that are working towards the reduction in carbon emission.

Therefore, it is very important that the carbon efficient investment must be promoted and practiced by the investors in emerging countries as well as the developed ones.

Therefore, it is considered justified to study the efficiency of carbon efficient indices in developed as well as emerging countries to know that whether carbon efficient investing is also economically viable or not.

Review of literature and research gap

There have been many studies on testing the efficiency of stock market in different countries and on different indices. The literature review is divided into three sections: firstly, those who accept the efficient market hypothesis; secondly, those who reject the efficient market hypothesis; and finally, those with mixed results on the efficient market hypothesis.

Studies that accept the efficient market hypothesis

Kendall and Hill (1953) found the movement of stock indices to be random in nature. Fama (1970) observed that there is enough evidence of a positive correlation in daily price changes and returns on common stocks, but this positive dependence was not large enough to reject the efficient markets hypothesis. Fama (1998) found that market efficiency holds good in the long run. Hassan (2002) found that Dow Jones Islamic Market Index [DJIMI] returns are normally distributed and the DJIMI has a remarkable market efficiency. Shmilovici, Alon-Brimer and Hauser (2003) found that there is potential market inefficiency in ten of the international stock index series. Milunovich and Joyeux (2007) found that the spot and futures markets share information efficiently and contribute to price discovery together.

Studies that reject the efficient market hypothesis

There are also many studies which reject the efficient market hypothesis in different stock markets. Lo and MacKinlay (1988) provide evidence that stock prices do not follow random walks. In a World Bank study, for twenty stock markets, evidence of predictable returns of the stock market was found (Claessens, Dasgupta & Glen,

1995). Roux and Gilbertson (1978) observed non-randomness in stock price behavior and the market inefficiency on the Johannesburg stock Exchange. Poshakwale (1996), Gupta and Basu (2011), and Srivastava (2010), in their studies, found that the Indian stock markets are weak form efficient. Singh *et al*. (2014) found non-randomness in the Indian Islamic equity index.

Dockery and Kavussanos (1996) rejected the presence of efficient market hypothesis in the Athens stock market. Hamid *et al*. (2010) found the absence of random walks in all the countries of the Asian-Pacific region and concluded that the investors can take the stream of benefits through the arbitrage process from profitable opportunities across these markets. Malkiel (2003) has found that market efficiency does not exist in the US stock market. Levy and Nobay (1986) suggested that efficient market hypothesis may be rejected because of inappropriate treatment of risk rather than the violation of rational expectation of the efficiency hypothesis. Islam and Watanapalachaikul (2005) reveled that Thai stock market is also not efficient.

Studies with Mixed Evidence on the Efficient Market Hypothesis

Borges (2010) found mixed evidence on the efficient market hypothesis. The hypothesis is rejected for Portugal, Greece, France, and the UK. The tests for Germany and Spain do not allow the rejection of efficient market hypothesis and found Spain market being the most efficient.

Laffont and Maskin (1990) found that the Efficient Market Hypothesis fails in case of imperfect competition. Ball (2009) defended the efficient market hypothesis and suggested that even if there are certain other concepts challenging the efficient market hypothesis, yet, this hypothesis is not totally discarded, rather this is supplementary to many new developments in this field.

Jordan (1983) stated that all investors are risk neutral, each investor has a constant relative risk aversion, and all investors have constant absolute risk aversion. Thus, all these explain the conditions to satisfy the efficient market hypothesis, specifically in looking at the risk and wealth creation relationship of investors. Miclăuş *et al*. (2008) found

that markets are not efficient when the correlation test is done. Bulkley and Tonks (1989) compared stock prices with rational expectations/efficient markets prices. Chao-Fu, Pandey and Gupta (1998) stated that the main objective of the Taiwan Government in liberalization and internationalization of Taiwan Stock Exchange is to make it informationally efficient.

Siering and Muntermann (2013) state that capital markets are information efficient, but, using behavioral finance theory, it was found that market efficiency may be limited. Chen and Kuo (2004) found that there are a few cases whereby Cubist can beat the random walk even though the series is independent. Kenourgios Samitas and Christodoulou (2006) found that the foreign exchange market is efficient in the long run but rejected the Forward Rate Unbiasedness Hypothesis in the short run.

Studies on carbon efficiency

Daskalakis and Markellos (2008) examined the efficiency of the European market for carbon dioxide emission allowances and found that the behavior of the markets under consideration is not consistent with the weak form efficiency. Miclăuş *et al*. (2008) studied the efficiency of carbon future market. The results are useful for emission intensive firms, policy makers, risk managers, and active or passive investors in the emerging class of energy and carbon hedge funds. Singh *et al*. (2015) have also conducted studies on carbon efficient indices.

Research gap from existing literature

It is seen that there have been many studies on testing the efficient market hypothesis in several markets and indices. There are many studies on testing the efficient market hypothesis in sectorial indices too. But, since 'Carbon Efficient Indices' are relatively new, no attempt has been made to test the efficient market hypothesis for this index.

Based on the above background and gap areas, the present study bridges the gap to the existing literature to investigate the applicability of efficient market hypothesis on carbon efficient indices along with

the efficiency of their respective market index in the four select stock exchanges across the world. The comparison between the carbon efficient indices of developed countries with that of emerging countries will be helpful in knowing the fact that whether the economic development is in any ways associated with the market efficiency of the respective indices.

This paper contributes to the literature on EMH in several aspects, for example, the data cover very recent years, up to 2015, which have not been covered in previous studies and the study is conducted on Carbon Efficient Indices, which is also not done in the previous studies.

Objectives of study

It is established that weak form of efficient market hypothesis states that market prices/indices follow random pattern, i.e. they moves randomly without any pattern. Keeping this in view, the following objectives have been set for the present study:

- To investigate if the carbon efficient indices of four countries [S&PBSE-CORBONEX (India), S&P 500 CARBON (USA), S&P/TOPIX CARBON (Japan), and ICO2 (Brazil)] follow random pattern.
- To investigate if the monthly return of the carbon efficient indices of four countries [S&PBSE-CORBONEX (India), S&P 500 CARBON (USA), S&P/TOPIX CARBON (Japan), and ICO2 (Brazil)] follow random pattern.
- To investigate if the respective market indices viz. S&P BSE-100 (India), S&P 500 (USA), S &P TOPIX 150 (Japan), and IBrX-50 (Brazil) follow random pattern.
- To investigate if the monthly return of respective market indices viz. BSE-100 (India), S&P 500 (USA), S &P TOPIX 150 (Japan), and IBrX-50 (Brazil) follow random pattern.

Hypotheses of the study

There are many authors like Kendall and Hill (1953), Hassan (2002),

Hamid *et al*. (2010), Lo and MacKinlay (1988), Roux and Gilbertson (1978), who have tested the weak form of efficient market hypothesis using the random movement of stock prices as well as stock indices in the market. This has given the impetus to frame the hypotheses to test the weak form of efficient market hypothesis. The study proposes to test the following hypotheses:

H_{01}: The carbon efficient indices of the countries viz. India, USA, Japan, and Brazil follow random pattern.

H_{02}: The corresponding benchmark market indices of the countries viz. India, USA, Japan, and Brazil follow random pattern.

H_{03}: The monthly return on carbon efficient indices of the countries viz. India, USA, Japan, and Brazil follow random pattern.

H_{04}: The monthly return on corresponding benchmark market indices of the countries viz. India, USA, Japan, and Brazil follow random pattern.

Research method

The present study is empirical in nature. It is the study of carbon efficient indices in India, USA, Brazil, and Japan. The following methodology is adopted to achieve the stated objectives:

Type of Study. The study is descriptive in nature.

Type of Data. The study is based on secondary data. Daily closing prices of the market indices of stock exchanges of India, USA, Japan, and Brazil and closing prices of carbon efficient indices are used for the study.

Collection of Data. The data are collected from the official websites of Bombay Stock Exchange (India), S&P (USA), Tokyo Stock Exchange (Japan), and BM&F Bovespa (Brazil). Daily closing prices of considered indices from October 1st, 2010 to December 31st, 2015 are taken.

Data Analysis. In this study, Kolmogorov-Smirnov and Shapiro-Wilk test (Lilliefors, 1967; Shapiro & Wilk, 1965) are used to check the distribution pattern of data to see if it is normally distributed or not. Shapiro-Wilk test is used to assess the goodness of fit if the sample size is less than 2000 (UNT, 2014). Run test is used to test the

randomness of movement of indices as well as of return. Run test has to be used because the data is not normally distributed and, therefore, parametric test cannot be performed on it. Auto correlation test is also used to determine randomness. For calculating monthly return, the following formula is used:

$$R_i = LN (P_t / P_{t-1}) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where

LN= Logarithmic return

R_i = The return obtained

P_t= Price at the end of the month of carbon efficient indices/benchmark market indices

P_{t-1}= Price at the staring of the month of carbon efficient indices/benchmark market indices.

Logarithm returns are used as they are more likely to be normally distributed which is required for further statistical tests (Strong, 1994).

Analysis and Findings

The analysis and findings of the present study is reported under the following paragraphs.

Testing weak form of efficient market hypothesis on daily closing values

The distributional patterns of the closing values of the considered stock indices are investigated by performing the Kolmogorov–Smirnov Test and Shapiro-Wilk Test. It is presented in Table 1.

Table 1. Result of Kolmogorov-Smirnov and Shapiro-Wilk tests on daily closing values of stock indices

Particulars	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	D.f.	Sig.	Statistic	D.f.	Sig.
S&P 500	0.116	803	0.000	0.940	803	0.000
S&P 500 CARBON	0.114	803	0.000	0.936	803	0.000
S&P-BSE 100	0.058	803	0.000	0.981	803	0.000
S&P-BSE CARBONEX	0.058	803	0.000	0.980	803	0.000
S&P-TOPIX 150	0.154	803	0.000	0.873	803	0.000
S&P-TOPIX CARBON	0.172	803	0.000	0.859	803	0.000
IBrX-50	0.091	803	0.000	0.953	803	0.000
ICO2	0.048	803	0.000	0.979	803	0.000

Source: Compiled from the data extracted from the websites of respective stock exchanges

In Table 1, it has been observed that the significant values for all the indices, for Kolmogorov-Smirnov test as well as for Shapiro-Wilk test, are 0.000. It is below 0.05 (5% level of significance), alluding that the distribution is not normally distributed.

Since the data is not normally distributed as evident in Table 1, parametric test cannot be performed on it and, therefore, non-parametric test has to be performed to test the random movement of considered indices. One sample run test is performed to investigate if the indices under consideration are randomly distributed. The test value against which the runs are determined is the median of the corresponding data set. Table 2 shows the result of the runs test on the daily closing prices of stock indices.

Table 2. Result of runs test of the daily closing prices of stock indices

Particulars	S&P 500	S&P 500 CARBON	S&P-BSE 100	S&P-BSE CARBONEX	S&P-TOPIX 150	S&P-TOPIX 150 CARBON	IBrX-50	ICO2
Test Value(a)	1365.6	120.3	5639.7	915.64	721.1	786.5	21155.0	1099.1
Cases< Test Value	412	412	410	410	402	402	401	401
Cases >= Test Value	413	413	410	410	402	402	402	402
Total Cases	825	825	820	820	804	804	803	803
Number of Runs	16	14	29	29	22	22	55	42
Z	-27.695	-27.835	-26.696	-26.696	-26.890	-26.890	-24.541	-25.459
Asymp. Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Source: Compiled from the data extracted from the websites of respective stock exchanges

In Table 2, it is observed that the significant value for run tests considered about the median of all the indices is 0.000 which is below 0.05 (5% level of significance), indicating that the stock indices do not follow random behavior leading to the rejection of the null hypotheses H_{01} (i.e., the carbon efficient indices of the countries viz. India, USA, Japan and Brazil are randomly distributed) and H_{02} (i.e., the corresponding benchmark market indices of the countries viz. India, USA, Japan, and Brazil are randomly distributed). Thus, null hypotheses H_{01} and H_{02} are rejected, given the test and methodology.

Therefore, it can be concluded that the considered indices reject the

weak form of efficient market hypothesis on the daily closing values of the considered indices. Negative values of Z in case of all the indices represents the weak form of inefficiency (Srivastava, 2010). In other words, all the indices show the weak form of market inefficiency.

Testing weak form of efficient market hypothesis of the monthly return given by the indices

Monthly return is calculated as per Eq. (1). Kolmogorov-Smirnov test and Shapiro-Wilk test have been conducted on monthly returns of the indices to test whether the data is normally distributed. The results of the Kolmogorov-Smirnov test and Shapiro-Wilk test have been shown in Table 3.

The significance value of Kolmogorov-Smirnov test and Shapiro-Wilk test in Table 3 shows that monthly returns of all indices are normally distributed, since it is less than 0.05 (5% level of significance) except S&P500 and S&P500 U.S. Carbon Efficient Index.

Table 3. Result of Kolmogorov-Smirnov and Shapiro-Wilk test on monthly returns of stock indices

Particulars	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
S&P 500	0.153	39	0.021	0.905	39	0.003
S&P500 U.S. Carbon Efficient Index	0.159	39	0.015	0.912	39	0.005
S&P-BSE 100	0.115	39	0.200(*)	0.972	39	0.443
S&P BSE CARBONEX	0.114	39	0.200(*)	0.972	39	0.444
S&P TOPIX 150	0.061	39	0.200(*)	0.988	39	0.946
S&P TOPIX Carbon Efficient Index	0.058	39	0.200(*)	0.989	39	0.960
IBrX-50	0.114	39	0.200(*)	0.972	39	0.437
ICO2	0.115	39	0.200(*)	0.959	39	0.171

Source: Compiled from the data extracted from the websites of respective stock exchanges

One sample run test is performed to investigate if the monthly returns of the indices under consideration are randomly distributed. The test value against which the runs are determined is the median of the corresponding dataset. Run test can be performed even if the data is not normally distributed. Hence, it can be performed for the monthly returns of all the considered indices, including the USA whose monthly return is not normally distributed as shown in Table 3.

Table 4 shows the result of the run test of the monthly returns of the considered stock indices.

In Table 4, it is observed that the significance value for run tests considered about the median of monthly returns of all the indices is more than 0.05 (5% level of significance) except for TOPIX 150 and TOPIX 150 CARBON. It indicates that the monthly return of the considered indices, except for TOPIX 150 and TOPIX 150 CARBON, follow random behavior leading to the acceptance of the null hypothesis.

Thus, null hypotheses H_{03} (The monthly return of carbon efficient indices of the countries viz. India, USA, Japan, and Brazil are randomly distributed) and H_{04} (The monthly return of corresponding benchmark market indices of the countries viz. India, USA, Japan, and Brazil are randomly distributed) are accepted for all the stock exchanges other than Japanese stock exchange, given the test and methodology.

Therefore, it can be concluded that the monthly return of considered indices show the weak form of efficient market hypothesis. Negative values of Z for TOPIX 150 and TOPIX 150 CARBON represent the weak form of inefficiency (Srivastava, 2010). Other than this, all other indices' monthly return show the weak form of market efficiency.

Table 4. Result of runs test of the monthly returns of stock indices

Particulars	**S &P 500**	**S &P 500 Carbon**	**S&P BSE 100**	**S&P- BSE-CARBONEX**	**S&P TOPIX 150**	**S&P TOPIX 150 CARBON**	**IBrX-50**	**ICO2**
Test Value	1.875	2	-1	-1	1	1	0	0
Cases < Test Value	19	19	19	19	19	19	19	19
Cases >= Test Value	19	19	19	19	19	19	19	19
Total Cases	38	38	38	38	38	38	38	38
Number of Runs	22	22	24	24	13	13	19	15
Z	0.493	0.493	1.151	1.151	-2.138	-2.138	-0.164	-1.480
Asymp. Sig. (2-tailed)	0.622	0.622	0.250	0.250	0.033	0.033	0.869	0.139

Source: Compiled from the data extracted from the websites of respective stock exchanges

Auto correlation test

To further confirm the relation of the prices on the preceding prices, auto correlation test is performed. The prices of S&P BSE 100, S&P BSE CARBONEX, S&P 500, S&P CARBON, S&P TOPIX 150, S&P TOPIX Carbon IBrX-50, and ICO2 show that there is a high correlation of 0.97, 0.99, 0.96, 0.97, 0.97, 0.99, 0.99, and 0.98, respectively. This again confirms the hypothesis that the considered indices do not follow a random behavior.

However, as far as monthly returns are concerned, it is found that the auto correlation is 0.30, 0.29, 0.27, 0.31, 0.66, 0.61, 0.35, and 0.37 for S&P BSE 100, S&P BSE CARBONEX, S&P 500, S&P CARBON, S&P TOPIX 150, S&P TOPIX Carbon, IBrX-50, and ICO2. This also further confirms the hypothesis that monthly returns are randomly distributed other than for Japan.

Conclusion and policy implications

From the analysis done above, it is revealed that the movements of the carbon efficient stock indices of India, USA, Japan, and Brazil as well as their respective benchmark market indices are not random, leading to the rejection of the weak form of EMH. Thus, it indicates that the present market prices do not reflect the outcome of all the past information and markets are informationally inefficient to reflect any given change in the information. It also suggests that prices do not adjust instantaneously to the infusion of new information in the market. This clearly indicates that the technical trading can be very apt fully applied in all the markets to predict future trends in the share prices and thereby increasing the possibility of earning more than normal returns.

It is also due to the fact that market most of the time over-react to a given information and therefore, the prices are either more than the fair value or less than the fair value (Singh, 2011). It means past prices may be used to forecast future returns to some degree. This fact is the starting point in any technical analysis. It also means that the investors in the carbon index can earn benefits through the arbitrage process

from profitable opportunities in these markets. Thus, this study supports the findings of Lo and MacKinlay (1988), Claessens, Dasgupta and Glen (1995), Roux and Gilbertson (1978), Poshakwale (1996), Gupta and Basu (2011), Srivastava (2010), Singh *et al*. (2014), Singh *et al*. (2015), Dockery and Kavussanos (1996), Hamid *et al*. (2010), Malkiel (2003), Ellinger (1971), and Borges (2010).

However, in case of monthly return of the considered carbon efficient indices and their respective benchmark market indices, it is found that movement of the monthly return is random in all other than Japanese market. This confirms the findings of Fama (1998), where it was found that market efficiency holds good in the long run. Hassan (2002) has also found that market returns are normally distributed. In case of Japan, it is found that monthly returns are not normally distributed. It means a trend is visible in case of monthly returns of stock index of Japan, i.e., Tokyo Stock Exchange and hence technical analysis can yield more than normal return in case of S&P- TOPIX Carbon and S&P TOPIX of Japan. The possible reason for this is that Japan was affected by Tsunami in the first quarter of 2011. Due to this, its stock market had to be closed for some time. There was a big fall in the market due to Tsunami. And after this natural calamity, Japanese economy took some time to recover. Therefore, a trend has been visible in case of Japan's stock indices.

Thus, it may be concluded that one can make profit in intraday trading by resorting to technical analysis and investing in the carbon efficient indices as it could have been made by investing in other portfolios, however, in the long run, one will be earning normal profit only as it is seen that monthly returns are not normally distributed. Therefore, it is advisable to invest in carbon efficient indices. Doing so, one will not be required to compromise on the return and at the same time the investors will have the satisfaction of investing in the environment-friendly company's stocks and not doing any kind of harm to the environment. For this, necessary investor education program may be launched by the policy makers (Singh & Bhowal, 2010) and these indices need to be made popular using necessary marketing driven approach (Singh & Bhowal, 2011).

Future scope of study

In this study, logarithmic returns of the stock indices are calculated. The EMF can be tested by considering weekly, fortnightly, quarterly, half yearly return of the carbon efficient indices for a substantially longer period. Only green indices of the United States of America, Japan, India, and Brazil have been considered in this study, more green indices from other nations of the world can be considered and cross sectional as well as longitudinal study can be conducted.

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Appendix A. Overview of sample countries

S. No.	Country	GDP (PPP)		GDP (Nominal)		HDI (2013)	Income Group	National emissions (thousand of tonnes of carbon) 2007	Emissions per person (tonnes of carbon) 2006	Stock Exchange	Carbon Efficient Index	Corresponding Market Index
		Total	Per capita	Total	Per capita							
1.	India	$7.997 trillion (3rd)	$6,266 (124th)	$2.308 trillion (7th)	$1,808 (141st)	Steady 0.586 medium · 135th	Lower Middle Income	479,039	0.37	Bombay Stock Exchange	BSE-CARBONEX	BSE-100
2.	Jnited States of Americ (USA)	$17.418 trillion (2nd)	$54,596 (10th)	$17.418 trillion (1st)	$54,596 (10th)	Steady 0.914 Very High 5th	High Income: OECD	1,547,460	5.18	New York Stock Exchange	S&P 500 CARBON	S&P 500
3.	Japan	$4.843 trillion (4th)	$38,216 (29th)	$4.210 trillion (3rd)	$33,223 (25th)	Decrease 0.890 very high 17th	High Income: OECD	357,534	2.80	Tokyo Stock Exchange	TOPIX CARBON	TOPIX 150
4.	Federative Republic of Brazil	$3.259 trillion (7th)	$15,941 (74th)	$2,247 trillion (8th)	$11,281 (60th)	Increase 0.744 high · 79th	Upper Middle Income	110,833	0.51	BM&F Bovespa	ICO2	IBrX

Source: Authors' Own Compilation from various sources
Note: GDP estimate for all countries is 2015 except USA is taken for 2014 estimate
HDI means human development index