Annals of Operations Research (2021) 299:349–373
https://doi.org/10.1007/s10479-019-03335-7

S.I. : RECENT DEVELOPMENTS IN FINANCIAL MODELING AND RISK MANAGEMENT

Investor behavior and weather factors: evidences from Asian region

Chinnadurai Kathiravan[1] · **Murugesan Selvam**[2] · **Sankaran Venkateswar**[3] · **S. Balakrishnan**[4]

Published online: 23 July 2019

Abstract
The behavioral finance studies generally analyse the relationship between investor moods, caused by weather factors and indices returns via investor moods. The present study examines the relationship between three weather factors (temperature, humidity, and wind speed) in capital cities (namely Beijing for China, Tokyo for Japan, Victoria City for Hong Kong, New Delhi for India and Singapore for Singapore), and sample stock indices (Shanghai Stock Exchange from China, Nikkei 225 from Japan, Hang Seng Index from Hong Kong, BSE Sensex from India and Singapore Exchange Limited from Singapore) of selected Asian countries. This study applied statistical tools like Descriptive Statistics, ADF Test, VAR Module and adopted the Granger Causality Approach. The found that among the three weather variables, temperature recorded a statistically significant influence on the returns of Shanghai Stock Exchange (Unidirectional Linkage), HANG SENG Index (Unidirectional Linkage) and also BSE Sensex (Bi-Directional Linkage). Wind speed recorded Bi-Directional Linkages with HANG SENG Index. The findings of this study could help the investors in making better investment management decisions. It is found that there are valuable opportunities to international investors for diversifying their stocks. The study does contribute to the behavioral finance literature.

Keywords Risk · Mood · Behavioral finance · Granger causality

JEL Classification G10 · G11 · G12 · G14 · G02

✉ Chinnadurai Kathiravan
kathirnba@bdu.ac.in

[1] Department of Commerce and Financial studies, Bharathidasan University, Tiruchirappalli, India

[2] Faculty of Management, Department of Commerce and Financial studies, Bharathidasan University, Tiruchirappalli, India

[3] School of Economics and Business Administration, Saint Mary's College of California, Moraga, CA 94575, USA

[4] Department of International Business Administration, College of Applied Sciences, Nizwa, Sultanate of Oman

1 Introduction

According to the Efficient Market Hypothesis (EMH), the participants of stock markets are always rational and their day to day investment decisions are based on economic information relevant to market prices (Keef and Roush 2002). Capital Asset Pricing Model (CAPM) also suggests that the investors, while making investment, take decisions rationally (Lucey and Dowling 2005). But some studies contradicted the finding of these modern portfolio theories and claim that it is not always possible to make rational investment decisions (Ameur et al. 2018; Kürüm et al. 2018) and many other factors also do influence the investors in taking investment decisions (Sheikh et al. 2017). The others factors include different weather factors also. It is well accepted, in the different studies conducted at different time periods, that the weather factors did not only influence the investors' behaviour but also influenced their risk aversion, their moods and investment decisions (Schwarz and Clore 1983; Kathiravan et al. 2017, 2018a, b, c). There are many studies which analysed the roles of weather factors on the returns stock indices in different countries and these weather variables covered temperature, sunshine, humidity, cloud cover, and wind speed (Cao and Wei 2005; Floros 2008a, b; Chang et al. 2006; Keef and Roush 2002, Shu and Hung 2009; Kathiravan et al. 2017, 2018a, b, c).

1.1 Decision-making process

According to the traditional view, the investors' decision making process is based on risk and uncertainty (Markowitz 1952), but there are many other factors that need to be considered. Investors have to analyse the costs and benefits of all possible outcomes (Sergio Ortobelli et al. 2018; Danışoğlu and Güner 2018) and decide on the best risk–benefit trade-off for their investment (Sharpe 1964). Figure 1 clearly explains and supports that risk and uncertainty of return are influenced by feelings and emotions of investors, triggered by different weather factors (Isen et al. 1978; Bower 1981).

Many studies have been conducted for examining the weather effects on stock indices in the developed world (Floros 2008a, b; Nikolaos Sariannidis et al. 2016; Shu and Hung 2009). Therefore, the present study examines the relationship between weather factors and stock indices returns in developing countries.

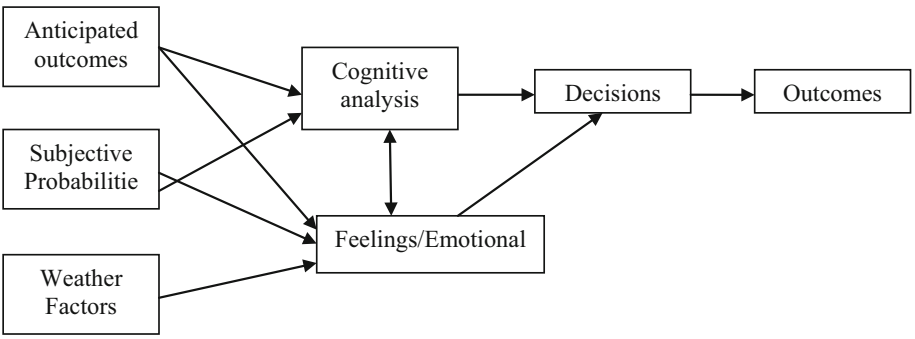

Fig. 1 Conceptual framework for the investors' decision-making process. *Source*: Developed from Brian M. Lucey and Michael Dowling 2005

2 Literature review

This section first defines studies on behavioral finance and then discusses the studies on weather factors and investors' moods that affect the stock markets. This study combines the studies relating to psychological and financial ideas, to understand the influence of weather factors on the stock market returns.

2.1 Behavioral finance

Behavioral Finance defines investors' behavior and analyses their psychology, investment strategy of investors etc. The behavior of individuals and their moods directly influence their financial decision-making process (De Bondt and Thaler 1995; Thaler 1999).

2.2 Weather and mood of investors

The day to day activities of human beings are affected by many internal and external factors, called environmental factors. The weather has been considered an important environmental factor, affecting the common public. Small changes in weather conditions may likely to change the daily activities of people. The changes in weather would normally lead, both directly and indirectly, to complex psychological and physical responses of investors (Lu and Chou 2012). Among the different weather factors, there has been extensive focus on cloud cover, temperature, humidity and wind speed. Cunningham (1979) studied both summer and winter sessions, and it was found that clear sky created a good mood while, high temperature created a bad mood during the summer period. Hollwich (1979) analysed the influence of day light on the human body and it was found that day light influenced the human psychology and physiology through the eyes. Furthermore, during the winter period, the day light made the people to feel depressed (Eagles 1994; Tietjen and Kripke 1994). According to Schwarz and Clore (1983), people felt happier on a bright day than a gloomy day while Symeonidis et al. (2010) opined that the cloud cover has a significant impact on the human attitude. Watson (2000) collected opinion from around 478 respondents from 1985 to 1993 and analysed the extreme weather conditions (days with 0% sunshine to 100% sunshine) and it was found that sunshine had no impact on human mood and only a weak relationship did exist between mood of the people and weather. Bauer et al. (2009) studied 360 patients, from different parts of the world and identified that weather factors had no association with the mood of the patients.

2.3 Effect of mood on judgment and decision-making

The mood of people played a vital role in their decision-making process (Cao and Wei 2005). Forgas and Bower (1987) found that people took positive decisions when they were in a good mood. On the contrary, Forgas et al. (2009) found that bad weather factors created negative mood among the people. Wright and Bower (1992) revealed that people tend to assess future predictions more positively when they are in a good mood than when they are in a bad mood. The above findings supported that the statement weather factor did influence mood, judgment and decision making behavior of investors.

2.4 Weather mood and stock market

This section displays recent and selective empirical studies, focusing on weather variables, like, temperature, humidity and wind speed and stock index movement.

Kathiravan et al. (2018a, b, c) investigated the co movement and causal relationship among the three weather factors (temperature, humidity, and wind speed) and agriculture commodity index in India. The study found that two factors, namely, temperature and wind speed influenced the investors' mood. Sariannidis et al. (2016) studied the effects of weather on stock index movement. It was found that weather factors (wind speed and temperature) not only affected positively the European stock market but also changes in oil and gold prices. Shim et al. (2015) examined the weather effects on the stock market volatilities in Korea, during three sub-periods, namely the before-crisis period, the during-crisis period and the after-crisis period. The study revealed that volatility of index tended to increase during cloudy days, wet and windless weather conditions. Cao and Han (2015) examined whether weather conditions affected the stock returns in Chines stock market. The study found that there was cross-correlation existed between weather variables and the stock markets on positive time. According to Bakar and Sapuan (2012), the relationship existed between stock returns and the weather variables in Malaysia. The study found that temperature exercised strong effects on stock market returns and stock return was lower when the weather was extremely hot. Brahmana et al. (2015) investigated the relationship between psychology, namely, weather-induced mood, in Indonesia and day-of-week anomaly (DOWA). The study revealed that, weather factor, namely temperature influenced the day-of-week anomaly. Brahmana et al. (2014) investigated relationship between weather variable on investors' trading pattern on Monday anomaly. The study clearly indicated that the weather influenced the investors' mood in Malaysia. Shu and Hung (2009) focused on the relationship between wind speed and daily stock index movement across 18 European countries. The results found that the temperature highly influenced the returns of European stock markets. Furthermore, Floros (2008a, b) found that there was stock market movement in relation to the weather effect in five European countries (Austria, Belgium, France, Greece and UK). The study found that there was negative relationship between temperature and stock market movement in Austria, Belgium and France while Greece and UK recorded a positive response but there was no significant correlation between temperature and stock market returns. Chang et al. (2006) ascertained the relationships between weather factors and stock market returns in Taiwan, using daily data. According to the findings of the study, the temperature and cloud cover were two important weather factors, which did affect the stock returns in Taiwan. The summary of reviews relating to weather and stock market are presented in Table 1.

3 Need and importance of the study

The present study could be useful in many ways. Majority of previous studies focused on developed world like USA and Europe, by investigating the relationship between stock markets return and weather factors and only a limited number of studies focused on emerging markets. Hence this study identified capital cities of five countries (Beijing for China, Tokyo for Japan, Victoria City for Hong Kong, New Delhi for India and Singapore for Singapore), three weather factors (Temperature, humidity and wind speed) and stock index return (Shanghai Stock Exchange from China, Nikkei 225 from Japan, Hang Seng Index from Hong Kong, BSE Sensex from India and Singapore Exchange Limited from Singapore) in the Asian region. The stock markets of this region are deemed to be emerging. Many previous studies

Table 1 Summary of literature review

Sl. no.	Authors and year	Tools used for analysis	Samples and inputs
1.	Keef and Roush (2002)	Regression analysis, and diagnostic tests	Weather data (temperature, humidity and cloud cover) and Bank bills, Government bonds, Stock indices
2.	Cao and Wei (2005)	Descriptive statistics. Bin-test, regression analysis	Eight financial markets (US, Canada, Britain, Germany, Sweden, Australia, Japan and Taiwan) and temperature data of eight countries
3.	Lucey and Dowling (2005)	Descriptive statistics, regression analysis	Irish Stock Exchange Price Index and Weather data (cloud cover, precipitation, and humidity)
4.	Chang et al. (2006)	Descriptive statistics, unit root tests, GJR-GARCH, and threshold model	Weather data (temperature, humidity and cloud cover) in Taipei city and daily closing index of the Taiwan stock market
5.	Dowling and Lucey (2008)	GARCH model and regression analysis	Weather data (precipitation, temperature, wind, geomagnetic storms) and biorhythm data (seasonal affective disorder, daylight savings time changes, lunar phases)
6.	Yoona and Kang (2009)	Descriptive Statistics, unit root tests and ARCH GJR-GARCH	Korea Composite Stock Price Index 200 (KOSPI 200) and daily weather data (temperature, humidity, and cloud cover)
7.	Kang et al. (2009)	Descriptive statistics, linear regression models, GARCH (1, 1) model	Hong Kong Exchange (HSI), Shenzhen Exchange (SSE), SSE A-Share Index (SZZA) and daily weather data (temperature humidity, cloud cover and sunshine)
8.	Kathiravan et al. (2017)	Descriptive statistics, ADF test, and GARCH (1,1) model	BSE SENSEX, S&P CNX NIFTY and weather (Temperature) in five metro cities of India (Chennai, Bombay, Calcutta, Delhi, and Hyderabad)
9.	Kathiravan et al. (2018a, b, c)	Descriptive statistics, ADF test, pearson correlation and Granger causality	Agriculture Commodity Index in India and weather (Temperature, humidity and wind speed) in five metro cities of India (Chennai, Mumbai, Delhi, Kolkata and Hyderabad)

focused only on volatility and causal relationship separately, but this study examined relationship between sample weather factors and indices returns (See Fig. 1) and their influences on investors' moods simultaneously (Huang et al. 2018; Bertrand and Lapointe 2018), using Granger Causality Approach. This study provides a detailed analysis of relationship between

weather factors and stock indices returns in Asia. This research would help to understand the forces that influence the time-series variation of equity markets in Asian regions.

4 Methodology and data

4.1 Objectives of the study

The main objective of this study was to examine the causal relationship between weather factors (Temperature, Humidity and Wind speed), and top stock indices in five Asian countries, over the sample period.

4.2 Hypotheses of the study

- *NH1* There is no normal distribution among the sample indices and weather factors in five sample countries in Asia
- *NH2* There is no stationarity among the sample indices and weather factors in five sample countries in Asia
- *NH3* There is no causal relationship among the sample indices and weather factors in five sample countries in Asia.
- *NH04* There is no influence among the sample indices and weather factors in five sample countries in Asia.

4.3 Data

For the purpose of this study, two types of data (weather factors data in line with the studies of Hirshleifer and Shumway (2003); Sheikh et al. (2017) and Stock market return data) were collected, for the period from January 2003 to December 2017.

4.4 Weather data

The study focuses on the daily weather factors, including humidity in percentage, temperature in Celsius degrees and wind speed in meters per second, in five sample countries' capital cities (Beijing of China, Tokyo of Japan, Victoria City of Hong Kong, New Delhi of India and Singapore of Singapore), derived from National Climate Data Center website http://www.ncdc.noaa.gov/oa/climate/isd/index.php.

4.5 Stock market data

The present study covered daily stock index data for five Asian markets (Shanghai Stock Exchange of China, Nikkei 225 of Japan, Hang Seng Index of Hong Kong, BSE Sensex of India and Singapore Exchange Limited of Singapore) from their respective websites of stock exchanges and yahoofinance.com. The index returns were calculated as:

$$R_t = L_n(P_t) - L_n(P_t - 1)$$

where R_t is daily index return, P_t and $P_t - 1$ are closing index values at time t and $t - 1$ respectively.

4.6 Tools used for analysis

For the purpose of testing the hypothesis, the following statistical tools were used.

- Descriptive Statistics (to find out the normal distribution of returns of sample index and weather factors in five sample countries) Salah et al. (2018)
- Unit Root Test (to test stationarity among the returns of sample index and weather factors in five sample countries).
- VAR (to find the lag order criterion among the returns of sample index and weather factors in five sample countries)
- Granger Causality Test (to examine the linkage among the selected Asian stock market Index and weather factors in five sample countries).
- OLS Regression Test (to examine the influence among the selected Asian stock market Index and weather factors in five sample countries)

4.7 Limitations of the study

- This study considered only five indices of Asia and three weather factors
- The study period was limited to 15 years i.e. from 1st January 2003 to 31st December 2017, and
- All the limitations, associated with statistical tools, used, were applicable to this study also.

5 Analysis and empirical results

This section analyses the effect of weather factors on sample stock indices in Asia, by using Descriptive Statistics, Unit Root Test, VAR Model and Granger Causality test. The analysis is presented as follows.

A. Normality for the returns of Sample Stock Indices and Weather Factors in Sample Cities in Asia,
B. Stationarity for the returns of Sample Stock Indices and Weather Factors in Sample Cities in Asia
C. Granger Causality for the returns of Sample Stock Indices and Weather Factors in Sample Cities in Asia,
D. OLS Regression Test for the returns of Sample Stock Indices and Weather Factors in Sample Cities in Asia, and
E. Graphical expression for the returns of Sample Stock Indices and Weather Factors in Sample Cities in Asia,

5.1 Normality for the returns of Sample Stock Indices and weather factors in Asia

The results of Descriptive statistics of daily returns of sample Asian stock market indices (SHANGHAI STOCK EXCHANGE, HANG SENG INDEX, BSE Sensex, NIKKEI 225, and SINGAPORE EXCHANGE LIMITED) and three weather factors (Humidity, Temperature and Wind Speed), during the study period from 01-01-2003 to 31-12-2017, are presented in Table 2. It is to be noted that the summary statistics, namely, mean, minimum, maximum,

Table 2 The results of descriptive statistics for the returns of Asian Stock Market Indices and weather factors during the study period from 01-01-2003 to 30-12-2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views of 6 version

Variables	Mean	Maximum	Minimum	SD	Skewness	Kurtosis	Jarque–Bera	Observations
China								
Shanghai stock exchange	0.000236	0.09857	− 0.088406	0.016272	− 0.211945	7.49787	3383.043	3978
Humidity (Beijing)	0.060793	3	− 1	0.362692	− 1.034028	6.36988	2591.161	5844
Temperature (Beijing)	0.004924	56	− 40	2.089875	− 3.291869	229.9553	8,544,754	5844
Wind speed (Beijing)	0.111274	7.607143	− 0.772	0.607035	− 3.254442	23.64388	77,659.74	5844
Hong Kong								
Hang Seng Index	0.00024	0.14347	− 0.127	0.01504	− 0.21259	11.7372	12,676.6	3976
Humidity (Victoria City)	0.00844	1.3	− 0.5584	0.13144	− 0.82615	9.52044	7495.79	5844
Temperature (Victoria City)	0.00376	0.675	− 0.5033	0.08541	− 0.1763	9.90197	7912.49	5844
Wind speed (Victoria City)	0.06969	3.5942	− 0.6975	0.42787	− 1.89956	9.69585	9818.69	5844
India								
BSE Sensex	0.00069	0.17339	− 0.1114	0.01415	− 0.15514	13.5607	18,534.4	3985
Humidity (New Delhi)	0.01989	2.71429	− 0.64	0.21798	− 2.38583	19.126	46,959.4	5844
Temperature (New Delhi)	0.00597	3.95652	− 0.75	0.12041	− 9.41935	297.649	64,959.4	5844
Wind speed (New Delhi)	0.10835	10.1429	− 0.9103	0.59196	− 3.83127	37.3432	205,588	5844
Japan								
Nikkei 225	0.0002	0.1415	− 0.1141	0.01588	− 0.0545	9.97359	8123.36	4008
Humidity (Tokyo)	0.03589	1.67742	− 1	0.27832	− 0.89251	5.65078	1705.56	5844
Temperature (Tokyo)	0.02577	5.09091	− 1	0.25366	− 3.92907	55.8301	476,413	5844
Wind speed (Tokyo)	0.06582	2.84615	− 1	0.40113	1.36471	6.51665	3309.37	5844
Singapore								
Singapore Exchange Limited	0.00061	0.17094	− 0.1584	0.01907	− 0.37145	9.40664	7042.02	4063
Humidity (Singapore)	0.00204	0.27273	− 0.2	0.06397	− 0.24664	3.58821	99.7664	5844
Temperature (Singapore)	0.0009	0.16309	− 0.1565	0.04192	− 0.04579	3.82817	117.531	5844
Wind speed (Singapore)	0.11333	11.5	− 0.9167	0.63443	− 5.30628	65.6887	684,361	5844

median, standard deviation (SD), skewness, kurtosis and the Jarque- Bera were used to analyse the sample indices and weather factors during the study period. It is clear from the Table 2 that the Wind Speed of SINGAPORE earned high mean value of 0.11333, followed by wind speed of Beijing in China with a value of 0.111274 and Japan stock index of NIKKEI 225 earned the lowest value of 0.0002, during the study period. It is evident that the mean value for all the sample indices and weather factors showed positive numbers and it shows the fact that all the indices earned high return during the study period. In terms of market unpredictability, as measured by the standard deviation of daily returns, China's capital city, recorded a Beijing temperature which earned the highest standard deviation value of 2.089875 and Delhi temperature attained a low standard deviation value of 0.12041. All the sample indices and weather factors values series exhibited negative skewness, which means that these variable, experienced a downside risk, or there was substantial probability of big negative returns. Furthermore, kurtosis values for samples indices and weather factors were greater than three, meaning that the return distributions of indices recorded excess value, indicating leptokurtic distributions, with higher densities of values at the extreme ends of the probability curves. The Jarque–Bera (JB) statistics indicate essential departures from normality, for all series, confirming the results for asymmetry. In other words, the sample indices were normally distributed. In short, the distribution of return data for all the sample indices in sample countries, due to weather factors, was normal. Hence the Null Hypothesis NH1: There is no normal distribution among the sample index and weather factors in five sample countries in Asia, was rejected during the study period.

5.2 ADF test for the Sample Indices and weather factors in Asia

Table 3 shows the results of Augmented Dickey Fuller (ADF) Test, for the selected five Asian countries stock indices (SHANGHAI STOCK EXCHANGE, HANG SENG INDEX, BSE Sensex, NIKKEI 225, and SINGAPORE EXCHANGE LIMITED) and three weather factors (Humidity, Temperature and Wind Speed) in capital cities of sample countries [Beijing (China), Tokyo (Japan), Victoria City (Hong Kong), New Delhi (India) and Singapore (Singapore)], during the study period from 01-01-2003 to 30-12-2017. Augmented Dickey–Fuller Test (Dickey and Fuller 1979) has been one of the best known and most widely used tests for ascertaining stationarity of the data (Box and Jenkins 1970). It is to be noted that the values of test critical for all sample indices and weather factors were deliberated at significant levels of 1%, 5% and 10%. The probability values for all the sample indices and weather factors were close to zero (0–0.0001). According to the Table, the statistical values for all sample indices and weather factors were at − 40.93581 for Shanghai Stock Exchange (CHINA), at − 65.158 for Hang Seng Index (HONG KONG), at − 45.257 for BSE Sensex (INDIA), at − 67.823 for NIKKEI 225 (JAPAN), and at − 60.913 for SINGAPORE EXCHANGE LIMITED (SINGAPORE). It is evident that the calculated statistical values for all sample indices weather factors were less than that of test critical values at 1%, 5% and 10% level of significance. This indicates the fact that the returns data of all sample weather factors and stock indices attained stationarity. The overall analysis of the ADF Test clearly shows that there was stationarity in the returns data of selected Asian stock indices and sample weather factors. Hence the Null Hypothesis (NH2) "There is no stationarity in the returns of selected stock indices and weather factors in five sample countries in Asia", was rejected during the study period.

Table 3 The results of unite root test for the returns of sample indices and weather factors in selected Asian countries during the study period from 01-01-2003 to 30-12-2017. *Source*: Collected from http://finance.yahoo.com/ http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-Views 7 Version

Shanghai Stock Exchange (China)	t-statistic	Prob.*
Augmented Dickey–Fuller test statistic	− 40.93581	0
Test critical values		
1% level	− 3.4313	
5% level	− 2.8618	
10% level	− 2.567	
Hang Seng Index (Hong Kong)		
Augmented Dickey–Fuller test statistic	− 65.158	0.0001
Test critical values		
1% level	− 3.4318	
5% level	− 2.8621	
10% level	− 2.5671	
BSE Sensex (India)		
Augmented Dickey–Fuller test statistic	− 45.257	0.0001
Test critical values		
1% level	− 3.4318	
5% level	− 2.8621	
10% level	− 2.5671	
Nikkei 225 (Japan)		
Augmented Dickey–Fuller test statistic	− 67.823	0.0001
Test critical values		
1% level	− 3.4318	
5% level	− 2.8621	
10% level	− 2.5671	
Singapore Exchange Limited (Singapore)		
Augmented Dickey–Fuller test statistic	− 60.913	0.0001
Test critical values		
1% level	− 3.4318	
5% level	− 2.8621	
10% level	− 2.5671	

Critical value at 1, 5, and 10% level of significant

5.3 Granger causality for the returns of sample stock indices and weather factors in sample cities in Asia

5.3.1 Lag order selection

In order to determine the significant lag value, the study used five different criteria, as follows (Rami 2010).

- *LR* Sequential Modified LR Test Statistic (each test at 5% level)
- *FPE* Final Prediction Error
- *AIC* Akaike Information Criterion
- *SC* Schwarz Information Criterion
- *HQ* Hannan–Quinn Information Criterion

Table 4 VAR lag order selection criteria for the returns of Shanghai Stock Exchange and weather factors in Beijing city from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views 6 version

Lag	LogL	Lag order criteria				
		1 LR	2 FPE	3 AIC	4 SC	5 HQ
0	− 2650.304	NA	4.52e−05	1.348047	1.354424	1.350309
1	− 2412.743	474.5189	4.04e−05	1.235522	1.267409	1.246834
2	− 2273.470	277.9103	3.80e−05	1.172915	1.230311*	1.193276
3	− 2226.154	94.31827	3.74e−05	1.157011	1.239915	1.186422
4	− 2190.092	71.81251	3.70e−05	1.146822	1.255236	1.185282*
5	− 2169.837	40.29411	3.69e−05	1.144661	1.278584	1.192171
6	− 2152.323	34.80612	3.69e−05	1.143892	1.303324	1.200451
7	− 2139.481	25.49555	3.69e−05	1.145496	1.330437	1.211104
8	− 2117.943	42.71476*	3.68e−05*	1.142683*	1.353133	1.217341
9	− 2105.615	24.42495	3.69e−05	1.144548	1.380507	1.228256
10	− 2090.347	30.21813	3.69e−05	1.144920	1.406388	1.237677

*Indicates lag order selection by the criterion

5.3.2 Causal relationship between returns of Shanghai Stock Exchange and weather factors in Beijing City

Table 4 clearly reveals the results of VAR lag order selection criteria during the study period from 01-01-2003 to 30-12-2017. It is to be noted that out of five (5) criteria, only three (3) criteria, namely LR, FPE and AIC, were selected and analysis of these three criteria indicated that the value of lag order of eight (8) was significant during the study period. The results for the causality test (using **lag order-8**), between Shanghai Stock Exchange of China and three weather factors (temperature, humidity and wind speed) in Beijing, the capital city of China, during the study period 01-01-2003 to 30-12-2017, are presented in Table 5. It is clear from the Table that among the three sample weather variables, only one weather variable, namely, temperature in Beijing City experienced unidirectional linkage with the returns of Chines stock exchanges, with the *P* value of 0.0025. It means that temperature in Beijing City had influence over the returns of the Shanghai Stock Exchange. Hence the Null Hypothesis (NH03)—"There is no Causal Relationship among the Shanghai Stock Exchange with weather variables (namely temperature, humidity and wind speed) in Beijing city", was partially accepted.

5.3.3 Causal relationship between the returns of Hang Seng Index and weather factors in Victoria City

The details of values of the test statistics and different lag order selection criteria (namely LR, FPE, AIC, SC and HQ), from 01-01-2003 to 30-12-2017, are provided in Table 6. It can be observed from the Table that three (3) lags (viz. LR, FPE and AIC), out of five (5), were selected and the analysis of these three lags indicate that lag order ten (10) was significant during the study period. The results of granger causality test (**using lag order-10**), for the returns of HANG SENG Index and three weather factors (temperature, humidity and wind

Table 5 Granger causality for the returns of Shanghai Stock Exchange and weather factors in Beijing City from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not Granger cause Shanghai Stock Exchange	3973	0.18015	0.8352	Accepted
Shanghai Stock Exchange does not Granger cause humidity		0.25724	0.7732	Accepted
Temperature does not Granger cause Shanghai Stock Exchange	3973	0.19788	0.0025	Rejected
Shanghai Stock Exchange does not Granger cause temperature		0.32199	0.7247	Accepted
Wind_speed does not Granger cause Shanghai Stock Exchange	3973	0.25432	0.7755	Accepted
Shanghai Stock Exchange does not Granger cause wind_speed		0.23743	0.7887	Accepted

Rejection of null hypothesis when the probability value is less than or equal to 0.05

Table 6 VAR Lag order selection criteria for the returns of HANG SENG index and weather factors in Victoria City from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views 6 version

Lag	LogL	Lag order criteria				
		1 LR	2 FPE	3 AIC	4 SC	5 HQ
0	15,291.99	NA	4.87e−09	− 7.788075	− 7.781681	− 7.785806
1	15,642.36	699.8374	4.11e−09	− 7.958409	− 7.926440	− 7.947066
2	16,015.57	744.7190	3.43e−09	− 8.140383	− 8.082840	− 8.119966
3	16,124.34	216.8161	3.27e−09	− 8.187641	− 8.104524	− 8.158150
4	16,206.96	164.5328	3.16e−09	− 8.221581	− 8.112889*	− 8.183016
5	16,254.30	94.16581	3.11e−09	− 8.237544	− 8.103278	− 8.189905
6	16,289.98	70.91247	3.08e−09	− 8.247572	− 8.087730	− 8.190858*
7	16,322.23	64.01991	3.05e−09	− 8.255849	− 8.070433	− 8.190061
8	16,337.58	30.43616	3.05e−09	− 8.255516	− 8.044525	− 8.180655
9	16,357.07	38.61334	3.05e−09	− 8.257294	− 8.020729	− 8.173358
10	16,385.63	56.53100*	3.03e−09*	− 8.263695*	− 8.001555	− 8.170685

*Indicates lag order selection by the criterion

speed) in Victoria City, the capital city of HANG KANG, during the study period from 01-01-2003 to 30-12-2017, are shown in Table 7. According to the Table, wind speed in Victoria City found bi-directional linkages with HANG SENG Index (*P* values of 0.022 for wind speed and 0.0352 for HANG SENG Index) and also temperature of Victoria City recorded unidirectional linkage with HANG SENG Index, with the *P* value of 0.0477. It is evident from the results of the Table that the changes of two weather factors, (except Humidity) had a statistically significant impact on the changes of values in the returns of Hang Seng index during the study period. Hence, the Null Hypothesis (NH03)—"There is no

Table 7 Granger causality for the returns of Hang Seng Index and Weather Factors in Victoria City from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not Granger cause Hang Seng Index	3966	0.44952	0.6380	Accepted
Hang Seng Index does not Granger cause humidity		0.25292	0.7765	Accepted
Temperature does not Granger cause Hang Seng Index	3966	3.04538	0.0477	Rejected
Hang Seng Index does not Granger cause temperature		0.71914	0.4872	Accepted
Wind_speed does not Granger cause Hang Seng Index	3966	3.82073	0.022	Rejected
Hang Seng Index does not Granger cause wind_speed		3.34843	0.0352	Rejected

Rejection of null hypothesis when the probability value is less than or equal to 0.05

causal relationship among the Returns of Hang Seng Index with Weather Variables (namely temperature, humidity and wind speed) in Victoria City" was partially accepted.

5.3.4 Causal relationship between the returns of BSE Sensex and weather factors in Delhi City

Table 8 shows the values of BSE Sensex return and weather factors (temperature, humidity and wind speed) of various lag order selection criteria, during the study period from 01-01-2003 to 30-12-2017. According to the results of the Table, out of five (5) criteria, only three (3) criteria (FPE, AIC and SC) were selected and analysis of these three criteria indicates that the lag order six (6) was significant during the study period. The results of granger causality for the returns of BSE Sensex and three weather factors (temperature, humidity and wind speed) in Delhi, the capital city of India, during the study period from 01-01-2003 to 30-12-2017, are given in Table 9. It is clear that among the three weather variables, the weather variable (wind speed) recorded bi-directional linkages with P value of 0.013 and BSE Sensex with P value of 0.0194 for wind speed. In other words, except for wind speed, other weather factors did not show statistically significant linkages with the returns of BSE Sensex during the study period. Hence the Null Hypothesis (NH03)—"There is no causal relationship among the BSE Sensex with weather variables (namely temperature, humidity and wind speed) in Delhi City" was partially accepted.

5.3.5 Causality between Nikkei 225 and weather factors in Tokyo City

Table 10 shows the values of various lag order selection criteria for the NIKKEI 225 and weather factors in Tokyo the capital city of Japan, during the study period from 01-01-2003 to 30-12-2017. It can be seen from the Table that three (3) criteria (LR, FPE and AIC) were selected and analysis of them clearly indicates that lag order six (6) was significant during the study period. The results of granger causality test, for the returns of sample index, NIKKEI 225 and three weather factors (temperature, humidity and wind speed) in Tokyo City during the study period from 01-01-2003 to 30-12-2017, are given in Table 11. According to the Table, no one weather factor in Tokyo City did show statistically significant impact

Table 8 VAR lag order selection criteria for the returns of BSE Sensex and weather factors in Delhi City from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views 6 version

Lag	LogL	Lag order criteria				
		1 LR	2 FPE	3 AIC	4 SC	5 HQ
0	10,926.66	NA	4.82e−08	− 5.495676	− 5.489348	− 5.493432
1	11,269.27	684.3704	4.09e−08	− 5.660011	− 5.628374	− 5.648793
2	11,398.82	258.5107	3.87e−08	− 5.717142	5.576137	− 5.696950
3	11,436.69	75.48677	3.82e−08	− 5.728145	− 5.645890	− 5.698978*
4	11,457.93	42.31276	3.81e−08	− 5.730785	− 5.623220	− 5.692644
5	11,480.95	45.79006	3.80e−08	− 5.734315	− 5.601441	− 5.687200
6	11,496.96	31.81926	3.80e−08*	− 5.734320*	− 5.660196*	− 5.678231
7	11,505.84	17.62924	3.81e−08	− 5.730738	− 5.547245	− 5.665674
8	11,516.00	20.14631	3.82e−08	− 5.727798	− 5.518996	− 5.653760
9	11,524.41	16.66751	3.84e−08	− 5.723980	− 5.489869	− 5.640968
10	11,541.82	34.46168*	3.84e−08	− 5.724690	− 5.465270	− 5.632703

*Indicates lag order selection by the criterion

Table 9 Granger causality for the returns of BSE Sensex and weather factors in Delhi City from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views

Rejection of null hypothesis when the probability value is less than or equal to 0.05

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not Granger cause BSE Sensex	3983	0.71656	0.4885	Accepted
BSE Sensex does not Granger cause humidity		0.82608	0.4378	Accepted
Temperature does not Granger cause BSE Sensex	3983	0.02731	0.9731	Accepted
BSE Sensex does not Granger cause temperature		0.778	0.3547	Accepted
Wind_speed does not Granger cause BSE sensex	3983	0.09087	0.0131	Rejected
BSE Sensex does not Granger cause wind_speed		1.03676	0.0194	Rejected

on the NIKKEI 225 during the study period. Hence the Null Hypothesis (NH03)—"There is no causal relationship among the NIKKEI 225 index with weather variables (namely temperature, humidity and wind speed) in Tokyo City" was accepted.

5.3.6 Causality between Singapore Exchange Limited and Singapore weather factors

The details of values for various lag order selection criteria for the Singapore Exchange Limited and weather factors in Singapore, are shown in Table 12. As per the results given in the Table, four (4) criteria (namely LR, FPE, AIC and HQ) were selected and analysis of them clearly indicates that the lag order ten (10) was statistically significant during the study period. The results of granger causality test, for the returns of Singapore Exchange Limited and three weather factors (temperature, humidity and wind speed) in Singapore,

Table 10 VAR lag order selection criteria for the returns of Nikkei 225 and weather factors in Tokyo City from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views 6 version

Lag	LogL	Lag order criteria				
		1 LR	2 FPE	3 AIC	4 SC	5 HQ
0	8277.304	NA	1.85e−07	− 4.149099	− 4.142789	− 4.146862
1	8936.955	1317.647	1.34e−07	− 4.471893	− 4.440343	− 4.460708
2	9244.448	613.5981	1.16e−07	− 4.618078	− 4.561288	− 4.597945
3	9347.195	204.8245	1.11e−07	− 4.661582	− 4.579552	− 4.632500
4	9438.142	181.1194	1.07e−07	− 4.699169	− 4.591899*	− 4.661139
5	9486.601	96.40665	1.05e−07	− 4.715447	− 4.582937	− 4.668468
6	9526.989	80.27053	1.04e−07	− 4.727678	− 4.569928	− 4.671751*
7	9546.190	38.12317	1.04e−07	− 4.729283	− 4.546294	− 4.664408
8	9571.896	50.98578	1.03e−07	− 4.734150	− 4.525921	− 4.660327
9	9593.134	42.08255	1.03e−07	− 4.736777	− 4.503308	− 4.654006
10	9618.523	50.25436*	1.03e−07*	− 4.741486*	− 4.482777	− 4.649766

*Indicates lag order selection by the criterion

Table 11 Granger causality for the returns of Nikkei 225 and weather factors in Tokyo City from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not Granger cause Nikkei 225	4004	0.44955	0.6379	Accepted
Nikkei 225 does not Granger cause humidity		1.04503	0.3518	Accepted
Temperature does not Granger cause Nikkei 225	4004	1.19879	0.3017	Accepted
Nikkei 225 does not Granger cause temperature		1.33533	0.2632	Accepted
Wind_speed does not Granger cause Nikkei 225	4004	0.72735	0.4832	Accepted
Nikkei 225 does not Granger cause wind_speed		3.64301	0.6379	Accepted

Rejection of null hypothesis when the probability value is less than or equal to 0.05

during the study period from 01-01-2003 to 30-12-2017, are presented in Table 13. It is clear that among, the three sample weather variables, only one weather variable, namely temperature with the *P* value of 0.0076 and Singapore stock exchange, with the *P* value of 0.0159, recorded bi-directionally relationship with each other. In other words, no one weather variable, except temperature, did show statistically significant relationship during the study period. Hence, (NH03)—"There is no causal relationship among the Returns of Singapore Exchange Limited with weather variables (namely temperature, humidity and wind speed) in Singapore" was partially rejected.

5.3.7 Analysis of OLS regression model for Shanghai Stock Exchange and weather factors in Beijing City

The results of the Ordinary Linear Regression (OLS) model, for the returns of three sample weather factors (temperature, humidity and wind speed) in Beijing, the capital city of China

Table 12 VAR lag order selection criteria for the returns of Singapore Exchange Limited and weather factors in SINGAPORE from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views 6 version

Lag	LogL	Lag order criteria				
		1 LR	2 FPE	3 AIC	4 SC	5 HQ
0	22,250.87	NA	2.01e−10	− 10.97798	− 10.97175	− 10.97577
1	22,958.24	1413.003	1.43e−10	− 11.31914	− 11.28802	− 11.30812
2	23,152.71	388.0675	1.31e−10	− 11.40721	− 11.35119	− 11.38736
3	23,277.40	248.5846	1.24e−10	− 11.46084	− 11.37992	− 11.43218
4	23,355.40	155.3336	1.20e−10	− 11.49144	− 11.38562*	− 11.45395
5	23,406.42	101.5283	1.18e−10	− 11.50872	− 11.37800	− 11.46242
6	23,445.86	78.39249	1.17e−10	− 11.52029	− 11.36467	11.44449
7	23,476.51	60.85628	1.16e−10	− 11.52752	− 11.34700	− 11.46357
8	23,504.75	56.01859	1.15e−10	− 11.53356	− 11.32814	− 11.46079
9	23,522.87	35.91167	1.15e−10	− 11.53460	− 11.30429	− 11.45302
10	23,539.46	32.83999*	1.15e−10*	− 11.53489*	− 11.27968	− 11.46516*

*Indicates lag order selection by the criterion

Table 13 Granger causality for the returns of Singapore Exchange Limited and weather factors in Singapore from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E-views

Rejection of null hypothesis when the probability value is less than or equal to 0.05

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not Granger cause Singapore Exchange Limited	4061	0.28575	0.7515	Accepted
Singapore Exchange Limited does not Granger cause humidity		0.29659	0.7434	Accepted
Temperature does not Granger cause Singapore Exchange Limited	4061	0.97873	0.0159	Rejected
Singapore Exchange Limited does not Granger cause TEMPERATURE		0.20135	0.0076	Rejected
Wind_speed does not Granger cause Singapore Exchange Limited	4061	1.32652	0.2655	Accepted
Singapore Exchange Limited does not Granger cause wind_speed		0.53221	0.5873	Accepted

and index of Shanghai Stock Exchange in China, during the study period from 01-01-2003 to 30-12-2017, are presented in Table 14. It is evident that there were negative values of coefficients recorded for three variables, namely, Temperature (− 5.002), Humidity (− 2.226), and Wind Speed (− 0.030). According to the analysis of the Table, the R^2 value was 0.7909 and F- statistic value was 1.8923. Further, Durbin–Watson clearly revealed the residuals. Except for temperature that attained significant value, the remaining two did not attain levels of significance. In other words, weather factors in Beijing City did not influence the returns of Shanghai Stock Exchange index during the study period. Hence the Null hypothesis NH04:

Table 14 The results of OLS regression model for testing the influence of Shanghai Stock Exchange and weather factors in China from 1st January 2003 to 31st December 2017. *Source*: Compiled from yahoo finance and Computed by using SPSS

Independent variable: Shanghai Stock Exchange

Variables	Coefficient	SE	T	Sig.
C	− 0.781	0.348	− 3.549	0.000
Temperature	− 5.002	6.648	− 0.756	0.030
Humidity	− 2.226	2.191	− 1.017	0.209
Wind speed	− 0.030	0.232	− 0.392	0.795
R-squared	0.7909	F-statistic		1.8923
Durbin–Watson stat	2.2255	Prob (F-statistic)		0.3743

Table 15 The results of OLS regression model for testing the influence of Hang Seng Index and weather factors in Hang Kang from 1st January 2003 to 31st December 2017. *Source*: Compiled from yahoo finance and Computed by using SPSS

Independent variable: HANG SENG INDEX

	Coefficient	SE	t	Sig.
C	− 0.892	0.246	− 3.620	0.000
Temperature	0.197	0.022	2.622	0.121
Humidity	− 0.167	3.564	− 0.047	0.963
Wind speed	− 0.230	0.443	− 0.520	0.603
R-squared	0.6809	F-statistic		1.0669
Durbin–Watson stat	2.4284	Prob (F-statistic)		0.5363

There is no influence among the Shanghai Stock Exchange and weather factors in China, was partially accepted.

5.3.8 Analysis of OLS regression model for Hang Seng Index and weather factors in Victoria City

Table 15 displays the results of Ordinary Linear Regression (OLS) model, for the returns of three weather factors (temperature, humidity and wind speed) in Victoria City, the capital city of Hong Kong and Hang Seng Index, during the study period 01-01-2003 to 30-12-2017. For the analysis of the study, three weather variables were considered as dependent variables, while Hang Seng Index was taken as the independent variable. According to the table, there was positive value (0.197) for Temperature but the values for Humidity (− 0.167) and for Wind Speed (− 0.230) were negative during the study period. Further, the R^2 was at 0.6809 during the study period. From the analysis of F-statistic value, it was found that there was positive value (1.0669). According to the Durbin–Watson analysis (2.4284), there were residuals. The significant value did not attain even conservative levels of significance and it indicated that weather factors in Victoria City did not influence Hang Seng Stock Exchange return during the study period. According to the Table, no one weather factor in Victoria City recorded statistically significant impact on the Hang Seng Index during the study period. Hence the Null hypothesis NH04: There is no influence among the Hang Seng Index and weather factors in HANG KANG, was accepted.

5.3.9 Analysis of OLS regression model for BSE Sensex and weather factors in Delhi City

The results of the Ordinary Linear Regression (OLS), for three sample weather factors (temperature, humidity and wind speed) in Delhi City and BSE Sensex in India, from 1st January 2003 to 31st December 2017, are presented in Table 16. It is to be noted that the coefficient values for all the three sample weather factors in Delhi City were negative during the study

Table 16 The results of OLS regression model for testing the influence of BSE Sensex and weather factors in India from 1st January 2003 to 31st December 2017. *Source*: Compiled from yahoo finance and Computed by using SPSS

Independent variable: BSE Sensex

	Coefficient	SE	t	Sig.
(Constant)	− 0.843	0.250	− 3.377	0.001
Temperature	− 2.805	1.897	− 1.479	0.758
Humidity	− 0.360	1.169	0.308	0.134
Wind speed	− 0.485	0.409	− 1.186	0.026
R-squared	0.6926	F-statistic		1.2389
Durbin–Watson stat	2.1255	Prob (F-statistic)		0.4337

Table 17 The results of OLS regression model for testing the influence of Nikkei 225 and weather factors in Japan from 1st January 2003 to 31st December 2017. *Source*: Compiled from yahoo finance and Computed by using SPSS

Independent variable: Nikkei 225

	Coefficient	SE	t	Sig.
(Constant)	− 0.904	0.247	− 3.653	0.000
Temperature	2.329	4.535	0.513	0.608
Humidity	0.575	2.389	0.241	0.810
Wind speed	0.048	0.215	− 0.225	0.822
R-squared	0.909	F-statistic		1.8923
Durbin–Watson stat	2.2255	Prob (F-statistic)		0.3743

period. But among the three weather factors, Wind Speed in Delhi City earned high negative value (− 0.360). It is inferred from the Table that the R^2 was at 0.6926. According to the F-statistic, there was positive value (1.2389) while the Durbin–Watson value (2.1255) indicated that there were residuals during the study period. Further, Wind Speed in Delhi City earned a value of 0.021. Among the three sample weather variables, only one weather variable, namely, wind speed with the *P* value of 0.0076 was found to be statistically significant. In other words, no one weather variable, except temperature, created statistically significant impact during the study period. Hence the Null hypothesis NH04: There is no influence among the BSE Sensex and weather factors in India, was partially accepted. The results of this study confirmed the findings of Vijayakumar et al. (2015) and Kathiravan et al. (2018a, b, c) who also found that there were effects of weather factors on Indian stock market returns.

5.3.10 Analysis of OLS regression model for Nikkei 225 and weather factors in Tokyo City

Table 17 shows the results of Ordinary Linear Regression (OLS) analysis, using the daily data of three weather variables (temperature, humidity and wind speed) and Nikkei 225 of Japan, during the study period from 1st January 2003 to 31st December 2017. The analysis of three weather variables (dependent variables) and sample stock index return (Nikkei 225 as the independent variable) clearly revealed that there were positive coefficient values for temperature (2.329), humidity (0.575) and wind speed (0.048) during the study period. Further, the value of R^2 was 0.909. As per the F-statistic, there was positive value of 1.8923 and Durbin–Watson statistic value was 2.2255, which clearly indicated residuals. The significant value did not attain conventional levels of significance in other words, weather factors in Tokyo City did not influence Nikkei 225 index return during the study period. Hence the Null hypothesis (NH04): There is no influence among the Nikkei 225 and weather factors in Japan, was accepted.

Table 18 The results of OLS regression model for testing the influence of Singapore Exchange Limited and weather factors in Singapore from 1st January 2003 to 31st December 2017. *Source*: Compiled from yahoo finance and Computed by using SPSS

Independent variable: Singapore Exchange Limited

	Coefficient	SE	t	Sig.
(Constant)	− 0.920	0.247	− 3.727	0.000
Temperature	− 0.520	7.338	− 0.071	0.024
Humidity	− 2.191	1.922	− 1.140	0.254
Wind speed	1.348	1.015	1.328	0.004
R-squared	0.7909	F-statistic		2.0779
Durbin–Watson stat	3.5395	Prob (F-statistic)		0.6474

5.3.11 Analysis of OLS regression model for Singapore Exchange Limited and weather factors in Singapore

The results of OLS Regression for Singapore Exchange Limited for the period from 1st January 2003 to 31st December 2017, are given in Table 18 it was evident that the coefficient values for the samples weather factors were mixed (positive and negative). Except the Wind Speed (1.348) in Singapore, the remaining two weather factors, namely, temperature (− 0.520) and humidity (− 2.191) were negative. But the value of R^2 was at 0.7909 and coefficient values were negative (− 0.920) while the values of F-statistic (2.0779) and Prob (F-statistic) (0.6474) were low. Durbin–Watson statistic value (3.5395) indicated residuals. According to the analysis of Table, two variables, namely, Temperature and Wind Speed have attained conventional level of significance. It is evident that the changes of sample weather factors, (except Humidity) had created statistically significant impact on the changes of values in the returns of Singapore Exchange Limited during the study period. Hence the Null hypothesis (NH04)—There is no influence among the Singapore Exchange Limited and weather factors in Singapore, was partially accepted.

5.4 Graphical expression for the returns of sample Stock Indices and weather factors in sample cities in Asia

5.4.1 Graphical expression for the returns of Shanghai Stock Exchange and weather factors in Beijing city

Figure 2 explains the results of graphical expression, for the returns of Shanghai Stock Exchange and three weather factors (temperature, humidity, and wind speed) in Beijing City of China, during the study period from January 01, 2003 to December 31, 2017. It is to be noted that according to the graphical lines for the Shanghai stock exchange and two weather factors (humidity and wind speed), it was highly volatile but the line of temperature in Beijing City was less volatile during the study period.

5.4.2 Graphical expression for the returns of Hang Seng Index and weather factors in Victoria City

The results of graphical expression, for the returns of Hang Seng Index and weather factors (temperature, humidity, and wind speed), in Victoria City of Hong Kong, during the study period from January 01, 2003 to December 31, 2017, are presented in Fig. 3. It is observed

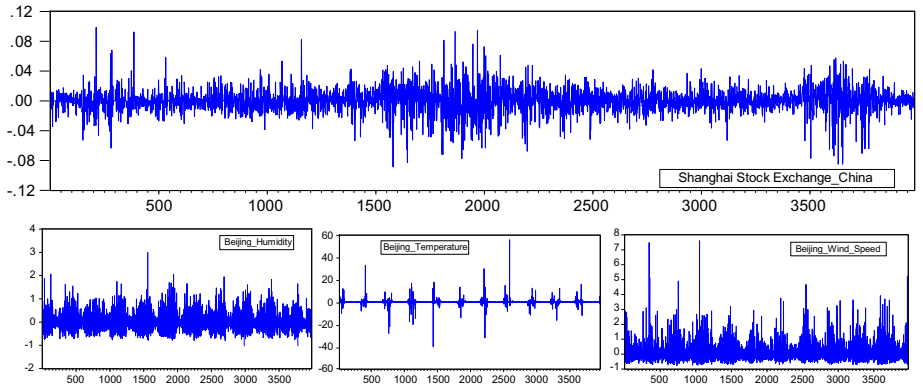

Fig. 2 Graphical expression for the returns of Shanghai Stock Exchange and weather factors in Beijing City of China from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E.Views-9

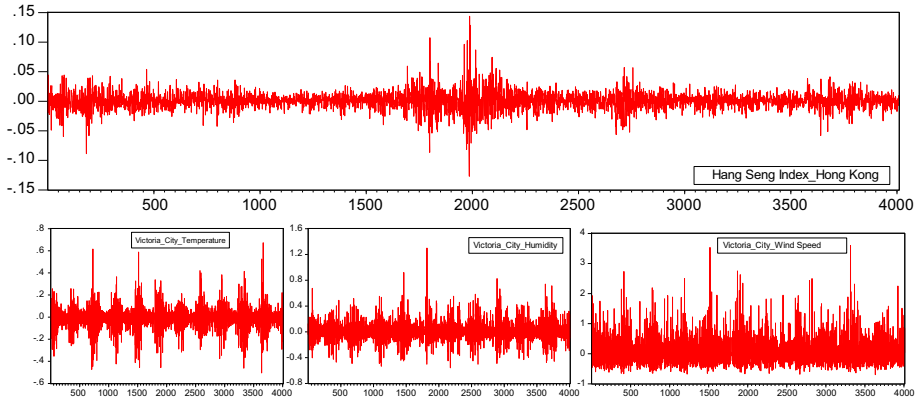

Fig. 3 Graphical expression for the returns of Hang Seng Index and weather factors in Victoria City of Hong Kong from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E.Views-9

from the Figure that the movement of Hang Seng Index curve was at the same level but wind speed showed high frequencies during the study period.

5.4.3 Graphical expression for the returns of BSE Sensex and weather factors in New Delhi

The results of graphical expression, for the returns of BSE Sensex and weather factors (temperature, humidity, and wind speed), in New Delhi of India, during the study period from January 01, 2003 to December 31, 2017, are presented in Fig. 4. It is to be noted from the above figure that the line of humidity and wind speed moved with higher frequencies than other two variables, namely, BSE Sensex and temperature during the study period.

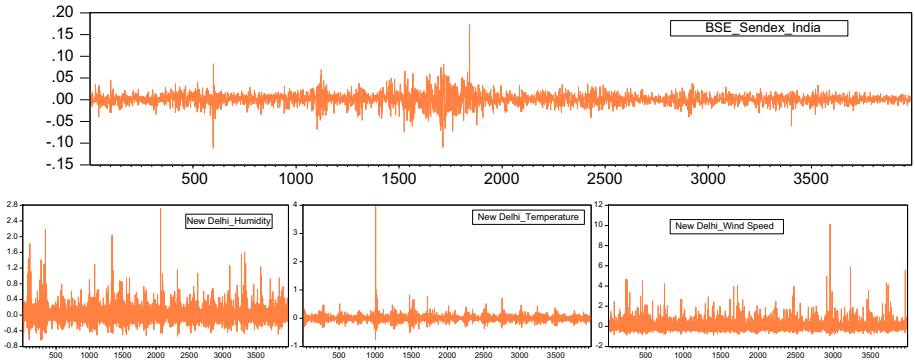

Fig. 4 Graphical expression for the returns of BSE Sensex and weather factors in Delhi City of India from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E.Views-9

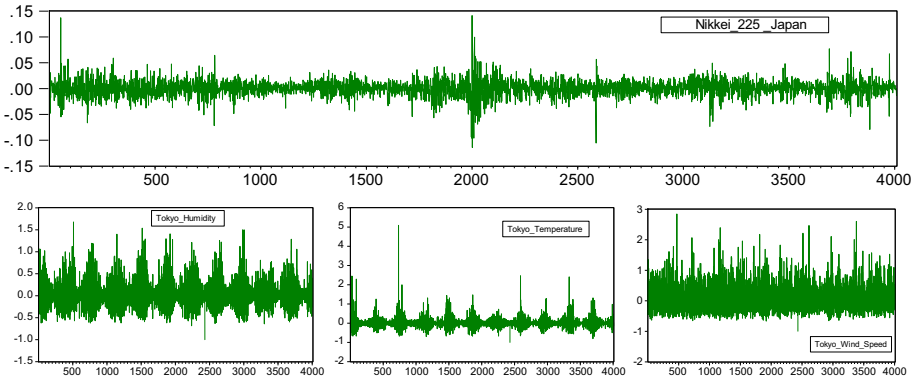

Fig. 5 Graphical expression for the returns of Nikkei 225 and weather factors in Tokyo City of Japan from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E.Views-9

5.4.4 Graphical expression for the returns of Nikkei 225 and weather factors in Tokyo

Figure 5 explains the results of graphical expression, for the returns of NIKKEI 225 and weather factors in Tokyo of Japan, during the study period from January 01, 2003 to December 31, 2017. It is to be noted that the graphical line for all the sample weather factors (except temperature) moved up and down with high frequencies during the study period.

5.4.5 Graphical expression for the returns Singapore Exchange Limited and weather factors in Singapore

The results of graphical expression, for the returns of SINGAPORE EXCHANGE LIMITED and weather factors (temperature, humidity, and wind speed) in SINGAPORE, during the study period from January 01, 2003 to December 31, 2017, are presented in Fig. 6. It is observed from the figure that the movement of curve for Singapore Exchange Limited and weather factors (except wind speed) showed volatility with high frequencies.

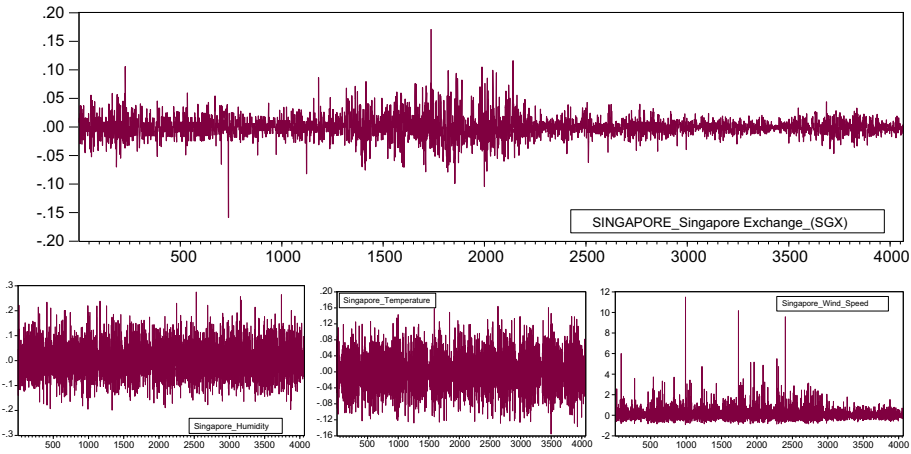

Fig. 6 Graphical expression for the returns of Singapore Exchange Limited and weather factors in Singapore from 1st January 2003 to 31st December 2017. *Source*: Compiled from http://finance.yahoo.com/ and http://www.ncdc.noaa.gov/oa/climate/isd/index.php and computed using E.Views-9

6 Summary and conclusions

Earlier, the research in finance area was based on the assumptions of traditional finance theory or neoclassical theory. Traditional finance theory was constructed on a different set of key concepts like the Expected Utility Theory and the Efficient Markets Hypothesis (Fama 1998). In the 19th Century, behavioral finance has been gradually applied to explain the violations of traditional finance theory and efficient market hypothesis (Thaler 2005), and behavioral finance explains that common investors are influenced by different behavioral factors like environment factors, biases and heuristics for making investment decisions (Kathiravan et al. 2017, 2018a, b, c). Weather conditions are considered an important environmental factor. Many previous studies accept that weather factors influenced the investor decision making (Howarth and Hoffman 1984; Krämer and Runde 1997; Kamstra, et al. 2000; Pardo and Valor 2003; Tufan and Hamarat 2004). This study also explored the relationship between the returns of stock indices in Asia (Shanghai Stock Exchange, Hang Seng Index, BSE Sensex, Nikkei 225, and Singapore Exchange Limited) and three weather factors (Humidity, Temperature and Wind Speed) in five capital cities, (Beijing of China, Tokyo of Japan, Victoria City of Hong Kong, New Delhi of India and Singapore of Singapore), using a Granger Causality Approach. It was found that among the three weather variables, temperature recorded a statistically significant influence on the returns of Shanghai Stock Exchange (Unidirectional Linkage), HANG SENG Index (Unidirectional Linkage), and also BSE Sensex (Bi-Directional Linkage). Wind speed reported a Bi-Directional Linkages with HANG SENG Index. This study concludes that the trading behaviour of investors have some statistically significant relationship with sample indices in Asian countries during the study period.

References

Ameur, H. B., Jawadi, F., Cheffou, A. I., & Louhichi, W. (2018). Measurement errors in stock markets. *Annals of Operations Research, 262,* 287. https://doi.org/10.1007/s10479-016-2138-z.

Bakar, S., & Sapuin, N. M. (2012). Are stock market returns related to the weather effects factors? Empirical evidence from Malaysia. *Terengganu International Finance and Economics Journal, 2*(2), 54–62.
Bauer, M., Glenn, T., Grof, P., Rasgon, N. L., Marsh, W., Sagduyu, K., et al. (2009). Relationship among latitude, climate, season and self-reported mood in bipolar disorder. *Journal of Affective Disorders, 116,* 152–157.
Bertrand, P., & Lapointe, V. (2018). Risk-based strategies: The social responsibility of investment universes does matter. *Annals of Operations Research, 262,* 413–429. https://doi.org/10.1007/s10479-015-2081-4.
Bower, G. H. (1981). Mood and memory. *American Psychologist, 36,* 129–148.
Box, G. E. P., & Jenkins, G. M. (1970). *Time series analysis forecasting and control*. San Francisco: Holden-Day. **(new printing (with exercises) 1976)**.
Brahmana, R. K., Hooy, C. W., & Ahmad, Z. (2014). The role of weather on investors' monday irrationality: Insights from Malaysia. *Contemporary Economics, 8*(2), 175–190. https://doi.org/10.5709/ce.1897-9254.139.
Brahmana, R., Hooy, C.-W., & Ahmad, Z. (2015). Monday irrationality of investors in Bursa Malaysia: The role of psychological biases. *Malaysian Journal of Economic Studies, 52*(2), 227–243.
Cao, G., & Han, Y. (2015). Does the weather affect the Chinese stock markets? Evidence from the analysis of DCCA cross-correlation coefficient. *International Journal of Modern Physics B, 29*(01), 1450236.
Cao, M., & Wei, J. (2005). Stock market returns: A note on temperature anomaly. *Journal of Banking & Finance, 29*(6), 1559–1573.
Chang, T., Nieh, C.-C., Yang, M. J., & Yang, T.-Y. (2006). Are stock market returns related to the weather effects? Empirical evidence from Taiwan. *Physica A, 364,* 343–354.
Cunningham, M. (1979). Weather, mood, and helping behavior: Quasi experiments with the sunshine samaritan. *Journal of Personality and Social Psychology, 37*(11), 1947–1956.
Danışoğlu, S., & Güner, Z. N. (2018). Do price limits help control stock price volatility? *Annals of Operations Research, 260,* 129. https://doi.org/10.1007/s10479-016-2317-y.
De Bondt, W. F. M., & Thaler, R. H. (1995). Financial decision-making in markets and firms: A behavioral perspective. In R. A. Jarrow et al. (Eds.), *Handbook of Finance* (vol. 9, pp. 385–410). North Holland: Elsevier.
Dickey, D., & Fuller, W. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74*(366), 427–431. https://doi.org/10.2307/2286348.
Dowling, M., & Lucey, B. M. (2008). Robust global mood influences in equity pricing. *Journal of Multinational Financial Management, 18*(2), 145–164.
Eagles, J. M. (1994). The relationship between mood and daily hours of sunlight in rapid cycling bipolar illness. *Biological Psychiatry, 36*(6), 422–424.
Fama, E. F. (1998). Market efficiency, long-term returns, and behavioral finance. *Journal of Financial Economics, 49,* 283–306.
Floros, C. (2008a). The monthly and trading month effects in Greek stock market returns: 1996–2002. *Managerial Finance, 34*(7), 453–464. https://doi.org/10.1108/03074350810874415.
Floros, C. (2008b). Stock market returns and the temperature effect: New evidence from Europe. *Applied Financial Economics Letters, 4*(6), 461–467.
Forgas, J. P., & Bower, G. H. (1987). Mood effects on person-perception judgments. *Journal of Personality and Social Psychology, 53*(1), 53–60.
Forgas, J., Goldenberg, L., & Unkelbach, C. (2009). Can bad weather improve your memory? An unobtrusive field study of natural mood effects on real-life memory. *Journal of Experimental Social Psychology, 45,* 254–257.
Hirshleifer, D., & Shumway, T. (2003). Good day sunshine: Stock returns and the weather. *Journal of Finance, 58*(3), 1009–1032.
Hollwich, F. (1979). *The influence of ocular light perception on metabolism in man and in animal*. New York: Springer.
Howarth, E., & Hoffman, M. S. (1984). A multidimensional approach to the relationship between mood and weather. *British Journal of Psychology, 75*(1), 15–23.
Huang, Z., Wei, Y. M., Wang, K., & Liao, H. (2017). Energy economics and climate policy modeling. *Annals of Operations Research, 255,* 1. https://doi.org/10.1007/s10479-017-2564-6.
Isen, A. M., Shalker, T., Clark, M., & Karp, L. (1978). Affect, accessibility of material in memory and behavior: A cognitive loop? *Journal of Personality and Social Psychology, 36,* 1–12.
Kamstra, M., Kramer, L., & Levi, M. (2000). Losing sleep at the market: The daylight-savings anomaly. *American Economic Review, 90*(4), 1005–1011.
Kang, S. H., Jiang, Z., & Yoon, S. M. (2009). Weather effects on the returns and volatility of Hong Kong and Shenzhen stock markets. Working Paper, Pusan National University.

Kathiravan, C., Raja, M., & Chinnadorai, K. M. (2018a). Stock market returns and the weather effect in Sri Lanka. *SMART Journal of Business Management Studies, 14*(2), 78–85. https://doi.org/10.5958/2321-2012.2018.00019.2.

Kathiravan, C., Selvam, M., Kannaiah, D., Lingaraja, K., & Thanikachalam, V. (2018b). On the relationship between weather and Agricultural Commodity Index in India: A study with reference to Dhaanya of NCDEX. *Quality & Quantity*. https://doi.org/10.1007/s11135-018-0782-x.

Kathiravan, C., Selvam, M., Venkateswar, S., Lingaraja, K., & Oli, S. M. (2017). Effect of temperature on stock market indices: A study on BSE and NSE in India. *International Journal of Economic Research, 14*(18), 171–181.

Kathiravan, C., Selvam, M., Venkateswar, S., Lingaraja, K., Vasani, S. A., & Kannaiah, D. (2018c). An empirical investigation of the inter-linkages of stock returns and the weather at the Indian stock exchange. *Academy of Strategic Management Journal, 17*(1), 1–14.

Keef, S., & Roush, M. (2002). The weather and stock returns in New Zealand. *Quarterly Journal of Business and Economics, 41*(1–2), 61–80.

Krämer, W., & Runde, R. (1997). Stocks and the weather: An exercise in data mining or yet another capital market anomaly? *Empirical Economics, 22*(4), 637–641.

Kürüm, E., Weber, G. W., & Iyigun, C. (2018). Early warning on stock market bubbles via methods of optimization, clustering and inverse problems. *Annals of Operations Research, 260,* 293. https://doi.org/10.1007/s10479-017-2496-1.

Lu, J., & Chou, R. K. (2012). Does the weather have impacts on returns and trading activities in order-driven stock markets? Evidence from China. *Journal of Empirical Finance, 19*(1), 79–93.

Lucey, B. M., & Dowling, M. (2005). The role of feelings in investor decision-making. *Journal of Economic Surveys, 19*(2), 211–237.

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance, 7*(1), 77–91.

Ortobelli, S., Vitali, S., Cassader, M., & Tichý, T. (2018). Portfolio selection strategy for fixed income markets with immunization on average. *Annals of Operations Research, 260*(1–2), 395–415. https://doi.org/10.1007/s10479-016-2182-8.

Pardo, A., & Valor, E. (2003). Spanish stock returns: Where is the weather effect? *European Financial Management, 9*(1), 117–126.

Rami, G. (2010). Causality between money, prices and output in India (1951–2005): A Granger causality approach. *Journal of Quantitative Economics, 8*(2), 20–41.

Salah, H. B., Chaouch, M., Gannoun, A., de Peretti, C., & Trabelsi, A. (2018). Mean and median-based nonparametric estimation of returns in mean-downside risk portfolio frontier. *Annals of Operations Research, 262,* 653. https://doi.org/10.1007/s10479-016-2235-z.

Sariannidis, N., Giannarakis, G., & Partalidou, X. (2016). The effect of weather on the European stock market: The case of Dow Jones Sustainability Europe index. *International Journal of Social Economics, 43*(9), 943–958. https://doi.org/10.1108/IJSE-04-2015-0079.

Schwarz, N., & Clore, G. (1983). Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. *Journal of Personality and Social Psychology, 45,* 513–523.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *The Journal of Finance, 19,* 425–442.

Sheikh, M. F., Shah, S. Z. A., & Mahmood, S. (2017). Weather effects on stock returns and volatility in South Asian markets. *Asia-Pacific Financial Markets, 24,* 75. https://doi.org/10.1007/s10690-017-9225-2.

Shim, H., Kim, H., Kim, J., & Ryu, D. (2015). Weather and stock market volatility: The case of a leading emerging market. *Applied Economics Letters, 22*(12), 987–992.

Shu, H. C., & Hung, M. W. (2009). Effect of wind on stock market returns: Evidence from European markets. *Applied Financial Economics, 19*(11), 893–904.

Symeonidis, L., Daskalakis, G., & Markellos, R. N. (2010). Does the weather affect stock market volatility? *Finance Research Letters, 7*(4), 214–223.

Thaler, R. H. (1999). Mental accounting matters. *Journal of Behavioral Decision making, 12*(3), 183–206.

Thaler, R. H. (2005). Advances in behavioral finance II, Russell Sage Foundation, New York, 712 pp., $45.00, ISBN: 0-691-12175-3.

Tietjen, G. H., & Kripke, D. F. (1994). Suicides in California (1968–1977): Absence of seasonality in Los Angeles and Sacramento counties. *Psychiatry Research, 53*(2), 161–172.

Tufan, E., & Hamarat, B. (2004). Do cloudy days affect stock exchange returns? Evidence from Istanbul stock exchange. *Journal of Naval Science Engineering, 2*(1), 117–126.

Vijayakumar, N., Dharani, M., & Muruganandan, S. (2015). Impact of weather on return and volatility: Evidence from indian stock market. *International Journal of Financial Management, 5*(2).

Watson, D. (2000). *"Situational and environmental influence on mood", mood and temperature, chapter 3* (pp. 62–103). New York, NY: Guilford Press.

Wright, W. F., & Bower, G. H. (1992). Mood effects on subjective probability assessment. *Organizational Behavior and Human Decision Processes, 52*(2), 276–291.
Yoon, S. M., & Kang, S. H. (2009). Weather effects on returns: Evidence from the Korean stock market. *Physica A: Statistical Mechanics and its Applications, 388*(5), 682–690.