Do Green Indices Outperform BSESENSEX and Energy Indices in India? Some Evidence on Investors' Commitment Towards Green Investing

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ABSTRACT

This study has examined the performance of two Indian stock indices capturing the commitment of industries towards mitigating risks arising from pollution and climate change viz., BSE Greenex and BSE Carbonex, vis- a-vis two indices augmenting carbon emissions - BSE Energy index and BSE Oil & Gas index, and also BSESNSEX, the apex index representing Indian stock market, during the period January 2010 to December 2019. Besides using three risk-adjusted return ratios, namely, the Sharpe ratio, Treynor ratio, and Jensen's Alpha, on all the five indices, we have also applied GARCH-in-mean model to find if there is a risk premium involved either for causing emission or for mitigating the ill effects of emission. The results show that BSE Carbonex outperforms BSESENSEX and all the three other indices in terms of the three-performance metrics. Moreover, the two green indices and BSESENSEX show significant presence of risk premium in the framework of GARCH-in-mean model while risk premium is insignificant in case of the two carbon emitting energy indices. Overall, therefore, the study finds that some of the green funds such as those representing BSE Carbonex outperform the investors' benchmark stock index BSESENSEX and the two energy indices which represent traditional funds in India. A brief look at the term structure of return and risk also gives support to the green investing index BSE Carbonex. The findings of this study thus advocate for carbon–efficient practices among the larger business entities in India even after addressing the environmental, social and governance issues of responsible investing.

Key words:*Energy Indices, Green Indices, GARCH-In-Mean Model, Risk-Return Relationship*
JEL Classifications : C32, G11, Q40, Q54

1. INTRODUCTION

In recent environmental policy debate, the concept of green economy has gained immense significance by redefining the traditionally antagonistic relationship among economic and ecological goals in modern society which presents these goals as being more complementary and synergistic than conflicting (see, for details, Fiorino, 2014). In the early stages of environmental movement, this perception of inevitable trade-offs among economic and ecological goals was recognized (Fiorino, 2001). In fact, there is a well- documented literature showing this trade-off between economic development and environment (see, for details, Trana

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et al., 2020). In this debate, researchers like Daly (1991) advocated imposing limits on economic growth for ecological sustenance. An alternative perspective was in favour of fueling economic growth as it leads to major human well-being. However, the present green economy perspective has reconciled these two conflicting perspectives (Giddens, 2014).

Considering the changing perspectives on economic development and environment, significant changes have happened in investors' objectives and social obligations following the principles of responsible investing. The 'Who Cares Wins' conference in 2005 hosted by the UN Global Impact had shown a remarkable degree of agreement among participants that environmental, social and governance (ESG) factors play an important role in the context of longer-term investment. In early 2005, the then United Nations Secretary-General invited a group of world's largest institutional investors to join an initiative to develop what is now known as the 'Principles for Responsible Investment' (PRI). This UN-based network of investors is committed to promoting sustainable investing so that companies can operate more sustainably with greater sense of corporate responsibility. The main objective of the PRI is to understand the investment implications of ESG factors. This is the most important modern portfolio approach, and green investing is now a part of sustainable investing. And hence, the investors, companies, policy planners, and also people and societies are increasingly facing ESG issues through finance, trade and investment.

The energy study report of the Organization for Economic Co-operation and Development (OECD) published in the year 2011 demonstrated that although energy is a fundamental input to modern economic activity since the era of industrial revolution, the energy sector poses a particular challenge in the context of green growth due to its size, complexity, path dependency and reliance on long-lived assets. In another report entitled 'Towards Green Growth: Monitoring Progress' in 2011, the OECD has pointed out (p. 9) that **"**Green growth is about fostering economic growth and development while ensuring that the natural assets continue to provide the resources and environmental services on which our well-being relies. To do this, it must catalyse investment and innovation which will underpin sustained growth and give rise to new economic opportunities."

Human activities are responsible mostly for the total increase in greenhouse gases in the atmosphere over the last 150 years. The largest source of greenhouse gas emission from human activities is from burning fossil fuels for electricity, heat, and transportation. It is alarming to note that driven by very high energy demand in recent times, global energy-related CO_2 emission rose by 1.7% in the year 2018 as per the Global Energy and CO_2 Status Report, 2019. While emission from fossil fuels has increased significantly during this period, the power sector accounted for nearly two-thirds of this emission growth. Coal use in power sector alone largely caused this increase - mostly in Asia, and in particular, in China and India.

The IPCC's (Intergovernmental Panel on Climate Change) three sets of 'Assessment Reports', the latest one being published in 2001, point to a range of serious potential outcomes from climate change that could cause great economic and social disruption. In fact, climate change is increasingly threatening economic development all over the world and adversely affecting many economic activities. It is, therefore, also likely that these impacts may undermine the ability of many institutional investors like, for instance, pension funds, to fulfill their economic targets. In this context, it is worth noting that energy security prices are more responsive to global shocks, and these have become attractive destinations to the institutional investors although eventually these cause greenhouse gas emissions. It is also encouraging to note that the investors, in line with the Net-Zero Asset Owner Alliance convened by the United Nations,

are gradually stepping up efforts to protect people and planet with the knowledge that companies that transform their businesses to deliver a low carbon economy will benefit most from the opportunities presented by environmental pollution and climate change.

In this context, it may be mentioned that there are different approaches followed by investors such as socially responsible investing, environmental, social and governance investing, sustainable investing, and long-term investing. Investors' attention to climate change, resource efficiency and green issues in general has been rising in recent years and their initiatives in this respect are growing in support (Inderst et al., 2012). Several green stock indices have been developed in many countries and also at the global level since indices are primary investment tool for investment managers and investment owners as they provide a benchmark or point of reference for the active investment decisions. It may be pointed out in this context that preferences for indices differ across developed countries. For instance, in Japan, there is a focus on environmentally themed indices. Technology and social aspects (e.g. community investing) are popular in the USA, whilst in Europe the interest has been generally broad across all responsible investment approaches. At the global level there are some indices such as NASDAQ OMX Green Economy index, a market capitalization weighted index since 2010, and Zacks Global Water index, which have been associated with the green economy of sustainable development. The green economy is expected to increase to 10% of global market value by 2030, according to a report by FTSE Russell Study, 2018.

In this backdrop, this study is primarily focused on the basic issue of green versus carbon emitting industries as represented by their respective stock indices for an important developing country called India. Before we state the objectives of this study clearly, we state briefly the present status of India on the crucial ESG issues. India is the world's third largest emitter of greenhouse gases (GHGs), after China and the USA. As per the study of the International Energy Studies Group under the Berkley Lab conducted in the year 2011, the industry sector in India consumes 35% of final energy consumption. The report also stated that the energy intensive industries represent 64% of the entire energy consumed in this sector in 2003-04 while only representing 32% of total industry value added. According to a study commissioned by Greenpeace, it is possible to change fundamentals of India's energy supply systems sufficiently by 2050 to check climate change. As per the Report of Confederation of Indian Industry (CII) on 'Building a Low Carbon Economy', published in 2008, India has adopted an approach that sets the trend towards a low carbon economy as India has become an important emerging economy through its increasing participation in the global economy through trade, outsourcing, technology deals and acquisition of companies and businesses. In line with 2030 Sustainable Development Goals, India has committed itself to reduce the emission intensity of its GDP by 33–35 per cent by 2030 from its level in 2005 and to achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (Global Green Growth Institute Report, 2015). In line with these commitments towards development agenda of 2030 for the country, India has improved its rank in the Global Green Economy Index (36 out of 130) in the year 2018. Moreover, India scored 4 in the 1-12 scale on corporate sustainability based on assessment of largest domestic companies while other major countries like Japan, USA and China have scores 8, 5 and 3, respectively.

Despite some improvements in recent times, the challenge before a country such as India is to enable an unprecedented shift in long-term investment from conventional to green alternatives. In fact, owing to the high level of risk faced, the immediate need is to shift to a low carbon growth path is clear. However, strategies for low carbon emission can only be implemented if

the emission landscape across different businesses and the effects of emission on sustainable growth are properly investigated and studied. This study is an attempt to this end. To be explicit, the primary aim of this study is to examine the performance of Indian stock indices representing green investing i.e., capturing the commitment of industries towards mitigating risks arising from pollution and climate change, such as S & P BSE Greenex, and S & P BSE Carbonex, vis-à-vis Indian stock indices augmenting carbon emissions such as S & P BSE Energy index, and S & P BSE Oil & Gas index and also the well-known investors' benchmark index of Indian stock market i.e., S & P BSESNSEX[1]. In other words, our study essentially examines the performance of two energy mitigating stock indices of India as compared to two energy enhancing stock indices and also BSESENSEX. This empirical study based on Indian five stock indices data is expected to throw light on the current status on the investment practices followed in India resolving the long-term sustainable investment ESG issues by following the six principles for responsible investment (PRI) as designated by the UN agency. Further, the findings of this study would help the potential investors in India, both domestic and foreign, to decide whether profit-driven investors can enjoy high-return-low-risk portfolio even after consideration of environmental issues within investment through market mechanism. The study also takes a brief look at the term structure of return and risk associated with these stock indices in the sense of finding how the indices behave over three maturities viz., at daily, monthly and yearly levels, and further if these indicate broadly similar conclusions as those obtained from the main study.

We conclude this section by stating the main hypothesis of this paper, namely, green investments energy mitigating sectors in India as represented by S & P BSE Greenex and S & P BSE Carbonex which take into account environmental issues such as climate change and pollution, outperform energy sector indices S & P BSE Energy, and S & P BSE Oil & Gas which are mostly responsible for increasing carbon emissions, as well as the benchmark stock index of India i.e., BSESENSEX.

The paper is organized as follows. Literature review is presented in the next section. Data and methodology are discussed in Section 3. Results and discussions are presented in Section 4. The paper ends with some concluding remarks in Section 5.

2. LITERATURE REVIEW

Some studies in this literature have looked into the performances of green economy indices as compared to conventional benchmark indices. For instance, a study by Schroder (2007) analysed whether stock indices that represent socially responsible investments (SRI) exhibit a different performance compared to conventional benchmark indices and found that SRI stock indices do not exhibit a different level of risk-adjusted return than the conventional benchmark indices. There are some studies evaluating performance differences of Islamic market indices with conventional benchmark indices, such as Atta (2000), Hassan (2001), Tilva and Tuli (2002), and Hakim and Rashidian (2002, 2004). These studies compared the performance of Dow Jones Islamic market index against some conventional benchmark index. However, in the context of green economy indices such comparative studies are almost non-existent.

With increasing focus on environmental protection, environment has become an integral part of investment decision making at different levels including corporation (see, for details,

[1]The Bombay Stock Exchange Sensitive Index (BSESENSEX) is the most widely accepted apex index representing Indian stock market. It is a free-float market-weighted stock market index of 30 well-established and financially strong companies representing various industrial sectors of the Indian economy.

Boulatoff and Boyer, 2009). As Sirbu et al. (2015) have noted, investments are now being increasingly replaced by green investments in order to ensure sustainability, especially in developed economies. Of course, there is some awareness on the benefit of green investment among the investors in developing countries as well. However, studies showing that high return with row risk is possible in green investing through application of appropriate market mechanism are necessary to motivate the potential investors. Although there are a few studies considering the state of sustainable investing and its status with benchmark indices in the context of developed countries, such studies in the context of Indian economy which is an important emerging economy, is almost non-existent. Moreover, whatever few studies have been done, those have essentially compared sustainable investing versus traditional investing. For instance, Tripathi and Kaur(2021) observed that that the sustainable strategy in emerging economies can provide investors with a safe investment vehicle during adversity. But, to the best of our knowledge, studies on the state of investing in India considering both energy and green issues in the light of the UN declared PRI is almost non-existent. Our work is an attempt to fill this important gap in studies on the current state of green investing in India as compared to carbon emitting energy intensive investing.

3. DATA AND METHODOLOGY

This study uses the time series data of four relevant Indian stock indices viz., S & P BSE Energy, S & P BSE Oil & Gas, S & P BSE Carbonex, and S & P BSE Greenex, at daily level for the period January 2010 to December 2019, and compares the performances of these indices in terms of risk-adjusted returns on S & P BSESENSEX[2] which is taken as the benchmark index. This comparison is done by considering three risk-adjusted return ratios, namely, the Sharpe ratio, Treynor ratio, and Jensen's Alpha. Data on all the five indices are taken from www.bseindia.com. These risk-adjusted metrics would enable investors to compare actual returns on each of these indices with that of BSENSEX, and determine whether stock indices mitigating risks arising from pollution and climate change, viz., BSE Carbonex and BSE Greenex, have higher risk adjusted returns as compared to the benchmark BSESENSEX or not. In the same way, this study will also be helpful to understand whether stock indices augmenting greenhouse gases, namely, BSE Energy index and BSE Oil &Gas index, outperform the benchmark BSESENSEX. In this study, 'yield on 10-year government bond' at daily level has been taken as the asset with risk-free interest rate; the data on this variable have been taken from the www.investing.com.

It is well-known that these risk-adjusted metrics are time invariant. But since these indices are likely to be volatile and hence time dependent, we also use GARCH model for considering volatility of BSESENSEX and these Green and Energy indices. Further, GARCH-in-mean (GARCH-M) model is applied to find if there is a risk premium involved either for causing emission or for mitigating the ill effects of emission. Since leverage effect is often present in stock indices, in addition to GARCH volatility model which is characterized by a symmetric response of current volatility to positive and negative lagged errors, we also consider the asymmetric volatility response as captured by exponential GARCH (EGARCH) model proposed by Nelson (1991).

[2]'S & P' is henceforth dropped for the sake of convenience.

3.1 Time-invariant Risk-adjusted Measures

Now, we briefly discuss the three time-invariant risk- adjusted measures which are used for assessing the performance of green economy indices as compared to the most well-known conventional stock index of India, BSESENSEX. The Sharpe ratio (SR) developed by Sharpe in 1966 is defined as the portfolio premium divided by portfolio risk which includes both systematic and unsystematic risk. In general, the portfolio showing highest Sharpe ratio should be chosen by the investors. It is defined as SR=$(r_p–r_f)/\sigma_p$ where r_p, $r_f$and σ_p stand for portfolio return, return on risk-free asset and portfolio risk, respectively. This ratio also measures the slope of the capital allocation line. The higher the value of slope, the better is the asset performance. Another portfolio performance measure used, namely, the Treynor ratio (TR), is an extension of the Sharpe ratio. Treynor ratio is defined as TR=$(r_p–r_f)/ \beta_p$, where β_p is the systematic risk, called 'Beta risk', determined from the Capital Asset Pricing Model (CAPM) due to Sharpe (1964), Linter (1965), and Mossin (1966).

Both the Sharpe ratio and Treynor ratio have the limitation that by itself these measures are relative performance measure rather than absolute one. Hence, we further use an absolute risk performance measure, called the Jensen' Alpha (1970), which determines whether a particular asset/index outperforms or underperforms the market portfolio. This measure, asα_p, is defined as:$\alpha_p = r_p - (r_f + \beta_p(r_M - r_f))$ where r_M stands for returns on market portfolio and the other notations being already defined.

3.2 GARCH-M Model

The GRACH-in-mean (GARCH-M) model, proposed by Lilien and Robins in 1987, which directly captures the effect of risk as measured by GARCH form of volatility in understanding the fundamental relationship between return and time-variant risk, is specified below. Risk-free interest rate (in stationary form) as an explanatory variable for daily returns is taken from consideration of appropriate specification of the conditional mean model since this variable has been found to have a significant role in Indian stock returns (see, for instance, Sarkar and Mukhopadhyay, 2005).

$$r_t = \sum_{k=1}^{m} \varsigma_k r_{t-k} + \omega \Delta i_t + \theta f(h_t) + \varepsilon_t \quad (3.1)$$

$$\varepsilon_t = z_t \sqrt{h_t} \quad (3.2)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \delta h_{t-1} \quad (3.3)$$

where $z_t \sim N(0,1)$, $\alpha_0 > 0$, $\alpha_1 \geq 0, \delta \geq 0, r_t$ is the continuously compounded rate of return defined as the first logarithmic(natural) difference of the stock index at time point t, and Δi_t is the first difference of risk-free interest rate at time *t*. r_t and $\Delta i_t$are required to be stationary variables. z_t, $t = 1, 2, \ldots, n$, are assumed to follow independent standard Normal distribution. Equation (3.1) represents the fundamental risk-return relationship in the framework of GARCH-M model. Parameter θ stands for risk premium; the expected sign of this is positive implying that an increase in the time-variant risk leads to an increase in mean return. The functional form of $f(h_t)$ has been taken as $\sqrt{h_t}$ as well as $\ln h_t$. As stated earlier, EGARCH (Nelson, 1991)) form of volatility has also been considered. In this case, the form of $h_t$is in logarithmic transformation, and it is as given below:

$$ln\, h_t = \alpha_0^* + \delta^* ln(h_{t-1}) + \gamma^* \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \alpha_1^* \left(\left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right| - \sqrt{2/\pi} \right) \quad (3.4)$$

Now, if $\alpha_1^* > 0$, the process in (3.4) generates volatility clustering under the condition that the quantity within brackets is positive. In addition, in case$\gamma^* < 0$, then there will be a negative relationship between volatility and returns and that is the leverage effect.

As mentioned in the preceding section, apart from considering three time-invariant risk-adjusted metrics, and GARCH-M/EGARCH-M model for studying the underlying return-risk relationship with risk affecting expected returns directly, this study briefly examines the term structure of returns of the five indices under study. This is done by finding if average annual return increases with maturities of these assets and time invariant risk as measured by standard deviation of these assets decreases with maturities, as are normally expected. This will also indicate the relative status of the five stock returns on three maturities of these assets, namely, daily, monthly and yearly, and hence if the conclusions are broadly similar as those found in the main study.

4. RESULTS AND DISCUSSIONS

This section presents the empirical results along with discussions on the findings. The summary statistics of all the five indices are presented in Table 4.1 below. The results show that BSESENSEX, the Indian benchmark stock index, has the highest mean value compared to all other energy and green indices considered in this study. Also, BSESENSEX has the lowest value of standard deviation followed by BSE Carbonex and BSE Greenex although the values are very close. As expected, BSE Energy, and BSE Oil & Gas indices have higher standard deviation values. All the five index returns are negatively skewed and have excess kurtosis. The BSE Oil & Gas has the maximum value of kurtosis at 9.865. The J-B test statistic values for all the five-return series are highly significant indicating rejection of the 'null of normality' for all the series. ARCH-LM test demonstrates presence of significant ARCH volatility in all the series.

Returns series	Mean	Std. deviation	Skewness	Kurtosis	J-B test statistic[#]	ARCH-LM test statistic[#]
BSESENSEX	0.000345	0.009520	-0.09714	4.997	415.367 (0.000)	12.440 (0.000)
BSE Energy	0.000256	0.012721	-0.26810	5.766	816.744 (0.000)	126.157 (0.000)
BSE Oil & Gas	0.000139	0.012822	-0.68729	9.865	5058.732 (0.000)	116.666 (0.000)
BSE Carbonex	0.000297	0.009573	-0.15821	5.105	432.362 (0.000)	10.445 (0.001)
BSE Greenex	0.000249	0.009798	-0.13138	4.529	248.679 (0.000)	6.175 (0.013)

Table 4.1 Summary Statistics of Returns on BSESENSEX and Green and Energy Indices.
Notes: # Values in parentheses are the corresponding *p*-values.

The plots of the return series are given in Figures 4.1 through 4.5. It is visually evident from these plots that volatility is present in all the five-return series. Further, plot (Figure 4.6) of daily risk-free interest rate series of 'yield on 10-year government bond', denoted as i_t, shows existence of some structural breaks.

Figure 4.1 BSESENSEX Daily Return

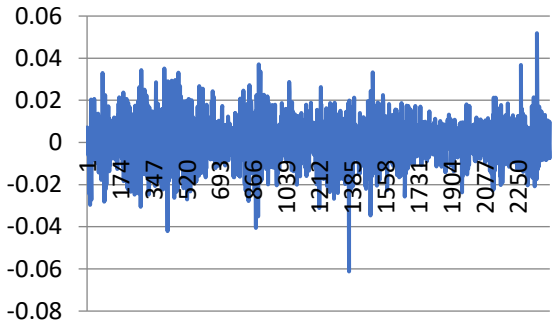


Figure 4.2 BSE Energy Daily Return

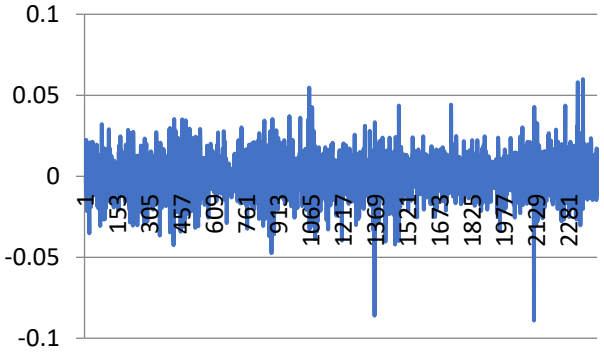


Figure 4.3 BSE Oil & Gas Daily Return

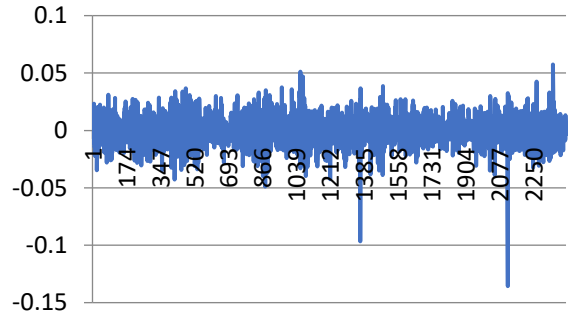


Figure 4.4BSE Carbonex Daily Return

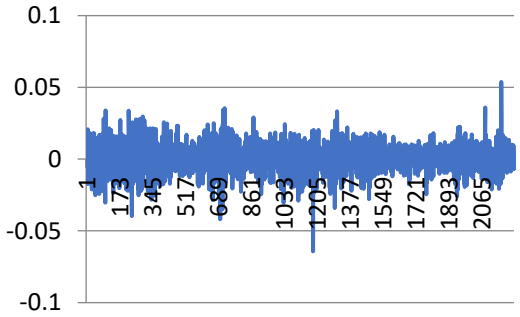


Figure 4.5 BSE Greenex Daily Return

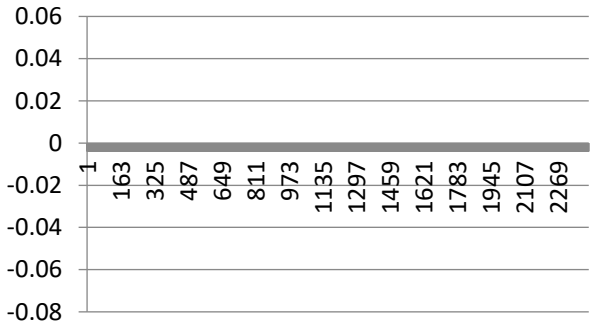
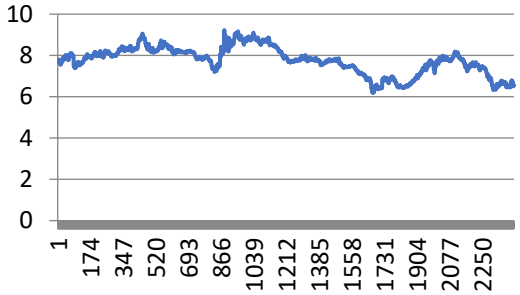


Figure 4.6 Yield on 10 Year Government bond



We now present, in Table 4.2, the results of unit root test for all the stock price index series at level values applying the well-known ADF test. All the stock price index series (in natural logarithm) except BSE Carbonex are found to have unit roots. BSE Carbonex is, however, found to be trend stationary at level values having *p*-value 0.022. After adjustment of the deterministic trend, BSE Carbonex becomes stationary being free of both the deterministic and stochastic trend. Since this time series has a unit root at 1% level of significance, first difference was taken and ADF test was applied only to find that the series has no unit root and also no deterministic trend. Further, the values of this series are almost identically the same as the detrended BSE Caronrx series[3]. As regards the other four indices, application of ADF test on their first difference values showed that all are free of unit roots and also of deterministic trend. It was also checked that i_t is stationary at first difference.

[3]It is because of this that this stationary series, like the other four, is being referred to as returns on BSE Carbonex.

Index	ADF test statistic value		*p*-value		Deterministic components	
	Level	First diff.	Level	First diff.	Level	First diff.
BSESENSEX	-3.126	-46.694	0.100	0.000	constant, trend	constant
BSE Energy	-2.234	-47.894	0.469	0.000	constant, trend	constant
BSE Oil & Gas	-2.588	-47.984	0.286	0.000	constant, trend	constant
BSE Carbonex	-3.707	----------	0.022	-----	constant, trend	----
BSE Greenex	-2.781	-46.660	0.204	0.000	constant, trend	constant
Interest rate	-2.420	-31.089	0.369	0.000	constant, trend	constant

Table 4.2 Results of Unit Root Test on BSESENSEX and Green and Energy Indices.
Notes: All the test statistic values are compared with MacKinnon (1996) one-sided critical values.Interest rate = Yield on 10-year government bond.

Correlation coefficients between any two variables at stationary values and their statistical significance or otherwise have been reported in Table 4.3. The results show significant correlations between any two stock returns. Further, the correlation coefficient between interest rate at first difference values which is stationary, as reported above, and any of the five stock returns is also found to be statistically significant.

Stationary Variable	BSESENSEX	BSE Energy	BSE Oil & Gas	BSE Carbonex	BSE Greenex	Interest rate
BSESENSEX	1					
BSE Energy	0.719 (48.897)**	1				
BSE Oil & Gas	0.730 (50.485)**	0.879 (87.131)**	1			
BSE Carbonex	0.988 (302.343)**	0.725 (49.753)**	0.751 (53.757)**	1		
BSE Greenex	0.942 (132.664)**	0.653 (40.572)**	0.684 (44.318)**	0.956 (154.02)**	1	
First difference in Interest rate	-0.135 (6.410)**	-0.091 (4.326)**	-0.098 (4.637)**	-0.143 (6.806)**	-0.135 (6.447)**	1

Table 4.3 Pairwise Correlations of Study Variables at Stationary Values.
Notes: ** indicates significant value at 1% level of significance.Interest rate = Yield on 10-year government bond.

We also apply multiple structural breaks test due to Bai-Perron (2003, 2005) to all the five returns as well as interest rate series to find if there are any structural breaks in any of these series since the span of these daily level time series is quite long being 10 years. As part of Bai-Perron testing procedure, first *UDmax* and *WDmax* test statistics are computed and it is concluded, as reported in Table 4.4, that there is no structural break in all the five-return series by both the tests. But the daily interest rate series i_t is found to have structural breaks at level values, numbering 4 and 5 by the two tests, respectively, although there is no break in the stationary first difference series i_t.

Index	Test statistic values and no. of break points			
Returns/interest rate series	UD_{max}test statistic value	No. of break points	WD_{max}test statistic value	No. of break points
BSESENSEX	6.613	0	7.781	0
BSE Energy	4.748	0	6.515	0
BSE Oil & Gas	6.244	0	8.382	0
BSE Carbonex	7.393	0	8.698	0
BSE Greenex	6.554	0	7.710	0
Interest rate (Level values)	2459.448*	4	4243.733*	5
Interest rate (First difference values)	7.708	0	10.576	0

Table 4.4 Results of the Bai-Perron Multiple Structural Breaks Test.
Notes: * indicates significant value at 5% level of significance.

Since a stock index is a compilation of stock/equity prices of different industries and its construction makes it possible to track a particular market or sector, we have presented the industry structure or sector-wise weightage of each of the five indices in Table 4.5. The figures show that BSESENSEX and BSE Carbonex are highly broad-based. The BSESENSEX has the highest share (among all the five indices) to 'Banking and Finance' sector, the figure being 32.64%. The corresponding figures for the two green indices BSE Carbonex (24.19%) and BSE Greenex (25.21%) are also quite high. The other important sector in case of these three indices is 'Technology'. The figures are 21.73%, 16.90% and 29.67%, respectively, for BSESENSEX, BSE Carbonex and BSE Greenex. BSE Energy and BSE Oil & Gas indices, the two carbon emitting energy indices, have almost their whole contribution, 86.30% and 99.26%, respectively, from 'Oil and Gas' sector. Obviously, these industry structures have profound implications in determining investment decisions. In fact, given such varying industry structures of the benchmark index and the two divergent categories of indices representing green and carbon emitting industries, it is likely that the return and risk behavior of these indices would be influenced by their underlying industry structures.

Sector	BSE SENSEX	BSE Energy	BSE Oil & Gas	BSE Carbonex	BSE Greenex
Automotive	4.38			6.03	10.16
Banking/Finance	32.64			24.19	25.21
Cement/Construction	1.96			2.76	
Chemicals	2.60	0.84	0.72	3.28	
Conglomerates				1.16	
Cons durables					
Cons non durable	5.81			6.04	
Engineering	2.07			4.07	4.16
Food & Beverage	1.71			2.43	
Technology	21.73			16.90	29.67
Manufacturing				0.48	
Media				0.13	
Metals & Mining		4.90		4.70	6.02
Miscellaneous					
Miscellaneous	1.37	7.38		1.21	2.89
Oil & Gas	14.64	86.30	99.26	12.49	3.12
Pharmaceuticals	2.73			5.22	8.20
Retail/Real Estate				0.48	1.40
Services				0.59	
Telecom	3.28			2.91	6.59
Tobacco	2.66			1.82	
Utilities	2.42			1.92	2.55

Table 4.5 Industry Structures of the Indices (in percentage).
Source: https://www.moneycontrol.com/stocks/marketstats/sector_weightage.php; Retrieved on 12 May 2021

Returns series	Sharpe Ratio	Treynor Ratio	Jensen's Alpha	CAPM Return#
BSESENSEX	0.00101	---------	----------	7.9926
BSE Energy	-0.00720	-0.00091	-2.32978	7.8833
BSE Oil & Gas	-0.01525	-0.00210	-4.99618	7.8832
BSE Carbonex	0.00261	0.00023	0.31343	8.0068
BSE Greenex	-0.01034	-0.00104	-2.72453	7.9605

Table 4.6 Risk-Adjusted Return Ratios on BSESENSEX, Energy and Green Indices.
Notes: #correspond to Portfolio returns.

We now report and discuss the main results. As discussed in the previous section, we have used three risk adjusted metrics for assessing the performance of the four green and energy indices considered *viz*., BSE Carbonex, BSE Greenex, and BSE Energy, and BSE Oil & Gas, against

the investors' benchmark index, BSESENSEX. The values of these metrics are presented in Table 4.6. It is noted from this table that, in terms of the Sharpe ratio, BSE Carbonex has the highest value among all the indices including BSESENSEX. However, the other green index *viz.*, BSE Greenex, has negative Sharpe ratio value, but still it is higher compared to BSE Oil & Gas index. As already stated, we have chosen 'yield on 10-year government bond' at daily level as the asset having risk-free return. When we consider the Treynor ratio which measures excess return weighted by beta (market risk), it is, once again, found that BSE Carbonex has the highest value (positive) with all other indices having negative values. Therefore, in terms of both the Sharpe ratio and Treynor ratio, BSE Carbonex outperforms all the other indices including BSESENSEX. Moreover, since both the ratios have yielded negative values for BSE Energy, and BSE Oil & Gas indices, this suggests negative excess return (risk adjusted) of holding both these financial assets over the 10-year (sample) period of study.

Coefficient	Conditional mean parameters for BSESENSEX			
	Estimate	Standard error	*t*-statistic	*p*-value
ς_1	0.062801	0.022580	2.781303	0.0054
ς_8	-0.043043	0.020770	-2.072361	0.0382
ω	-0.018999	0.002869	-6.622939	0.0000
θ	0.072498	0.019965	3.631241	0.0003
GARCH parameters				
α_0	1.63E-06	4.42E-07	3.683013	0.0002
α_1	0.066123	0.008731	7.573006	0.0000
δ	0.916672	0.011525	79.53673	0.0000
Conditional mean parameters for BSE Energy				
ς_1	0.057352	0.022672	2.529597	0.0114
ς_5	-0.047219	0.020447	-2.309318	0.0209
ς_9	0.038323	0.020105	1.906174	0.0566
ω	-0.016549	0.004168	-3.970829	0.0001
θ	0.035192	0.020648	1.704360	0.0883
GARCH parameters				
α_0	1.02E-05	2.18E-06	4.696095	0.0000
α_1	0.080918	0.009340	8.663195	0.0000
δ	0.855456	0.020649	41.42932	0.0000
Conditional mean parameters for BSE Oil & Gas				
ς_1	0.056258	0.022926	2.453924	0.0141
ς_3	-0.045164	0.022573	-2.000787	0.0454
ω	-0.019083	0.003925	-4.862418	0.0000
θ	0.025384	0.020660	1.228698	0.2192
GARCH parameters				
α_0	1.46E-05	2.62E-06	5.556644	0.0000
α_1	0.100195	0.007877	12.72071	0.0000
δ	0.810880	0.021213	38.22507	0.0000
Conditional mean parameters for BSE Carbonex				
ς_1	0.087990	0.023609	3.726892	0.0002
ω	-0.024546	0.003038	-8.081093	0.0000
θ	0.060312	0.020622	2.924669	0.0034
GARCH parameters				
α_0	2.03E-06	5.32E-07	3.810734	0.0001
α_1	0.069264	0.009416	7.355646	0.0000
δ	0.909583	0.013007	69.92911	0.0000
Conditional mean parameters for BSEGreenex				
ς_1	0.072519	0.022148	3.274254	0.0011
ω	-0.021027	0.003088	-6.809895	0.0000
θ	0.047887	0.020347	2.353555	0.0186
GARCH parameters				
α_0	3.07E-06	6.58E-07	4.668985	0.0000

α_1	0.074737	0.010254	7.288916	0.0000
δ	0.894188	0.013822	64.69422	0.0000

Table 4.7GARCH-M Models for Returns on BSESENSEX, Energy and Green Indices.
Notes: Only the significant lags of the dependent variable have been reported.

The best performance of BSE Carbonex is also established in terms of the absolute risk performance measure, the Jensen's Alpha, having the highest risk-adjusted return ratio value of 0.31343. Since all the remaining indices have negative values, this means that these portfolios have not earned their required returns as suggested by CAPM, and hence they have underperformed. Even the estimated return based on CAPM estimation shows that BSE Carbonex has the highest return at 8.0068. The others are very close with BSESENSEX having 7.9926 followed by BSE Greenex with 7.9605. Therefore, on the basis of the above risk adjusted metrics, we can conclude that BSE Carbonex outperforms the market benchmark index as well as two energy indices and the other green index, BSE Green. Although CAPM uses beta risk which is well diversified and systematic, this has the limitation that it is time-invariant.

We now report the results of time varying risk-return relationship obtained in the framework of GARCH-M and EGARCH-M models in Table 4.7 and Table 4.8, respectively. In this reporting[4], $f(h_t)$has been taken as$\sqrt{h_t}$. It may be noted that the parameter θin equation (3.1), called the coefficient of relative risk aversion of a representative investor, is also interpreted as the parameter representing time-varying risk premium. This is so because in presence of time varying risk, the variance of returns might increase over time, and consequently the agents ask for greater compensation in order to hold the asset. A positive value of θimplies that the agent is compensated for an additional risk. We have considered the orders of both GARCH and EGARCH models to be (1, 1), and this has been found to be adequate as coefficients of higher order terms of these volatility models were found to be statistically insignificant. It is noted from Table 4.7 that both the GARCH (1, 1) parameters are significant in case of all the five-return series. The lag order of returns, m, in equation (3.1) has been obtained using the Hall's procedure. In this table as well as in Table 8, only the significant lag coefficients have been reported.

The risk premium parameter is found to be significant in all but BSE Energy, and BSE Oil & Gas indices when $h_t$is taken to be GARCH. This finding of insignificant value of the risk premium parameter for these two energy indices means that potential investors cannot expect any significant gain in terms of risk premium in case of investment in these two energy sectors. Thus, we can conclude that it is only in case of BSESENSEX, BSE Carbonex, and BSE Greenex for which the estimated values of the risk premium parameter $\theta$are 0.0725, 0.0603and 0.0479, respectively, that the time varying risk using GARCH form of volatility, has significant role in explaining variations in portfolio returns. This finding clearly demonstrates that investors in India are compensated significantly in case of green indices and the benchmark index as compared to energy indices. This suggests that representative investors would claim high risk premium for these three indices. Further, as expected, ω, the coefficient associated with change in risk-free interest rate variableΔi_t, has been found to be negative as well as significant for each index. Hence, it is concluded that change ini_t has inverse relationship with portfolio returns for all the five indices.

As regards EGARCH (1,1) model for volatility, we note from Table 4.8 that both the lag parameters are significant for all the five-return series, and higher lag orders have insignificant coefficients. Further, γ^*, the parameter representing leverage effect, is significant for all the five

[4] With the other choice of $f(h_t)$*viz.*, $\ln h_t$, all conclusions are found to remain the same.

indices. Also, the parameter α_1^* is significant for all the five indices meaning thereby that volatility clustering is also captured significantly through the EGARCH model. Thus, it can be concluded that EGARCH (1,1) is also an appropriate volatility model for all the five stock indices. However, the risk premium parameter θ has been found to be insignificant at 5% level (vide Table 4.8) for all the five returns series. Hence the conclusion on risk premium is that insofar as EGARCH volatility model is concerned, there is no statistically significant risk premium for investment either in energy or in green industries; it is only in case of the benchmark index BSESENSEX that θ is barely significant with *p*-value being 0.0646. Lastly, like in GARCH model,ω has been found to be negative and significant for all the five indices.

Coefficient	Conditional mean parameters for BSESENSEX			
	Estimate	Standard error	*t*-statistic	*p*-value
ς_1	0.072244	0.021444	3.368938	0.0008
ς_8	-0.038442	0.019416	-1.979897	0.0477
ω	-0.018619	0.002847	-6.538998	0.0000
θ	0.037932	0.020528	1.847778	0.0646
EGARCH parameters				
α_0^*	-0.418110	0.053013	-7.886966	0.0000
α_1^*	0.112468	0.017317	6.494497	0.0000
$\boldsymbol{\gamma}^*$	-0.105803	0.010038	-10.54078	0.0000
$\boldsymbol{\delta}^*$	0.965059	0.004968	194.2673	0.0000
Conditional mean parameters for BSE Energy				
ς_1	0.066152	0.020698	3.196049	0.0014
ς_5	-0.050355	0.020191	-2.493901	0.0126
ς_5	0.040085	0.019609	2.044226	0.0409
ω	-0.016622	0.004137	-4.018177	0.0001
θ	0.017474	0.020367	0.857982	0.3909
EGARCH parameters				
α_0^*	-0.679277	0.111881	-6.071421	0.0000
α_1^*	0.153635	0.013766	11.16018	0.0000
$\boldsymbol{\gamma}^*$	-0.075509	0.008966	-8.421456	0.0000
$\boldsymbol{\delta}^*$	0.936493	0.012131	77.20153	0.0000
Conditional mean parameters for BSE Oil & Gas				
ς_1	0.066734	0.021253	3.139923	0.0017
ς_3	-0.041582	0.021503	-1.933810	0.0531
ω	-0.020045	0.003876	-5.171303	0.0000
θ	0.003245	0.019818	0.163723	0.8699
EGARCH Parameters				
α_0^*	-1.029890	0.139600	-7.377411	0.0000
α_1^*	0.206836	0.011967	17.28346	0.0000
$\boldsymbol{\gamma}^*$	-0.091926	0.008471	-10.85133	0.0000
$\boldsymbol{\delta}^*$	0.901249	0.015634	57.64680	0.0000
Conditional mean parameters for BSE Carbonex				
ς_1	0.102420	0.022306	4.591590	0.0000
ω	-0.023163	0.002965	-7.810852	0.0000
θ	0.028636	0.020947	1.367076	0.1716
EGARCH parameters				
α_0^*	-0.413570	0.053012	-7.801447	0.0000
α_1^*	0.112139	0.018419	6.088352	0.0000
$\boldsymbol{\gamma}^*$	-0.109742	0.009659	-11.36211	0.0000
$\boldsymbol{\delta}^*$	0.965503	0.004929	195.8951	0.0000
Conditional mean parameters for BSEGreenex				
ς_1	0.073177	0.021498	3.403959	0.0007
ω	-0.021525	0.003051	-7.054601	0.0000
θ	0.013050	0.020513	0.636202	0.5246
EGARCH parameters				

α_0^*	-0.458532	0.064326	-7.128204	0.0000
α_1^*	0.128144	0.018447	6.946714	0.0000
$\boldsymbol{\gamma}^*$	-0.096136	0.009375	-10.25501	0.0000
$\boldsymbol{\delta}^*$	0.961663	0.006178	155.6667	0.0000

Table 4.8EGARCH-M Models for Returns on BSESENSEX and Energy and Green Indices.
Notes: Only the significant lags of the dependent variable have been reported.

On the basis of all the empirical findings, it may broadly be concluded that some of the green investing such as those representing BSE Carbonex outperforms BSESENSEX and other traditional energy funds in India.To put it differently, the study shows that the energy and oil sectors seem to be more volatile and risky to the investors compared to green and carbon-reducing industries which are associated with environment-friendly projects such as reduction of transportation and industrial pollution, climate change, deforestation, and carbon footprints in India. Hence investors in India may find it worth investing in green projects even after addressing the environmental, social and governance issues of responsible investing.

Finally, we refer to Table 4.9 where the average annual returns and standard deviation values of annual returns on three maturities *viz*., daily, monthly, and annual levels, are presented. These would throw some light on the term structure of return and also of risk as measured by standard deviation among these five stock indices, as mentioned earlier. It may be noted from the figures that average annual return at monthly level is higher than the corresponding daily level for each of the indices. But, the annual level return figures are found to be lower than the corresponding monthly figures for all the indices. This is rather unusual. Looking into the annual index values, we noted that the index value at yearly (annual) level fell substantially at the end of 2011 as compared to 2010 for all the five stock indices.Hence, treating the annual figure for the year 2010 as like an outlier, these computations were redone excluding the year 2010 and reported within parentheses in Table 4.9 in order to be able to make appropriate comparisons over the three maturity levels. Now, looking at the figures within parentheses we find that the average annual returns are higher with longer period of maturities, as expected. As regards time invariant risk as measured by standard deviation of annual returns, we find that both for the entire sample period and the period excluding the year 2010, the values are lower with increasing maturities. This is also very much in the expected line. It is also observed that the earlier finding of overall good outperformance of the carbon index called BSE Carbonex more or less stands out. This index has the highest average annual return at daily level at 8.320% but BSESENSEX has highest value at monthly level with 9.813. At the yearly level of maturity, both this index and the benchmark index BSESENSEX have almost the same value i.e., 12.149 and 12.273, respectively. Both the energy indices, namely, the BSE Oil & Gas and BSE Energy, have much lower values. The other green index, BSE Greenex, has a mixed performance in the sense that it has better average annual return than that of the energy index BSE Oil & Gas but not better than the carbon emitting energy index, BSE Energy. Thus, the overall finding on the term structure of these indices is somewhat similar to the main finding of this study, which advocates carbon efficient practices among larger business houses in India.

Index	Average annual returns (%) on three maturities			Standard deviation ofannual returns on three maturities		
	Daily	Monthly	Yearly	Daily	Monthly	Yearly
BSESENSEX	7.992	9.813	7.765	236.649	61.252	17.279
	(7.103)	(8.451)	(12.273)	(235.167)	(62.102)	(11.499)
BSE Energy	5.554	7.651	6.883	314.345	77.569	19.613
	(6.674)	(7.747)	(12.354)	(316.788)	(78.817)	(11.478)
BSE Oil & Gas	2.887	3.197	3.666	319.017	74.597	19.767
	(3.803)	(2.845)	(8.401)	(322.55)	(75.634)	(14.693)

BSE Carbonex	8.320	8.018	7.497	216.836	63.366	18.341
	(6.608)	(8.169)	(12.149)	(219.032)	(63.910)	(12.723)
BSE Greenex	5.236	8.120	5.521	243.573	63.662	18.911
	(5.081)	(6.871)	(10.391)	(244.002)	(64.734)	(12.391)

Table 4.9 Term Structure of Returns and Risk.
Notes: Values in parentheses indicate the figures excluding the year 2010 as the index value at yearly (annual) level fell substantially at the end of 2011 as compared to 2010 for all the five stock indices.

5. CONCLUSIONS

Green finance has emerged as a new area of finance where sustainable environmental impacts are being generated by both private and public initiatives through financial instruments towards carbon emission, climate change and deforestation. Since financial sector, in particular, stock market, plays significant role through its intermediary functions and risk management towards economic development, this sector has to be forward looking in determining the future direction of investment. In the determination of suitable portfolios, investors are considering carbon risk which may arise in the transition from fossil fuel intensive economy. Worldwide equity portfolios are shifting towards lower carbon, with more climate-resilient future.

This study provides a new perspective in green finance for a major emerging economy like India which not only is one of the fastest growing economies in the world but also has increasingly high energy demand. Researches on green finance as opposed to traditional carbon emitting energy investing are very few in India. This study has made an attempt to contribute to this very limited literature by analyzing the performance of four BSE stock indices - two carbon emitting energy and two green indices – along with the most widely accepted index of Indian stock market called BSESENSEX. It is worth noting that investors showing commitment towards mitigating risks associated with emission of greenhouse gases can have very important implications for designing business strategies towards protecting the earth from getting further warmer. This work is expected to be useful to the investors and policy makers in India in their decision making on this crucial issue, and also to researchers in carrying our further studies on this increasingly important topic of green finance.

The findings of this study show that among the five major portfolios of the Indian stock market considered for performance measurements during the last 10 years i.e., from January 2010 to December 2019, BSE Carbonex has performed the best in terms of three well-known risk-adjusted metrics and also in respect of risk-return relationship using time-varying risk model, i.e., GARCH-M / EGARCH-M model. Next in performance is the benchmark BSESENSEX index. In fact, it is very close to BSE Carbonex. This outperformance of BSE Carbonex, the Indian low carbon stock index, found in this study is very encouraging, especially because at the global level, the MSCI index carbon footprint metrics show that India is in very high risk zone in terms of carbon-risk category. It may be pointed out, in this context, that BSE Carbonex index is constructed on the basis of those companies which have commitments to mitigating risks arising from environmental pollution, climate change etc. This index takes care of the risk associated with the environmental issues by addressing two dimensions of carbon exposure, namely, carbon emissions and fossil fuel reserve. It may also be noted that although the other green index considered in this study *viz*., BSE Greenex, is found to be very close to the benchmark index BSESENSEX in terms of performance, yet it could not outperform it. But the energy indices BSE Energy and BSE Oil & Gas are far behind BSESENSEX in respect of all the three metrics and time varying risk- return model. BSESENSEX, the benchmark stock index of the country, is well diversified and can reduce systematic risk substantially as a market portfolio. The term structure of average annual return as well as its risk among these five stock

indices also indicates support to BSE Carbonex, one of the two low carbon stock indices considered in this study, on the three maturities at daily, monthly and yearly levels.

The study overall thus shows that investments in green projects and consideration to other environmental commitments such as climate change, reduction of transportation and industrial pollution, and aforestation may be attractive to the investors in India as compared to the energy and oil sectors which are causing more damage to the environment in the long run. The outperformance of BSE Carbonex means investing in green industries has several advantages as compared to investing in carbon emitting energy industries, and hence investors choosing this portfolio can buy time on climate change, transparency and its potential in the market to mobilize huge amount of finance while, at the same time, taking care of ESG i.e., environmental, social and governance, factors.

When environmental issues such as climate change, carbon emissions, depletion of natural resources dominate world trade and investment debates in the international forum even in terms of North-South divide, potential foreign and domestic investors must consider issues which are important for long-term investment rather than short-term profits. Even after considering the highly volatile nature of stock markets in India, investors should be careful about the long-term sustainability of investment because of which portfolio such as BSE Carbonex representing sustainability may be the final destination for them. In this context, it may be pointed out that there are reports that 26% US-domiciled assets are managed by sustainability criteria. Since the main finding here advocates for energy saving technology, it may be stated that this study has made some contribution in resolving the major environmental challenges faced by the policy planners, regulators, and, in fact, the society at large in India even if the corporate world is solely guided by its private profit motives. The solutions are still market-based where investors even after showing commitment towards global environmental challenges can earn higher risk-adjusted returns. The results of this study, in a sense, also indicates the dynamics of the Indian stock market by showing increasing long-run profitability of sustainability index *vis-à-vis* conventional indices.

There are some shortcomings of this study, and accordingly further researches can be done by extending this study in several directions so as to address some of the shortcomings. For instance, it would be interesting to examine whether the Sharpe ratio and the other return ratios are declining with maturity, and the volatility of equity yields is downward sloping with maturity. There are mixed responses with respect to these observations in different asset classes. There is evidence that average returns and standard deviations increase with maturity for assets such as nominal bonds, corporate bonds, volatility and housing, as shown by Binsbergen and Koijen (2015). Another direction towards extending this study could be to bring in economic fundamentals and then examine if our finding favouring green indices in case of India remains the same or not. The study of return and volatility spillovers from the green indices as well as from the benchmark stock to the other indices by applyingmultivariate GARCH model can also be an interesting and useful study.

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