An Empirical Note on Delhi Weather Effects in the Indian Stock Market

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Abstract: ***This research paper investigates the dynamic linkage, between three weather factors and two top stock Indices in India, namely, BSE SENSEX and NSE NIFTY. In order to study the weather factor on stock indices, daily weather data of Delhi and daily closing stock price of BSE SENSEX and NSE NIFTY, from January 1st 2001 to 31st December 2017, were collected and analyzed. The study found that the Delhi weather namely humidity influence BSE Sensex returns. The investing community may note the findings, for making intelligent investment decisions. The findings would be useful to investors, speculators and officials managing the Indian Securities Exchanges. This is the first empirical study testing the relationship between stock market returns and weather factors in the City of Delhi in India.***

Index Terms: Weather Factor, BSE SENSEX, S&P CNX NIFTY, Descriptive Statistics, Unit Root Test, and Granger Causality Test.

I. INTRIDUCTION

According to the Capital Asset Pricing Model (CAPM) the stock market investor's always select portfolio by evaluating its maximum returns **(Sharpe, 1964).** Recent Studies use two popular assumptions, to analyze investors' behavior, in the stock markets. The first one is that investors are totally rational and another assumes that investors are only partially rational **(Sharp, 1964).** Many behavioral studies addressed the role of investors' mood, in decision-making processes. Investors' risk assessments, financial decisions, investors' preferences, can be affected by their sentiment and the state of their mood **(Shu, 2010).** Investor opt for optimal decisions when they are in good mood while people in bad mood, tend to make pessimistic decisions (**Wright and Bower, 1992**). Investors are subject to various behavioral and psychological biases, such as fluctuation in the mood, and overconfidence; they could also be affected by factors such as culture, climate religion, and other related factors.

There is significant evidence that psychology of investors could be affected by weather factors, such as temperature **(Kathiravan, C. et al. 2019),** wind speed **(Kathiravan, C. et al. 2019),** rainfall, and humidity. These weather factors could influence people's thinking, mood, and judgment and impact their behavior and decision making **(Pardo and Valor, 2003).** Many behavioral finance studies indicate that good mood resulting from good weather could indicate optimistic decision, on their future investments **(Hirshleifer, 2001).** Many earlier studies, on the relationship between the weather and stock markets, focused on the developed markets. However, the trading mechanisms, in developed capital markets are different from the Indian stock exchanges. In the Indian Sub-Continent, the weather conditions of Delhi are unique **(Kathiravan.C et al. 2019).** Due to the high latitude at which Delhi is located, the length of day time is of substantial significance. Motivated by the various empirical study results, from different parts of the world, on the effects of weather factors on the local stock market index, this study proposes to analyze the effects in Delhi weather factors like temperature, humidity, and wind speed, on Indian stock indices, namely, BSE Sensex and S&P CNX Nifty.

II. REVIEW OF LITERATURE

An attempt has been made to review previous research studies undertaken in the area of weather effects on stock indices to identify research gaps, tools used and findings of earlier studies. **Keef and Roush (2002)** examined the relationship between weather factors in Wellington and stock market return in New Zealand. The authors found that cloud cover had no influence but temperature and wind speed of New Zealand did have significant influence on stock market return. **Cao and Wei (2005)** incorporated eight countries' weather factors in order to investigate the relationship between the weather factors and stock markets. The results of study showed that domestic investors were negatively influenced by temperature levels. Ori Levy and Itai Galili (2008) examined the relationship between weather factors and stock buying behavior in Israel. The study found that during cloudy days, the investors were willing to buy more equity than other days. **Shu and Hung (2009)** analysed the relationship between stock markets and weather factors of 18 European countries (UK, Turkey, Switzerland, Sweden, Spain, Russia, Portugal, Poland, Norway, Luxemburg, Italy, Ireland, Hungary, Greece, France, Finland, Czech Republic, and Belgium), during the period from 1994 to 2004. It was found that wind speed had created negative and significant impact on stock price, rather than other two weather variables, namely, sunlight and temperature. Yoon and Kang (2009) studied the relationship between Korean stock returns and three weather variables, during pre-crisis and post-crisis period. This study revealed that humidity level negatively influenced the stock return. Sang Hoon Kang et al. (2010) investigated the relationship between weather and Shanghai Stock market return during the period from 1996 to 2007. The study revealed that weather effects had significant influence on Shanghai Stock market return. **Mitra Akhtari (2011)**

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analyzed the relationship between weather and market return in New York City of USA, using the daily data from 1948 to 2010. It was found that there was a positive relationship between weather factors of New York City and returns of Dow Jones Industrial Average in USA. **M. Kaustia, E. Rantapuska (2016)** demonstrated the dynamic relationship between environmental variables and stock returns in Finland for the period from 1995 to 2010 using regression analysis. The findings clearly indicated that the strong and statistically significant relationship between environmental factors and stock return. **Kathiravan et al. (2018)** studied the effect of weather factors on the Sri Lanka stock index (Colombo Stock Exchange) during the period 2008 to 2017. It was found that wind speed significantly influenced the Colombo stock market index.

III. OBJECTIVE

The objective of the present study was to study the linkages between sample indices (BSE Sensex and CNX Nifty) and weather factors (Temperature, Humidity, and Wind speed)), in the city of Delhi over the sample period.

IV. NULL HYPOTHESES OF THE STUDY

- NH1: No normality in the daily data of the sample indices and sample weather factors in the City of Delhi.
- NH2: No stationarity in the daily data of the sample indices and sample weather factors in in the City of Delhi.
- NH3: No co-relation between the daily data of the sample indices and sample weather factors in the City of Delhi.
- NH4: No causal relationship between daily data of the sample indices and sample weather factors in the City of Delhi.
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V. RESEARCH METHODOLOGY

5.1. Sample Selection

For the purpose of analyzing the linkages and relationship between stock indices and weather factors in Delhi, the study identified two popular stock indices of India, namely, BSE SENSEX and S&P CNX NIFTY and three weather factors, namely, Humidity, Temperature and Wind Speed in the City of Delhi. The study period was from 01.01.2001 to 31.012.2017.

5.2. Sources of Data

For the purpose of analysis, the required daily data of BSE SENSEX were collected from http:www.bseindia.com and data for S&P CNX NIFTY were collected from http:www.nseindia.com. Similarly, the other required data, relating to sample weather factors, in Delhi were collected from IMD (www.imd.gov.in), Developed by Government of India.

5.3. Statistical Tools Used for the Analysis

The following Statistical tools were used for the analysis of this study.

- ❖In order to find out the normal distribution of sample indices and sample weather factors in Delhi, Descriptive Statistics was applied.
- ❖Unit Root test (ADF) was applied to test the stationarity of sample indices and sample weather factors in Delhi.
- ❖To find the correlation between returns of sample indices and sample weather factors in Delhi, the Correlation Matrix was used.
- ❖Granger Causality Test was used, to examine the linkage between sample indices and weather factors in Delhi

5.4 Limitations of the Study

The present study suffered from the following limitations.

- ❖ The present study was limited to only two sample indices (BSE Sensex and S&P CNX NIFTY) and three weather factors in Delhi of India.
- ❖ The present study was based on only secondary data.

VI. ANALYSIS OF DATA

The analysis of Normality (Descriptive Statistics), Stationarity (Unit Root Test), Correlation (Correlation Matrix) and Granger Causality, for two sample indices, and three weather factors, is presented as follows:

a) Movements of the Returns for Sample Indices and Weather Factors in Delhi.

b) Analysis of Normality for the Returns of Sample Indices and Weather Factors in Delhi.

c) Analysis of Stationarity for the Returns of Sample Indices and Weather Factors in Delhi.

d) Analysis of Pearson Correlation for the Returns of Sample Indices and Weather Factors in Delhi,

e) Analysis of Granger Causality for the Returns of Sample Indices and Weather Factors in Delhi.

a) Movements of the Returns for Sample Indices and Weather Factors in Delhi.

In order to find out the movements of sample stock indices, the line chart was used. The fluctuations of sample index return, for the BSE Sensex and S&P CNX NIFTY, were compared with all the three weather variables separately.

Figure 1 shows the co-movements of BSE SENSEX and the humidity in Delhi, during the study period from 01 January 2001 to 31 December 2017. It is clear from Figure 1 that humidity return, in Delhi, was fluctuating at a higher rate than that of BSE SENSEX, during the study period.

The co-movements of BSE SENSEX and temperature in Delhi, during the study period from 2001 to 2017, are shown in **Figure 2.** The sample index, namely, BSE SENSEX and temperature in Delhi, performed equally. But the BSE SENSEX moved highly upward, from 01 January 2001 to 31 December 2017. The temperature, in Delhi, also gradually moved up and down. In other words, the performance of BSE SENSEX (India) earned higher return than Delhi temperature, during the study period.

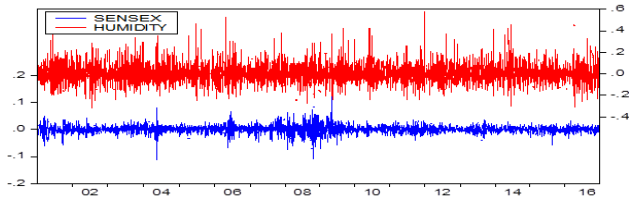
Figure 3 shows the co-movements of BSE SENSEX and wind speed in Delhi City, during the study period from 01.01.2001 to

31.12.2017. The index curve of SENSEX was highly volatile from 2005 to 2011 but the wind speed curve movement was in the same direction. Besides, it is clearly understood that there was no interrelationship, between the BSE SENSEX and wind speed, in Delhi, during the study period.

The co-movements of S&P CNX NIFTY and Delhi humidity, during the study period, from 01 January 2001 to 31 December 2017 are given in **Figure 4.** The performance of Delhi humidity was highly volatile when compared to S&P CNX NIFTY. It is evident that the movement of both variables, registered different movements, throughout the study period.

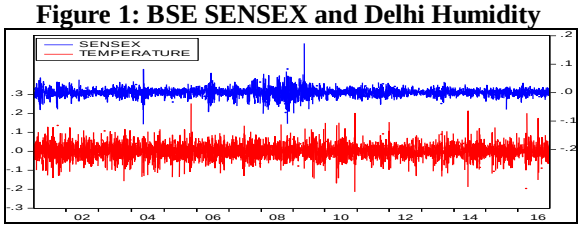
Figure 5 illustrates the co-movements of S&P CNX NIFTY and Delhi temperature, during the study period from 01 January 2001 to 31 December 2017. The growth level of S&P CNX NIFTY was not volatile when compared with the Delhi temperature. But both variables registered the same level of risk and return for the investors, during the study period.

The co-movements of S&P CNX NIFTY and Delhi wind speed, from 01.01.2001 to 31.12.2017, are provided in **Figure 6.** It is clearly observed from the Figure that there was no interrelationship, between both variables of S&P CNX NIFTY and wind speed in Delhi.



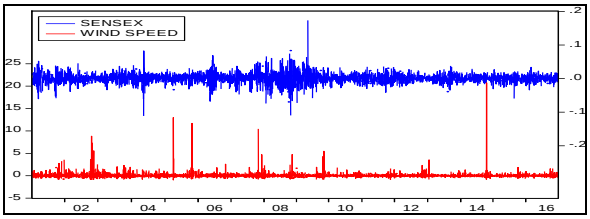
Source: Yahoo finance and IMD, computed using E-Views (Version 6)

Figure 1: BSE SENSEX and Delhi Humidity



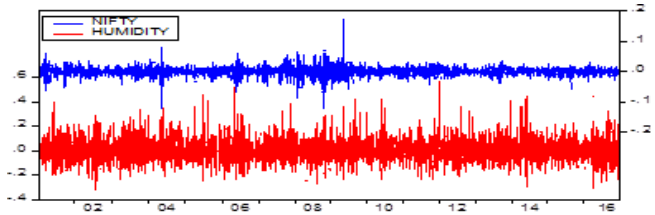
Source: Yahoo finance and IMD, computed using E-Views (Version 6)

Figure 2: BSE SENSEX and Delhi Temperature



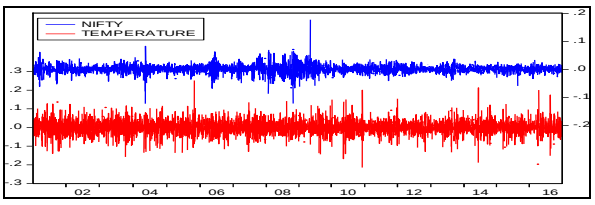
Source: Yahoo finance and IMD, computed using E-Views (Version 6)

Figure 3: BSE SENSEX and Delhi Wind Speed



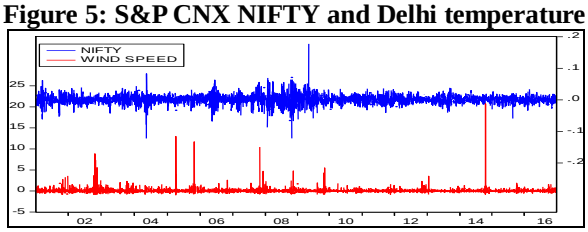
Source: Yahoo finance and IMD, computed using E-Views (Version 6)

Figure 4: S&P CNX NIFTY and Delhi Humidity



Source: Yahoo finance and IMD, computed using E-Views (Version 6)

Figure 5: S&P CNX NIFTY and Delhi temperature



Source: Yahoo finance and IMD, computed using E-Views (Version 6)

Figure 6: S&P CNX NIFTY and Delhi wind speed

b) Analysis of Normality for the Returns of Sample Indices and Weather Factors in Delhi.

Table–1 shows the results of descriptive statistics, for BSE SENSEX and Weather Factors in Delhi City, during the study period from 01-01-2001 to 31-12-2017. Table–2 shows the results of descriptive statistics, for S&P CNX NIFTY and Weather Factors in Delhi city, during the study period.

It is clear from Table-1 that during the study period, the Delhi wind speed earned the highest mean value of 0.080180, and BSE SENSEX earned the lowest mean value of 0.00059. The mean value, for all the two-sample indices, showed positive sign. In terms of market volatility, as measured by the standard deviation (SD) of daily returns, the wind speed of Delhi attained the highest risk value (0.651228), followed by Delhi humidity (0.088684), Delhi temperature (0.037435) and BSE SENSEX (0.014710). The analysis of skewness clearly indicated that the values, for all sample variables (two stock market indices, namely, BSE Sensex and CNX Nifty and three weather variables, namely, temperature, humidity and wind speed) had fallen between -1 to +1. It is significant to note from the Table that all values of kurtosis, earned by sample indices, were positive, during the study period. Besides, the values of Jarque-Bera of the sample variable revealed that the values for all sample variables were normally distributed. In short, the distribution of return data, for two sample indices (BSE Sensex and S&P CNX NIFTY), was normal.

It is clear from the Table-2 that during the study period, the lowest mean value of 0.0006 was recorded for S&P CNX NIFTY while the highest mean value of 0.0802 was registered for wind speed during the study period. The highest variation (Std. Dev) of wind speed was recorded at 0.6512 while the lowest value of Std. Dev, for S&P CNX NIFTY, was registered at 0.0148. The analysis of skewness values, for all sample variables, had fallen between -1 to +1. But the level of kurtosis was positive, for Delhi and sample stock market indices, during the period. The overall analysis results vividly confirmed that normal distribution was noticed in respect of two sample indices (BSE SENSEX and S&P CNX NIFTY), against three weather factors in Delhi (humidity, temperature, and wind speed), during the period. Hence, the null hypothesis **(NH01), "No**

normality in the daily data of the sample indices and sample weather factors in the City of Delhi.", was accepted.

Table 1:
Descriptive Statistics of Weather Factors in Delhi city and BSE SENSEX

	Sensex	Humidity	Temperature	Wind Speed
Mean	0.000587	0.003758	0.000696	0.080180
Std. Dev.	0.014710	0.088684	0.037435	0.651228
Skewness	0.099713	0.696058	0.022353	14.40649
Kurtosis	12.121990	5.704478	6.080793	353.9133
Jarque-Bera	13819.590	1535.863	1575.885	20579074
Obser.	3984	3984	3984	3984

Source: (http://finance.yahoo.com/ IMD) and Computed using E-Views 6 Version.

Table 2:
Descriptive Statistics of Weather Factors in Delhi city and S&P CNX NIFTY

	S&P CNX Nifty	Humidity	Temperature	Wind Speed
Mean	0.0006	0.0038	0.0007	0.0802
Std. Dev.	0.0148	0.0887	0.0374	0.6512
Skewness	-0.0245	0.6961	0.0224	14.4065
Kurtosis	13.0824	5.7045	6.0808	353.9133
Jarque-Bera	16875.0100	1535.863	1575.885	20579074
Obser.	3984	3984	3984	3984

Source: (http://finance.yahoo.com/ IMD) and Computed using E-Views 6 Version.

c) Analysis of Stationarity for the Returns of Sample Indices and Weather Factors in Delhi.

As stated earlier, the Augmented Dickey-Fuller Test and the Phillips-Perron Test were used to test the stationarity, among two sample indices and three weather factors, in Delhi. The results of the Augmented Dickey-Fuller Test (ADF) and Phillips Perron test (PP), for daily closing values of two sample indices (BSE SENSEX and S&P CNX NIFTY) and three weather factors in Delhi (temperature, humidity, and wind speed), during the period 01.01. 2001 to 31.12. 2017, are displayed in Table-3. The test critical values, for two sample indices and three weather factors in Delhi city, were analyzed at three different significant levels of 1%, 5%, and 10%. The P-Value, for sample index return and sample city weather factors, was zero, on the basis of all the two tools used for the analysis. The statistical values, using The Augmented Dickey-Fuller Test for all the sample were: BSE SENSEX (-45.3019), CNX NIFTY (-47.6390), humidity (-47.6390), temperature (-29.9410), and wind speed (-72.0018), and the statistical values of Phillips-Perron Test, for sample indices, were : BSE SENSEX (-58.3913), CNX NIFTY -48.1780), humidity (-180.8841), temperature (-139.7422), and wind speed -71.4654). The statistical values were less than that of test critical values at 1%, 5% and 10% level of significance. The results of Unit Root Test indicated the returns, stationarity between for sample indices (BSE SENSEX and S&P CNX NIFTY) and the three weather factors in Delhi city (temperature, humidity and wind speed) during the study period. Hence, **the Null Hypothesis (NH02) - No stationarity in the daily data of the sample indices and sample weather factors in in the City of Delhi"**, was accepted.

Table 3:
Unit Root Test for two Sample Indices and three Weather Factors in Delhi city

		Augmented Dickey-Fuller Test			Phillips-Perron Test		
	C.V	Statistical Value	Critical Value	P Value	Statistical Value	Critical Value	P Value
SENSEX	1%	-45.3019	-3.43181	0.0001	-58.3913	-3.4318	0.0001
	5%	-45.3019	-2.86207	0.0001	-58.3913	-2.8621	0.0001
	10%	-45.3019	-2.56710	0.0001	-58.3913	-2.5671	0.0001
NIFTY	1%	-47.6390	-3.43000	0.0001	-48.1780	-3.4300	0.0001
	5%	-47.6390	-2.86000	0.0001	-48.1780	-2.8600	0.0001
	10%	-47.6390	-2.57000	0.0001	-48.1780	-2.5700	0.0001
H	1%	-30.0080	-3.43181	0	-180.8841	-3.4318	0.0001
	5%	-30.0080	-2.86207	0	-180.8841	-2.8621	0.0001
	10%	-30.0080	-2.56710	0	-180.8841	-2.5671	0.0001
T	1%	-29.9410	-3.43181	0	-139.7422	-3.4318	0.0001
	5%	-29.9410	-2.86207	0	-139.7422	-2.8621	0.0001
	10%	-29.9410	-2.56710	0	-139.7422	-2.5671	0.0001
W	1%	-72.0018	-3.43181	0.0001	-71.4654	-3.4318	0.0001
	5%	-72.0018	-2.86207	0.0001	-71.4654	-2.8621	0.0001
	10%	-72.0018	-2.56710	0.0001	-71.4654	-2.5671	0.0001

Source: (http://finance.yahoo.com/IMD) and Computed using E-Views 6 Version.

Note: T-Temperature, H-Humidity, and W-Wind Speed

d) Analysis of Pearson Correlation for the Returns of Sample Indices and Weather Factors in Delhi

Table-4 displays the results of the correlation matrix among the two sample indices, and three weather factors in Delhi, during the period, 01.01.2001 to 31.12.2017. It is understood from the results of the Table-4, correlation values, for weather factors had ranged from -0.0213 (Temperature and Wind Speed) to 0.0179 (Humidity), in respect of BSE SENSEX. Similarly, the values of correlation, ranged from -0.0191 (Wind Speed) to 0.0252 (Humidity), in respect of S&P CNX NIFTY. The values of correlation, for weather factor in Delhi, in respect of BSE SENSEX and S&P CNX NIFTY, were less than one and this showed that there was no correlation between the returns of weather factors in Delhi, with respect of returns for BSE SENSEX and S&P CNX NIFTY, during the study period. Hence, **the Null Hypothesis (NH3), No co-relation between the daily data of the sample indices and sample weather factors in the City of Delhi"**, was accepted.

Table – 4:
Pearson Correlation statistics for the Sample indices and Weather Factors in Delhi city

		SENSEX	NIFTY
H	Pearson Correlation	0.0179	0.0252
	Sig. (2-tailed)	0.2579	0.1111
T	Pearson Correlation	-0.0213	-0.0253
	Sig. (2-tailed)	0.1794	0.1106
W	Pearson Correlation	-0.0181	-0.0191
	Sig. (2-tailed)	0.2534	0.2285

* Significant at the 0.05 level (2-tailed).
**Significant at the 0.01 level (2-tailed).
H- Humidity, T- Temperature, W- Wind Speed

e.1.) Analysis of Granger Causality for the Returns of Sample Indices and Weather Factors in Delhi.

Analysis of Granger Causality Test between the returns of BSE SENSEX and weather factors in DELHI. The results of Granger Causality, for examining the linkages between weather factors (temperature, humidity and wind speed), in Delhi and BSE Sensex, during the study period from 1 January 2001 to 31 December 2017 are provided in Table-5. It is clear that among the sample weather variables in Delhi, only one weather variable, namely, humidity, influenced BSE SENSEX and recorded one way – bidirectional causality relation (as per F-statistics, with the value of 4.60740 and P-Value of 0.6276). Besides, the other two weather factors, namely, temperature and wind speed in Delhi city, had recorded no causal relationship with BSE SENSEX. Hence, the null hypothesis (NH4), No causal relationship between daily data of the sample indices and sample weather factors in the City of Delhi, was partially accepted.

f. Granger Causality Test between CNX NIFTY and three weather factors in DELHI city

To study the causal relationship between the S&P CNX NIFTY and three weather factors (temperature, humidity and wind speed), in Delhi, during the period from 01.01.2001 to 31 December 2017. It is assumed from the above Table-6 that among the three weather variables in Delhi, no weather factor influenced the returns of S&P CNX NIFTY. Hence, **the Null Hypothesis (NH04), "No causal relationship between daily data of the sample indices and sample weather factors in the City of Delhi",** was accepted.

Table – 5
Granger Causality for the for the BSE Sensex and three Weather Factors in Delhi city

Null Hypothesis:	Obs	F-Statistic	Prob.	Result
SENSEX does not Granger Cause TEMPERATURE	3980	0.9688	0.4233	Accepted
TEMPERATURE does not Granger Cause SENSEX		2.08556	0.0800	Accepted
SENSEX does not Granger Cause WIND_SPEED	3980	1.0346	0.3877	Accepted
WIND_SPEED does not Granger Cause SENSEX		0.56697	0.6866	Accepted
SENSEX does not Granger Cause HUMIDITY	3980	**4.60740**	**0.6276**	**Rejected**
HUMIDITY does not Granger Cause SENSEX		0.21245	0.9316	Accepted
Sources: Compiled from www.ncdex.com and IMD/ using E-Views 6 Version				
Rejection: The Probability value is less than 0.05				

Table – 6
Granger Causality for S&P CNX NIFTY and three weather factors in Delhi city

Null Hypothesis:	Obs	F-Statistic	Prob.	Result
HUMIDITY does not Granger Cause NIFTY	3980	0.95452	0.4313	Accepted
NIFTY does not Granger Cause HUMIDITY		0.84564	0.4960	Accepted
TEMPERATURE does not Granger Cause NIFTY	3980	0.9294	0.4457	Accepted
NIFTY does not Granger Cause TEMPERATURE		0.56041	0.6914	Accepted
WIND_SPEED does not Granger Cause NIFTY	3980	0.08122	0.9881	Accepted
NIFTY does not Granger Cause WIND_SPEED		0.65166	0.6257	Accepted
Sources: Compiled from www.ncdex.com and IMD/ using E-Views 6 Version				
Rejection: The Probability value is less than 0.05				

VII. CONCLUSION

Environment factors do affect human mood and as the results **(Kathiravan, C et al. 2018),** weather factors do affect the decision-making process of people, particularly their investment decision. Recent studies, in behavioral finance, investigated the effect of weather factors on the investors' emotional state. It has been found that weather variables did affect investors' mood, in particular sunshine and humidity levels. This paper investigated causal relationship between the three weather factors (temperature, humidity, and wind speed) in Delhi city and the returns of the two popular Indian stock indices (BSE Sensex and S&P CNX Nifty). With the help of the Granger Causality Test, 16-year data of both Delhi weather factors and Indian stock indices (BSE Sensex and S&P CNX Nifty) were analyzed. This study discovered some statistically significant relationship between Delhi weather factor, namely, humidity and BSE Sensex returns. The findings of this study are also consistent with those reported by **Goetzmann, 2005**, based on US data **(Kathiravan, C, et al. 2019).**

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