Received: 27 November 2019 | Accepted: 8 March 2020
DOI: 10.1002/pa.2117

ACADEMIC PAPER

WILEY

Does temperature influence the carbon index? Evidences from India

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The present study investigates the impact of temperature, on the returns of the Carbon Index, otherwise called BSE GREENEX in India. The study employed the secondary data of temperature in five sample cities (Chennai, Delhi, Hyderabad, Kolkata, and Mumbai), and the BSE GREENEX in India. Statistical tools like Descriptive Statistics, Unit Root, OLS Regression Test, and Granger Causality Test, were used. This study would be useful for the investors to make green investment in India.

1 | INTRODUCTION

According to the Intergovernmental Panel on Climate Change (IPCC) at the mid part of the 21st century, majority of continents like Australia, Asia, and Europe are expected to suffer from temperature issues. Besides, Europe and North America would experience unusual rain fall throughout the year. They all witness climate change as alerted by IPCC. Hence there is an urgent need, for developing solution, for the problems of climate changes. Weather factors generally influence individual attitudes, which can be proved through different psychological studies, already undertaken in the area of weather effect on stock market, in different parts of the world (Cao & Wei, 2005; Goetzmann and Zhu (2005); Lee and Wang, 2011; Lu & Chou, 2012; Yoon & Kang, 2009). Recent academic research studies found that people generally make correct decision when they are in a feel in happy mood. The decision-making process, conceived as the risk-as-feelings model (Loewenstein, Weber, Hsee, & Welch, 2001) is provided in Figure 1. The role of individual feelings in finance or stock market was studied early in USA, by Saunders (1993). This study raved the way for a number of follow-up works, on the same area, in different parts of the world.

1.1 | BSE GREENEX

The present study analyzed the BSE GREENEX Index in India, as it is the first eco-friendly index developed by the BSE in India. This index include top 20 companies, on the basis of their carbon emissions capacity. The main purpose of the index is to encourage and promote green investment in India. The conceptual framework, showing the impact of temperature on stock market is given in Figure 2.

The remaining section of the study has been organized, as follows. Section 2 reviews the related literature. Section 3 provides the methodology of the present study while Section 4 displays the results and interpretation. The final section concludes the study and examines the scope for future researchers.

2 | LITERATURE REVIEW

The stock price could be influenced by climate change also because could be influenced investors' feelings and moods. The literature review of this study gives a brief review of studies, relating to weather factors like temperature and stock markets.

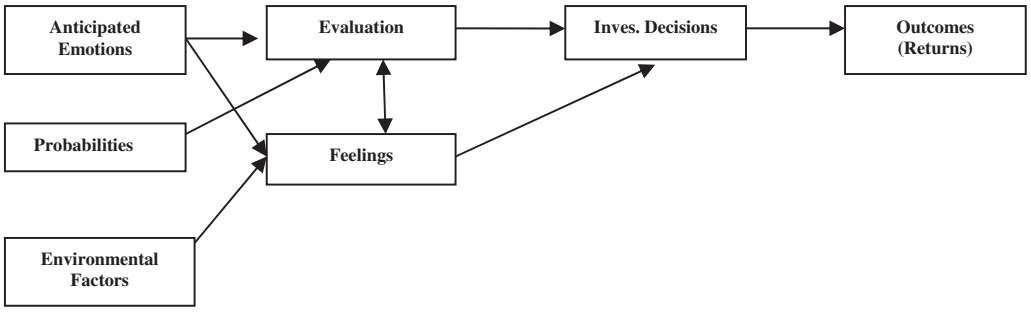

FIGURE 1 Theoretical framework for investment decision-making process. *Sources*: Improved upon the model by Loewenstein et al. (2001)

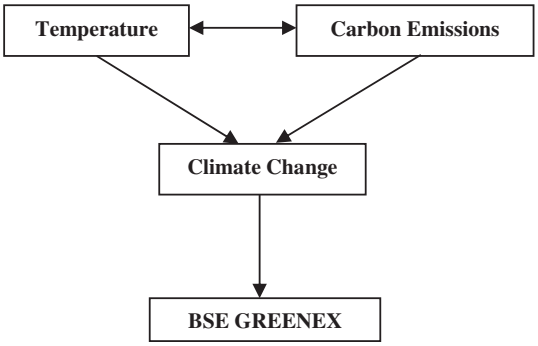

FIGURE 2 Conceptual framework showing the impact of temperature on BSE GREENEX. *Source*: Developed by authors

Keef and Roush (2002), in their work, explained how weather factors influenced New Zealand Stock Exchange return and volatility. Sample weather factors included cloud cover, temperature, and wind speed. It was concluded that wind speed had a significant impact, temperature factors has a small impact, and cloud cover has no impact on stock returns. Keef and Roush (2005) in the research paper, studied the influence of local weather factors (temperature, sunshine, and wind speed) on New Zealand financial securities like government bonds, bank bills, and the stock indices return. The study found that sunshine influenced positively bank bills' interest rate and wind speed negatively influenced stock indices. Cao and Wei (2005) selected a sample from eight countries' stock markets (Australia, Britain, Canada, Germany, United States, Sweden) and temperature factors. The study found that lower temperature factors were related to higher profit while higher temperature factors were related to lower profit. Chang, Nieh, Yang, and Yang (2006) investigated the relationships between three weather factors and stock market returns in Taiwan. Three weather factors (cloud cover, humidity, and temperature and Taiwan stock market) were analyzed, using the threshold model with the GJR-GARCH and it was found that two weather factors (cloud cover and temperature) exercised an impact on the stock returns in Taiwan. Floros (2008) analyzed the temperature and five European countries, stock market data (Austria, Belgium, France, Greece, and United Kingdom), by using Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model. The Greece and United Kingdom stock market confirmed the positive correlation and Austria, Belgium, and France stock market had reported negative correlation. Worthington (2009) studied four weather factors (precipitation, humidity, temperature, and sunshine) and Australian Stock Market return data. The study found that Australian Stock Market did not influence the weather factors. Yoon and Kang (2009) found the relationship between weather factors and stock index returns. The study found that weather factors influenced the market efficiency negatively. Kathiravan, Selvam, Venkateswar, et al. (2019b) analyzed the impact of weather factors on stock market in some of Asian countries. The study was based on two types of data, namely, weather data and stock market data. The study found that weather factors has a statistically significant influence on the Asian Stock Exchange returns. Andrikopoulos, Wang, and Zheng (2019) examined the impact of weather factors on asset prices on United States and London stock markets. The results of the research indicated that the investors' mood changes were influenced by the weather factors. Shahzad (2019) identified the relationships between weather factors, namely humidity, temperature, air pressure, and wind and stock returns in the China's stock market. The study concluded that the weather factors did have a statistically significant influence on China's stock markets. The summary of previous studies, relating to temperature and stock market, are presented in Table 1.

The earlier researchers have studied various markets, in different parts of the world (stock index, commodity index agricultural index, and financial market) but not the Carbon Index of GREENEX which is the main focus of the present study. The issue of temperature has received considerable academic attention in the present day world.

3 | RESEARCH METHODOLOGY

3.1 | Objectives of the study

The main objective of this study was to investigate, the effects of temperature, on the BSE GREENEX Index in India.

3.2 | Hypotheses of the study

The study tested the following hypotheses:

NH 01: There is no normal distribution among the sample index and temperature in sample cities of India.

TABLE 1 Summary of literature on temperature and stock market

S. No.	Authors and year	Country	Main findings	
			Impact	No impact
1	Keef and Roush (2002)	New Zealand	X	–
2	Keef and Roush (2005)	New Zealand	X	–
3	Cao and Wei (2005)	United States, Canada, Britain, Germany, Sweden, Australia	X	–
4	Chang et al. (2006)	Taiwan	X	–
5	Floros (2008)	Austria, Belgium, France, Greece, and United Kingdom	X	–
6	Worthington (2009)	Australia	–	X
7	Yoon and Kang (2009)	Korea	X	–
8	Kang, Jiang, Lee, and Yoon (2010)	Shanghai	X	–
9	Silva and Almeida (2011)	Portugal	X	–
10	Lu and Chou (2012)	China	–	X
11	Wang, Lin, and Lin (2012)	Taiwan	–	X
12	Brahmana, Hooy, and Ahmad (2014)	Malaysia	X	–
13	Cao and Han (2015)	China	X	–
14	Brahmana, Hooy, and Ahmad (2015)	Indonesia	–	X
15	Frühwirth and Sögner (2015)	Austria	X	–
16	Kathiravan et al. (2017)	India	X	–
17	Shah et al. (2018)	China and Pakistan	X	–
18	Andrikopoulos et al. (2019)	United States and London	X	–

Source: Developed by authors.

NH 02: There is no stationarity among the sample index and temperature in sample cities of India.

NH 03: There is no impact on the sample index by sample cities temperature over the sample period.

NH 04: There is no causal relationship between temperature in sample cities and GREENEX index.

3.3 | Data

The data for present study consisted of the daily values of the BSE GREENEX and daily closing values of temperature, in top cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai) of India. The data covered a period of 10 years, from 2009 to 2018. The GREENEX index was founded in 2009 and hence the study covered a period of 10 years from April 1, 2009 to March 31, 2018. The daily closing values of the sample index were extracted from Bombay Stock Exchange of India (BSE), index (http:www.bseindia.com) and data of temperature were collected from Indian Metrological Department—www.imd.gov.in.

3.4 | Tools used for analysis

The following statistical tools were used for the analysis.

- Descriptive statistics (to find out the normal distribution).
- ADF Test (to find out the stationarity).
- OLS Regression Model (to investigate the impact).
- Granger Causality Test (to examine the causal relationship).

4 | EMPIRICAL RESULTS AND DISCUSSION

This section discussed the effects of temperature on BSE GREENEX, by using Descriptive analysis, Unit Root Test, OLS Regression Model, and Granger Causality Test.

4.1 | Normality test for the BSE GREENEX and temperature in sample cities of India

Table 2 presents the results of the narrative statistics (descriptive analysis) of BSE GREENEX and temperature levels, at sample metro cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai), during the study period from January 1, 2012 to December 31, 2018. The values of temperature of sample cities and BSE GREENEX index scored positive mean returns. The Chennai temperature earned the highest mean return of 0.0621 while Kolkata temperature recorded the lowest mean return of 0.0003. But Delhi temperature scored the highest standard deviation value of 0.1269, during the study period. It means that the Delhi temperature was highly dispersed than temperature in other cities. The possible reason for high temperature is that Delhi has been the capital city of India and hence it

TABLE 2 Results of descriptive statistics for BSE GREENEX and temperature factors in India

	Mean	Min	Max	*SD*	Kurtosis	Skew	Obs.
GREENEX	0.0006	−0.0655	0.1662	0.0117	21.0240	1.0416	2,463
Bangalore Temp.	0.0008	−0.2500	0.2000	0.0417	4.8451	−0.0770	2,463
Chennai Temp.	0.0621	−0.2143	0.2129	0.0358	7.0388	0.0370	2,463
Delhi Temp.	0.0059	−0.7500	3.9565	0.1269	385.0076	12.6393	2,463
Kolkata Temp.	0.0003	−0.0655	0.1662	0.0117	21.0240	1.0416	2,463
Mumbai Temp.	0.0008	−0.2500	0.2000	0.0417	4.8451	−0.0770	2,463

Source: Data analysis and Author computed.

has more number of industrial corridors or vehicle pollution. It is to be noted that temperature level in Delhi City has spread widely than others sample cities' temperature. It shows that the temperature in Delhi would have affected the behavior of rational market players, particularly investors. According to the present study, the observed mean values of temperature, in the five sample cities (in descending order) were as follows: Chennai > Delhi > Mumbai > Bangalore > Kolkata. The skewness values clearly indicated that the values for all sample variables, except Bangalore temperature (−0.0770) and Mumbai temperature (−0.0770) were positive during the study period. The analysis of Kurtosis indicated that values of sample index and temperature of all the five cities, scored more than three. Hence it was leptokurtic distributions of data with higher densities of values at the extreme level of the probability curves. Besides, the Jarque–Bera (JB) values of the sample index implied that all the sample indices were normally distributed. The analysis of Jarque–Bera (JB) values clearly revealed that data of all the sample variables were normally distributed. Hence, the Null Hypothesis (NH1): There is no normal distribution among the sample index and temperature in sample cities in India, was rejected.

4.2 | Stationarity test for BSE GREENEX and temperature in sample cities of India

The stationarity is the most basic condition, for the financial time series analysis. There are many models used to find out stationarity. In the present study, the stationarity of the two variables (sample index and temperature), was tested by using the traditional unit root tests, namely, Augmented Dickey–Fuller unit root test. A summary results of ADF test (Dickey and Fuller, 1981), for the returns of sample index, namely, BSE GREENEX and temperature in sample cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai), during the study period from January 1, 2012 to December 31, 2018, are presented in Table 3. Equation (1) was used to analyze the test statistics for sample index and temperature in sample cities during the study period.

$$\Delta Y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \delta \Delta y_{t-i} + \varepsilon t \quad (1)$$

In Equation (1), Y_t describes the sample variable, namely, BSE GREENEX and temperature in sample cities, α stands for constant term, β is the coefficient of time trend, εt stands for error term, p denotes the number of lags in the auto regressive process.

According to the Table 3, the probability values for all the eight sample indices were zero. The statistical values, for all the sample variables, were −62.22 (BSE GREENEX), −46.18 (Bangalore), −23.83 (Chennai), −31.56 (Delhi), −83.91 (Kolkata), and −85.53 (Mumbai), during the study period. From the above equation, absolute values of t statistic test for sample index (BSE GREENEX) and temperature factors in sample five cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai), were lower than the absolute values of critical test value at 1, 5, and 10%. The results of ADF test clearly confirmed the fact that the sample index, namely, BSE GREENEX and temperatures in sample cities attained stationarity level, during the study period. The results of the ADF tests indicated that all the sample variables, including the temperature

TABLE 3 Results of augmented Dickey–Fuller (ADF) test for BSE GREENEX and temperature factor in sample cities of India

	Test critical values				
	1% Level	5% Level	10% Level	Test statistic values	*p Value*
BSE GREENEX	−3.4328	−2.8625	−2.5673	−62.22	.0001***
Bangalore City	−3.4328	−2.8625	−2.56733	−46.18	.0001***
Chennai City	−3.4328	−2.8625	−2.56733	−23.83	0***
Delhi City	−3.4328	−2.8625	−2.5673	−31.56	.0001***
Kolkata City	−3.4328	−2.8625	−2.56733	−83.91	.0001***
Mumbai City	−3.4328	−2.8625	−2.56733	−85.53	.0001***

Note: ***Unit root test stationary at first difference with 1% significant level.
Source: Compiled from BSE and IMD and computed using E-Views-7.

factors and the sample stock index (BSE GREENEX) attained stationarity. Therefore, the Null Hypothesis (NH2), namely, There is no stationarity among the sample index and temperature in sample cities India was not accepted.

4.3 | The OLS regression test of temperature and BSE GREENEX

The traditional OLS Regression Model was used, so as to study the impacts of endogeneity problems, and the model was inspired by Cao and Wei (2005), Keef and Roush (2007), Hammami and Abaoub (2010). The Equation (2) has been widely used, for analyzing impact of temperatures and sample stock index.

$$R_t = \beta_o + \sum_{i=1}^{N} \beta_i W_{it} + \varepsilon t, \quad (2)$$

where R_t represents the sample stock index return on day t_1, W_{it} for temperature values on day t, where i = 1, 2, … N, β refers parameters, and εt is the error term.

Table 4 shows the results of OLS regression, for the BSE GREENEX and temperature in five samples cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai), during the study period from January 1, 2012 to December 31, 2018. The study used daily returns of sample stock index (BSE GREENEX) as the dependent variable while changes temperature in five cities of India were used as independent variables. As could be seen from Table 4, there was no statistical evidence to prove that there was significant correlation between temperature in Bangalore City, Chennai City, and Kolkata City and BSE GREENEX index, under the OLS Regression test. The values for temperature in Delhi City (coefficient −0.00600, *SE* 0.02000, *t*-value 2.62200, and significant *p*-value .00900) and temperature in Mumbai city (Coefficient 0.00100, *SE* 0.01800, *t*-value 2.09300, and significant *p*-value .02740) were positive and statistically significant. It is evident from the table that there was statistically significant impact by temperature of Delhi City and temperature of Mumbai City on the sample index, during the study period. Hence the Null hypothesis (NH3): There is no impact on the sample index by temperature in sample cities over the sample period, was partially accepted.

4.4 | Granger causality test for BSE GREENEX and temperature in sample cities of India

4.4.1 | Diagnostic checks

The results of VAR model, tested for AR root are displayed in Figure 1. The AR root graph reports the inverse root of the characteristic AR Polynomial. The estimated VAR is stationary, if all roots have modulus less than one and lie inside the unit circle. According to Figure 3, all roots are inside the unit circle, indicated which indicated the fact that the VAR was residual.

In this study, Granger Causality Test was to test the hypotheses, regarding the direction of causality (Uni and Bi), between sample index and temperature in sample cities and it has three different directions.

- One way (uni-directional) causality: $X \Rightarrow Y$
- Two-way causality (bi-directional): ($X \Leftrightarrow Y$)
- Lack of causality

The results of Granger Causality Test, for the returns of sample index, namely, BSE GREENEX and temperature in sample cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai), during the study period from January 1, 2012 to December 31, 2018, are presented in Table 5. It is found that *p*-value was more than .05 ($p \leq .05$), at the level of significance. It is observed that Delhi Temperature did not create Granger Cause on the GREENEX, at 95% confidence level (with *p*-value .0067) while Mumbai Temperature did not create Granger Cause on the GREENEX, at 95% confidence level (with *p*-value .0003). It could be inferred that Delhi Temperature and Mumbai Temperature caused one way (uni-directional) causality: X ⇒ Y with BSE GREENEX index during the study period while there was no causality between temperature in three cities (Bangalore, Chennai, and Kolkata) with BSE GREENEX. Hence the Null Hypothesis (NH04): "There is no causal relationship among the

TABLE 4 The results of OLS regression analysis for analyzing the impact of BSE GREENEX and temperature in sample cities during from January 1, 2012 to December 31, 2018

Variables	Coefficient	*SE*	*t*	Sig.
Bangalore City	0.02300	0.02200	0.62200	.58300
Chennai City	−0.00900	0.02000	−0.45200	.65100
Delhi City	−0.00600	0.02000	2.62200	**.00900*****
Kolkata City	−0.02900	0.02000	−0.00800	−1.48800
Mumbai City	0.00100	0.01800	2.09300	**.02740***
(Constant)	0.00781	0.00048	2.0549	.01700
R-squared	0.6926	F-statistic		1.0669
Durbin–Watson stat	2.2255	Prob (F-statistic)		0.3743

Note: Dependent variable: BSE GREENEX. ***Significant at 1% level, *Significant at 10% level.
Source: Compiled from yahoo finance and IMD and computed by using SPSS.

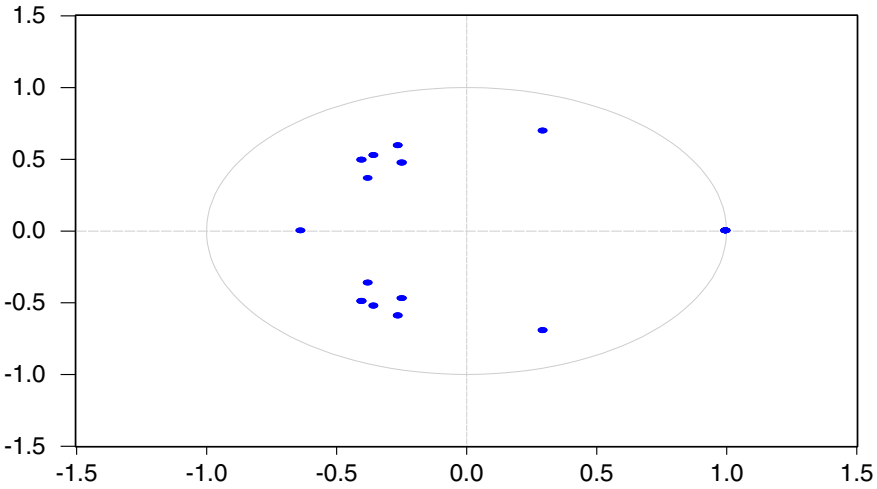

FIGURE 3 AR characteristic polynomial of the endogenous graph of the GREENEX and temperature in five sample cities. *Source*: Developed by authors

TABLE 5 Results of Granger causality for the BSE GREENEX with temperature in five sample cities during From January 1, 2012 to December 31, 2018

Null hypothesis	Obs.	F-statistic	Prob.
Bangalore Temperature does not Granger Cause GREENEX	2,474	0.3793	.6844
GREENEX does not Granger Cause *Bangalore* Temperature		0.0106	.9894
Chennai Temperature does not Granger Cause GREENEX	2,474	0.24708	.7811
GREENEX does not Granger Cause *Chennai* Temperature		0.99446	.3701
Delhi Temperature does not Granger Cause GREENEX	2,474	5.11766	**.0067****
GREENEX does not Granger Cause *Delhi* Temperature		0.63422	.5313
Kolkata Temperature does not Granger Cause GREENEX	2,474	4.14144	.016
GREENEX does not Granger Cause *Kolkata* Temperature		0.32773	.7206
Mumbai Temperature does not Granger Cause GREENEX	2,474	8.21938	**.0003****
GREENEX does not Granger Cause *Mumbai* Temperature		0.32773	.8206

**Null hypothesis is rejected at 95% confidence level.
Source: Compiled from yahoo finance and IMD and computed by using E-views 6 version.

sample index and sample cities temperature over the sample period," was partially accepted.

4.5 | Graphical expression for the returns of BSE GREENEX with temperature in five sample cities

The graphical expression of BSE GREENEX and temperature in sample five cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai) during the study period from January 1, 2012 to December 31, 2018 is presented in Figure 4. It is to be noted that the line of temperature was more volatile in all the three sample cities, but the line of temperature in Delhi City and line sample index movement moved on the same line and hence it is inferred that the Delhi City temperature influenced BSE GREENEX, during the study period.

5 | CONCLUSION

Many earlier research studies proved that weather factors influenced the mood or emotion of individuals, preventing them from taking rational investment decisions (Cao & Wei, 2005; Chang et al., 2006; Goetzmann and Zhu, 2005; Kathiravan et al., 2018a, 2018b, 2019a, 2019b; Lee and Wang, 2011; Lu and Chou, 2012; Yoon and Kang, 2009). The present study clearly found that weather variable, namely, temperature did affect the investment decision of investors' on carbon emission index formerly known as BSE GREENEX. Besides, the present study analyzed the relationship that existed between temperature in top cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai) and BSE GREENEX Index in India. From the normality test, it was found that in all the five sample cities, temperature factor and sample index were normally distributed. In addition, the results of ADF Test also proved the fact that sample variables attained stationarity. According to the results of OLS regression test, the values for temperature in Delhi City (coefficient-0.00600, *SE* 0.02000, *t*-value 2.62200 and significant *p*-value .00900) and values of temperature in Mumbai city (Coefficient 0.00100, *SE* 0.01800, *t*-value 2.09300, and significant *p*-value .02740) were statistically significant and they influenced the sample index, namely BSE GREENEX, during the study period. Besides, among the five sample cities, only in two cities (Mumbai and Delhi) the temperature had influenced the sample index. Finally, the study found that temperature did exercise significant impact on BSE GREENEX, and this study also supported the findings of previous studies (Andrikopoulos et al., 2019; Cao and Wei, 2005; Chang et al., 2006; Frühwirth and Sögner, 2015; Kang et al., 2010;

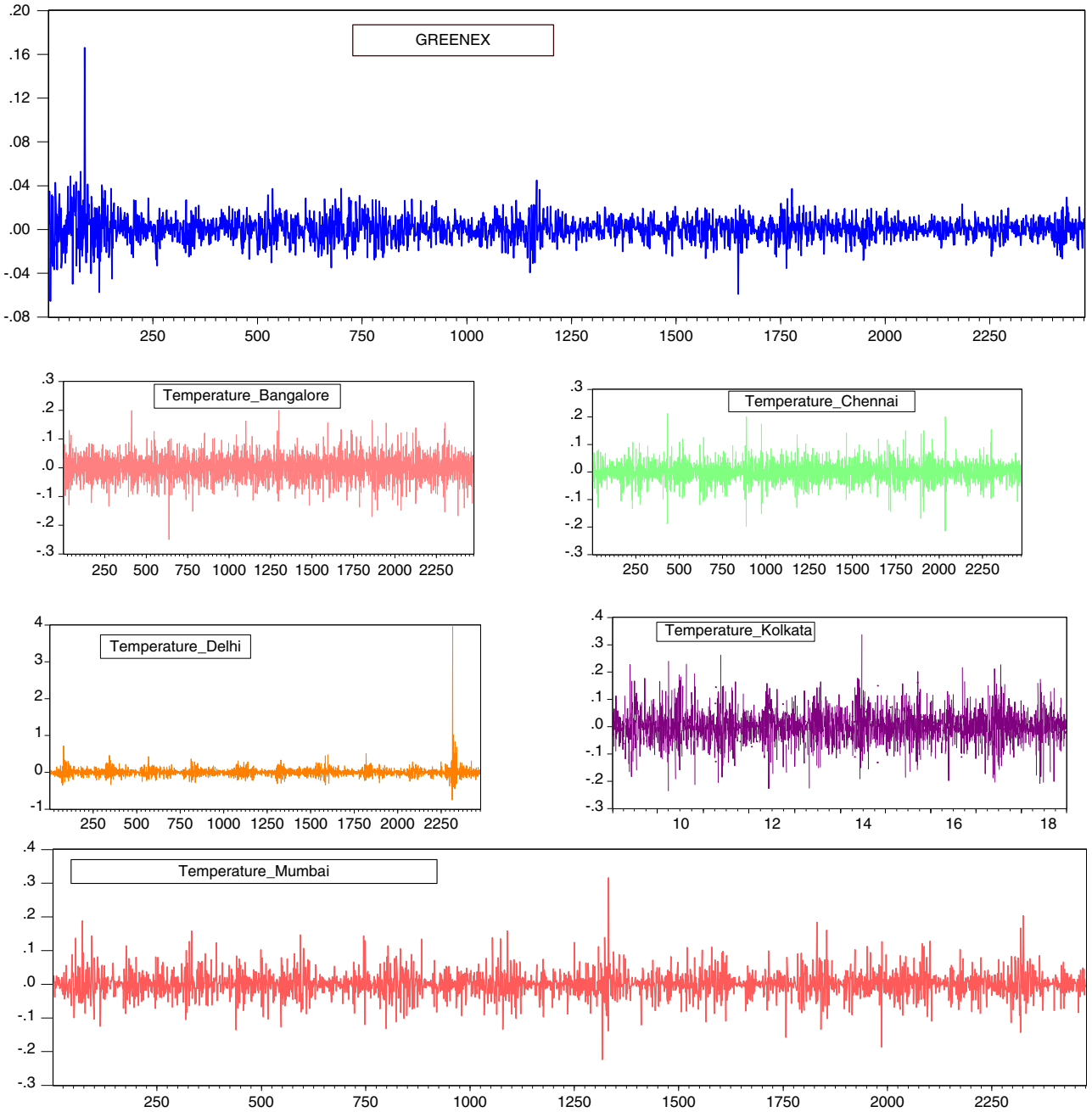

FIGURE 4 Graphical expression for the returns of BSE GREENEX with temperature in five sample cities. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-Views-9

Kathiravan et al., 2017; Keef and Roush, 2002, 2005; Silva and Almeida, 2011; Yoon and Kang, 2009). In the light of the findings, it is suggested that the management of firms should invest more on R&D, for using novel and latest technologies, to minimize Carbon emission. There is a need for educating community as a whole, on climate changes. Future direction of the research should be focused on weather factors, Carbon emission and researchers may use different and latest trends, to probe this phenomenon across the globe.

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How to cite this article: Kathiravan C, Selvam M, Maniam B, Venkateswar S, Sigo MO. Does temperature influence the carbon index? Evidences from India. *J Public Affairs*. 2020; e2117. https://doi.org/10.1002/pa.2117