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Relationship among Weather Effects, Investors' Moods and Stock Market Risk: An Analysis of Bull and Bear Markets in Taiwan, Japan and Hong Kong

Summary: Literature shows that weather encourages people to engage in certain behaviors and that three factors, particularly sunshine, temperature, and humidity, have the greatest psychological impact on investors (Edgar Howarth and Michael S. Hoffman 1984). On the contrary, some results indicate that the weather has insignificant effect on investors (Ben Jacobsen and Wessel Marquering 2008; Jing Lu and Robin K. Chou 2012). Hence, our research used three weather variables, namely temperature, humidity, and cloud cover, to detect the effects of extreme weather conditions on stock returns. The sample data used in this study consisted of the intraday data, with thirty minutes stock price, of Taiwan, Japan, and Hong Kong from 2012 to 2015. By taking into consideration the effects of asymmetric volatility, we employed the GJR-GARCH model to capture stock market returns. In addition, as the volatility of the stock market is affected by a number of economic factors, this study included the market situation, whether a bear or bull market type, as an additional condition to explore whether market condition renders the weather effects more significant. The results of this research support relevant literatures and can be used as a reference for investors.

Key words: GJR-GARCH, Market situation, Weather effect, Investors sentiment.

JEL: C22, G14.

In recent years, extreme climates occur more frequently due to deterioration resulting from global warming. According to the fourth report of the Intergovernmental Panel on Climate Change (IPCC), by the end of the 21st century, some parts of the globe, including Europe, Asia, and Australia, are more likely to suffer from heat waves; whereas, North America and Europe may witness heavy rain more frequently. Therefore, the dramatic changes caused by climate change are problems that necessitate urgent solutions.

The traditional finance theory assumes that all participants in the market are rational, and that profit maximization is the ultimate goal pursued by all participants, which leads to high market efficiency. However, since the 1980s, a number of empirical studies have suggested the existence of an unusual phenomenon that cannot be explained by traditional finance theory. For example, Rajnish Mehra and Edward C. Prescott (1985) found that there is a 6% gap between the rate of return of the S&P500 and risk-free interest rates. Daniel Kahneman, Jack L. Knetsch, and Richard Thaler (1986) suggested that people are concerned about the phenomena that the traditional finance theory is unable to explain, and it includes changes in nominal wages rather than actual wages and the Monday and January effects. The motivation of this study is not only influenced by the traditional financial theory but also the emotional reactions affecting the stock market behavior. Based on the above analysis, this study aims to utilize stock return volatility to investigate the influence of weather effects on various market situations to explore the dynamic relationship between stock market reaction and weather effects in various market situations in Taiwan, Japan, and Hong Kong.

1. Literature Review

Psychologists have noticed that climate change has considerable psychological effects on people, thus prompting people to behave in particular ways (Margaret A. Allen and Glora J. Fischer 1978; Tian-Yi Hu, Xiaofei Xie, and Jie Li 2013). Howarth and Hoffman (1984) tested all weather variables, and they found that sunshine, temperature, and humidity have the greatest psychological impact on humans. Norbert Schwarz and Herbert Bless (1991) reported that people in a good mood make judgments based on intuition, while a bad mood leads them to carefully scrutinize and analyze everything. Furthermore, according to William F. Wright and Gordon H. Bower (1992), people in a good mood make comparatively positive judgments.

Edward M. Saunders (1993) was the first to study the relationship between the weather in New York City and stock returns on the New York Stock Exchange (NYSE). The study concluded that there is a significant correlation between cloud cover and equity market returns; thus, it started to draw the attention of economists to the possible effect of weather changes on stock market returns. Mark J. Kamstra, Lisa A. Kramer, and Maurice D. Levi (2000) investigated the relationship between daylight saving time and the stock market, and they found that equity market returns fluctuate with daylight saving. Stephen P. Keef and Melvin L. Roush (2005) examined the correlation between variables, such as cloud cover, temperature, wind speed, and equity market returns in New Zealand. David Hirshleifer and Tyler Shumway (2003) studied the stock markets in 26 countries, and they found the influence of the presence of sunshine in 25 countries. Seong-Min Yoon and Sang Hoon Kang (2009) indicated that extremely low temperatures have positive effect on returns. In contrast, high humidity has adverse effects on returns as seen in the financial crisis in 1997. Kang et al. (2010) sampled data from the Shanghai Stock Exchange and found that extreme weather affects market volatility. Finally, Yuan-Ming Lee and Kuan-Min Wang (2011) indicated that the effects of sunshine on the Taiwanese stock market have persisted post-Asian financial crisis.

However, related studies on weather and stock market ignored the effects of market economy trends on investors' moods (Lu and Chou 2012; Yi-Hsien Wang, Chin-Tsai Lin, and Jung Dan Lin 2012; Doron Kliger and Andrey Kudryavtsev 2014;

Hyein Shim et al. 2015; Chih-Yuan Yang, Ling-Jhen Jhang, and Chia-Chien Chang 2016), which consequently affected the regression analysis results of these studies. As investment decisions are influenced by psychological factors, cannot be completely out of public information on the dependence, thus this study focuses on the dynamic relationship between stock market reaction and weather effects during various market situations. In addition, this study used high-frequency data to capture the emotional reaction of investors and to reduce the impact of foreign investors.

2. Research Methodology

The data regarding weather-indicating factors, such as temperature, humidity, and cloud cover, were obtained from Jiffy Technology (JFT 2015)[1]. The data on stock market returns were obtained from the Taiwan Economic Journal (TEJ 2015)[2]. Our study was conducted from 2011 to 2015.

2.1 Variables of Weather Effects

The daily activities of the public are affected by various environmental factors, such as the weather, which is of great importance as it may alter our daily plans and outcomes; thus, people must pay special attention to the weather. Over the course of human evolution, people have been able to adapt to weather changes to a certain degree; however, when the change in the weather becomes severe and hence beyond our physiological function of self-adjustment, we tend to become psychologically distressed and even show physical symptoms. In other words, weather changes, either directly or indirectly, cause complicated psychological and physiological reactions (Kang et al. 2010; Lu and Chou 2012; Mohammed Mraoua, Rachid Ellaia, and Abdelkhalak El Hami 2013).

Michael R. Cunningham (1979) reported that clear weather induces good moods, high temperatures in summer negatively affect people's moods, and that high temperature in winter positively affects a person's mood. Lazaros Symeonidis, George Daskalakis, and Raphael N. Markellos (2010) pointed out that cloud cover can be regarded as a natural factor affecting people's moods. Donald A. Redelmeier and Simon D. Baxter (2009) studied the factors influencing the medical college admission examinees, and they found that examinees scored 10 points higher on sunny days than on rainy days. Finally, the most recent empirical studies suggest that weather influences the attitudes of investors regarding risks (Anna Bassi, Riccardo Colacito, and Paolo Fulghieri 2013; Willam N. Goetzmann et al. 2014). This study explores the relationship between stock market returns and various weather-related factors such as temperature, humidity, and cloud cover.

As original weather data are subject to the changes of seasons and as the temperature in the summer is typically higher than that in the winter, this paper adopts the

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[1] **Jiffy Technology (JFT).** 2015. Big Data. http://www.jfetek.com/JFT/html/bigdata.html (accessed May 10, 2015).

[2] **Taiwan Economic Journal (TEJ).** 2015. Database. http://www.finasia.biz/ensite/ (accessed May 11, 2015).

first difference. This method retains information regarding weather changes and effectively eliminates the seasonal effect. The equation is as follows:

$$newW_t = W_t - W_{t-1}, \tag{1}$$

where W_t is the weather variable such as temperature and humidity.

2.2 Variables of Market Situation

As weather changes have considerable psychological impact on people, stock market trends also influence investors' decision making. Thus, this paper takes market trends into consideration. Furthermore, we believe that when a bull market is expected, investors are comparatively optimistic and their decisions regarding investments are not susceptible to weather changes; however, when a bear market is anticipated, investors are more careful in making decisions. Therefore, weather changes affect investment strategies. We employed Asger Lunde and Allan Timmermann's (2004) method to distinguish between market trends; and with this method, we were able to systematically analyze upward and/or downward market trends. The equation is as follows:

$$\tau_{max}(P_t^{max}, \mathrm{t}|Bull_t = 1) = inf\{t + \tau : P_{t+\tau} \geq P_t^{max}\}, \tag{2}$$

$$\tau_{min}(P_t^{max}, \mathrm{t}, \lambda_1|Bull_t = 1) = inf\{t + \tau : P_{t+\tau} < (1 - \lambda_1)P_t^{max}\}, \tag{3}$$

where $Bull_t$ is the dummy indicator variable of a bull market. A dummy variable of 1 indicates a bull market, whereas a dummy variable of 0 indicates a bear market. P_t refers to the stock market index at present *t* time point. λ_1 is the trigger value for the conversion of bear market into a bull market, and λ_2 is the trigger value for the conversion of bull market into bear market. If the stock market index is the relative maximum at the present "*t*" time point, then $BB_t = 1$ and $P_t^{MAX} = P_t$. At this time point, the duration of a bull market is the time it takes from τ_S to τ_{min}. If $\tau_S = \tau_{max}$, then the bull market will last for $t + \tau_{max}$, and P_t will be updated as $P_{t+\tau_{max}}^{max}$. On the contrary, if the stock market index is the relative minimum at the present *t* time point, then $BB_t = 0$, $P_t^{min} = P_t$ and the equation is as follows:

$$\tau_{min}\left(P_t^{min}, \mathrm{t}\middle|BB_t = 0\right) = inf\left\{t + \tau : P_{t+\tau} \leq P_t^{min}\right\}, \tag{4}$$

$$\tau_{max}\left(P_t^{min}, \mathrm{t}, \lambda_2\middle|BB_t = 0\right) = inf\left\{t + \tau : P_{t+\tau} > (1 + \lambda_2)P_t^{min}\right\}. \tag{5}$$

2.3 GJR-GARCH

As volatility clustering frequently occurs to financial products, and volatility varies over time, Robert F. Engle (1982) proposed the autoregressive heteroscedastic (ARCH) model, which assumes that the variance of the current error term is the function of the actual size of the previous time periods error terms. It therefore allows the error term to vary over time. Tim Bollerslev (1986) extended the ARCH model by including the influence of the conditional variance itself and proposed the generalized autoregressive conditional heteroscedasticity (GARCH) model, which endows the ARCH model with more flexibility and explanatory power (Chung-Chu Chuang et al. 2014). Although the GARCH model is able to catch volatility clustering, it fails to seize the asymmetric effect of the market in reflecting good and bad news. Engle and Victor K. Ng (1993) found that price volatility in the capital market is asymmetric, and generally, there is larger volatility when the market indicates a minus yield rather than a positive yield. Antonios Antoniou, Phil Holmes, and Richard Priestley (1998) pointed out that the asymmetric effect of the market, in terms of reflecting good and bad news, causes a deviation of the results estimated by the GARCH model. Furthermore, Grant McQueen and Keith Vorkink (2004) noted that when faced with bad news, investors tend to experience risk aversion and become more sensitive, hence greater volatility can be expected. In addition, Engle and Ng (1993) compared EGARCH with GJR-GARCH and found that estimations in light of GJR-GARCH are more accurate when volatility is asymmetric (Engle and Magdalena E. Sokalska 2012; Han-Ching Huang, Yong-Chern Su, and Jen-Tien Tsui 2015). This paper employed the GJR-GARCH model, as proposed by Lawrence R. Glosten, Ravi Jagannathan, and David E. Runkle (1993), to capture the said asymmetric effect.

2.4 Considering the Variables of Weather Effects

The explanatory variables are embedded in GJR-GARCH model to detect the weather effects as follows:

$$R_t = \alpha_0 + a_1 R_{t-1} + a_2 R_{t-2} + \alpha_1 Temp_t + \alpha_2 Hum_t + \alpha_3 Cloud_t + \varepsilon_t, \tag{6}$$

$$h_t = \beta_0 + b_1 h_{t-1} + \beta_1 Temp_t + \beta_2 Hum_t + \beta_3 Cloud_t + b_2 \varepsilon_{t-1}^2 + b_3 S_{t-1} \varepsilon_{t-1}^2, \tag{7}$$

where:

$$S_{t-1} = \begin{cases} 1, & \text{if } \varepsilon_{t-1} < 0 \\ 0, & \text{if } \varepsilon_{t-1} \geq 0 \end{cases}.$$

S_{t-1} is the dummy variable of the asymmetric effect of volatilities. If $\varepsilon_{t-1} < 0$, it indicates that previous bad news led to a rise in the present variation value and that the leverage effect exists. R_{t-1} and R_{t-2} are autocorrelated periods of the stock market. $Temp_t$ refers to the variable of temperature variation. Hum_t is the variable of humidity variation. $Cloud_t$ is the dummy variable of cloud cover.

2.5 Considering the Variables of Market Situation

Finally, stock market situation is further classified as bull market and bear market. The study also introduce dummy variables in GJR-GARCH (1,1) model to test the interaction between weather effects and stock market situation:

$$\begin{gathered} R_t = \pi_0 + \emptyset_1 R_{t-1} + \emptyset_2 R_{t-2} + \pi_1 Temp_t \times Bull_t + \pi_2 Hum_t \times Bull_t \\ + \pi_3 Cloud_t \times Bull_t + \varepsilon_t, \end{gathered} \tag{8}$$

$$\begin{gathered} h_t = \delta_0 + \delta_1 Temp_t \times Bull_t + \delta_2 Hum_t \times Bull_t + \delta_3 Cloud_t \times Bull_t \\ + \vartheta_1 h_{t-1} + \vartheta_4 \varepsilon_{t-1}^2 + \vartheta_5 S_{t-1} \varepsilon_{t-1}^2, \end{gathered} \tag{9}$$

$$\begin{gathered} R_t = \gamma_0 + \omega_1 R_{t-1} + \omega_2 R_{t-2} + \gamma_1 Temp_t \times Bear_t + \gamma_2 Hum_t \times Bear_t \\ + \gamma_3 Cloud_t \times Bear_t + \varepsilon_t, \end{gathered} \tag{10}$$

$$\begin{gathered} h_t = \varphi_0 + \varphi_1 Temp_t \times Bear_t + \varphi_2 Hum_t \times Bear_t + \varphi_3 Cloud_t \times Bear_t \\ + \theta_1 h_{t-1} + \theta_2 \varepsilon_{t-1}^2 + \theta_3 S_{t-1} \varepsilon_{t-1}^2, \end{gathered} \tag{11}$$

where $Bull_t$ is the dummy variable of the bull market. A $Bull_t$ of 1 indicates a growth in the stock market, and a $Bull_t$ of 0 demonstrates a decline in the market. In the bear market, $Bear_t$ denotes the dummy variable of the bear market. A $Bear_t$ of 1 indicates a fall in the stock market, whereas a $Bear_t$ of 0 indicates a growth in the stock market. The lag length of conditional mean returns of GARCH(1,1) model was determined by the minimum value of Akaike Information Criterion and Schwarz Bayesian Criterion. The parameters of the mean and time-varying conditional variance-covariance were estimated recursively by the maximum likelihood estimation and Berndt-Hall-Hall-Hausman (BHHH) algorithm (Ernst R. Berndt et al. 1974), which was applied to maximize the likelihood estimates.

3. Empirical Results

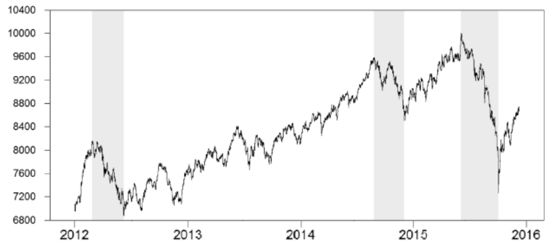
3.1 Descriptive Statistics

Table 1 shows the narrative statistics during the sample period. The trend of Taiwan, Hong Kong and Japan stock market and stock market situation are shown in Figures 1, 2 and 3. In the bear market, the average stock market return was apparently lower as compared to that of the bull market; furthermore, the standard deviation was higher in the bull market. This proves that volatilities are comparatively drastic when the value of stock index is low.

Table 1 Descriptive Statistics

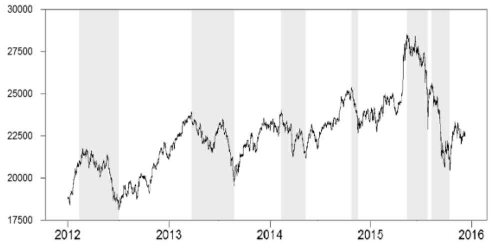
	Taiwan		Hong Kong		Japan	
	Mean	**Std**	**Mean**	**Std**	**Mean**	**Std**
	Panel A: Without considering the market situation					
Stock returns	0.2258E-5	0.2620	0.1781E-5	0.3103	0.1015E-4	0.4264
Temp	74.7776	9.9824	76.5882	9.5626	65.9583	14.5352
Hum	65.2732	9.5484	67.3048	10.2884	72.3643	15.5266
Cloud	2.0344	0.1912	1.9586	0.2112	2.0682	0.3932
	Panel B: Bull market					
Stock returns	0.1939E-4	0.3103	0.3084E-4	0.4264	0.1130E-4	0.2620
Temp	72.1082	9.8623	77.1010	9.2864	61.7624	13.4636
Hum	62.9568	9.7113	67.3033	10.1191	71.9477	16.8244
Cloud	2.0410	0.2046	1.9562	0.2227	2.0898	0.4422
	Panel C: Bear market					
Stock returns	-0.2656E-4	0.2866	-0.5148E-4	0.3431	-0.2649E-4	0.3194
Temp	78.5613	9.5494	75.7629	9.9369	70.8459	14.2041
Hum	68.7776	8.9458	67.3073	10.5564	70.7848	15.6676
Cloud	2.0146	0.1361	1.9625	0.1912	2.0064	0.3363

Source: Authors' calculation.



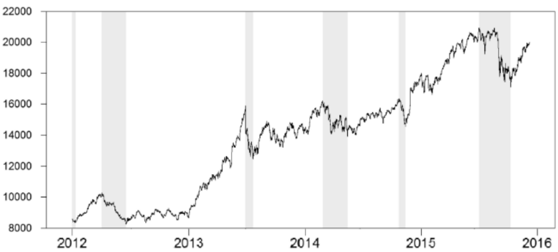
Source: Authors' own elaboration.

Figure 1 Taiwan Stock Market Situation



Source: Authors' own elaboration.

Figure 2 Hong Kong Stock Market Situation



Source: Authors' own elaboration.

Figure 3 Japan Stock Market Situation

3.2 Test of ARCH Effect and Asymmetric Volatilities

In Table 2, we employed Engle's (1982) Lagrange Multiplier (LM) to verify the autocorrelation of the error term and to calculate the chi-square distribution of measured variable TR^2 under a null hypothesis that is free of the ARCH effect. T refers to the number of samples, and R^2 refers to the coefficient of determination. The results of measured variable TR^2 are 237.838, 366.544, and 443.731, with three degrees of freedom at a significance level of 1% and were higher than the chi-square distribution. However, there was no sufficient evidence to support the ARCH effect. Therefore, the volatilities of share price had conditional heterogeneous variance that varies with time.

Table 2 Test of ARCH Effect

LM_Taiwan	237.838 ***
LM_Hong Kong	366.544 ***
LM_Japan	443.731 ***

Notes: *** significance at the 1% level.

Source: Authors' estimation.

Table 3 shows that the joint chi-square test (JT) values are 406.3615, 361.8244, and 204.4339, which indicate an evident effect at a 1% significance level and negative expected returns. Different degrees of positive and negative expected returns have joint impact on volatilities. Furthermore, the table also shows the volatilities of stock market, which is heterogeneous and asymmetric. Hence, we employed GJR-GARCH to capture the asymmetric effect of volatilities.

Table 3 Test of Asymmetric Volatilities

	SBT^2	$NSBT^2$	$PSBT^2$	JT^2
Taiwan	-0.0022 (0.0116)	-0.0526* (0.0298)	-0.0202 (0.0330)	204.4339***
Hong Kong	-0.0072 (0.0126)	-0.1182*** (0.0274)	0.1099*** (0.0300)	361.8244***
Japan	0.0025 (0.0218)	-0.1345*** (0.0362)	0.0358 (0.0360)	406.3615***

Notes: *** significance at the 1% level, * significance at the 10% level. SBT - sign best test; PSBT - positive size bias test; NBST - negative size bias test; JT - joint test.

Source: Authors' estimation.

3.3 Results

For model diagnosing (Tables 4-6), we used the Ljung-Box statistics to test the standardized residual and square processes. The results of model diagnosing demonstrate that there was no correlation or conditional heteroscedasticity in the standardized residuals of the empirical model. Thus, we report that the above GJR-GARCH models are satisfactory.

Table 4 summarizes the GJR-GARCH estimates of the stock markets in Taiwan, Hong Kong, and Japan according to the weather factors during the complete sampling period. Based on Table 4, there is no significant correlation between stock market returns and weather factors, such as temperature ($Temp_t$), humidity (Hum_t), and cloud cover ($Cloud_t$), during the entire sampling period - with the exception of the negative correlation between the stock market returns in Japan and cloud cover ($Cloud_t$). We believe that the lack of significant correlation between stock market returns and weather factors may be attributed to the impact of market moods on stock market returns. John R. Nofsinger (2005) noted that social moods affect the investment decisions of consumers, investors, and companies. High and low social moods magnify optimistic and pessimistic sentiments, respectively; and both contribute to decision bias and affect investment and business activities. Meanwhile, we found a significant relationship between weather factors and the volatilities of stock market returns. Temperature ($Temp_t$) and humidity (Hum_t) were positively related to volatilities of stock returns but were negatively related to cloud cover ($Cloud_t$). Alternatively, high temperature or high humidity increased market volatilities. The results indicate that high temperature, high humidity, and cloudy weather conditions made investors feel irritable, thereby affecting the trading behavior and enhancing stock market volatilities. Moreover, based on previous studies, the volatilities of stock market returns changes with the weather (Lu and Chou 2012; Shim et al. 2015).

Table 5 shows the GJR-GARCH estimates of the stock markets in Taiwan, Hong Kong, and Japan and the weather factors during the bull market period. These numbers suggest no significant correlation between weather factors and stock markets returns of Taiwan, Hong Kong, or Japan in the bull market. We believe that individual investors attribute excess returns from the continuous strength of the stock market and from their own capabilities. The bull market sentiment fuels optimism and overconfidence; weather factors have little bearing on sentiments, thus explaining the lack of significant correlation between weather factors and stock market returns in bull weather.

The significant correlation between weather factors and the stock market volatilities of Taiwan was observed in the bull market. It is worth noting that the influence of humidity (Hum_t) and cloud cover ($Cloud_t$) on market volatilities is different during the complete sampling period and during the bull market period. Hence, this paper presumes that different investor moods amid different market sentiments result in different response to weather changes. Investors have a pessimistic mood in the optimistic market that is associated with amendments to the stock market volatilities.

Table 6 presents the GJR-GARCH estimates on weather factors and stock market returns in Taiwan, Hong Kong, and Japan during the bear market period. The results indicate a significant relationship between weather factors and market returns in Hong Kong and Japan. This implies that investor moods shift along with weather changes when the market is weak. As a result, investors modify their investment decisions, which lead to changes in stock market returns. Our results, which are in line with previous studies, indicate that there is a negative relationship between cloud cover ($Cloud_t$) and market returns in Taiwan and Japan. As investors feel happy in good weather, such optimism leads to stock buying and price rally (Wright and Bower 1992; Symeonidis, Daskalakis, and Markellos 2010). There is positive correlation between humidity (Hum_t) and stock market returns in Hong Kong and Japan. This suggests high stock returns are more likely when humidity is high, which is in line with the study by Yoon and Kang (2009), wherein they stated that the higher the humidity is, the lower the stock returns would be. Our study contributes to the positive relationship between humidity and stock market returns in the bear market due to the prevalence of pessimism among investors. Melanie Cao and Jason Wei (2005) found that people tend to respond aggressively in low temperatures. A higher risk appetite leads to higher returns in the stock market. The empirical findings of this paper suggest a negative effect of temperature ($Temp_t$) on stock market returns in Japan during the bear market period.

Moreover, a comparison of results in Tables 4 and 5 illustrates the inconsistent influence of weather factors on the volatilities of stock market returns in Taiwan during the bull and bear market periods. While there is a significant inverse relationship between temperature ($Temp_t$) and market volatilities, a positive relationship exists between humidity (Hum_t) and market volatilities in the bull market. However, in the bear market, the relationship between temperature ($Temp_t$) and market volatilities significantly positive, whereas the relationship between humidity (Hum_t) and market volatilities mainly negative. The inconsistency in the results suggests that market sentiments affect investor moods and therefore their response to weather factors. Thus, we believe that different investor moods in a trending market explain the contrasting correlations between market volatilities and weather factors.

Finally, the effects of weather can be observed in stock markets. However, investor moods and responses are subject to the influence of factors other than weather, thus market sentiments and trends affect investor behaviour as well. The empirical results in this paper indicate inconsistent correlations between market returns and weather factors in different markets, as emotional responses differ due to market sentiments or simply in different markets. However, the correlations between market volatilities, as a reflection of investor moods, and weather factors were consistent in different markets.

Table 4 Weather Effects of Taiwan, Hong Kong and Japan Stock Market

Parameter	Taiwan		Hong Kong		Japan	
	Returns	Volatilities	Returns	Volatilities	Returns	Volatilities
C	-2.06E-01 (1.16E+00)	2.64E-05*** (2.36E-06)	1.06E-01 (1.82E+00)	3.28E-05*** (2.13E-06)	1.35E-01*** (4.14E-02)	1.04E-08*** (2.86E-10)
$Temp_t$	-1.33E-02 (5.02E-02)	5.78E-07*** (1.19E-07)	1.61E-02 (5.66E-02)	4.50E-07*** (1.56E-07)	4.17E-04 (1.00E-03)	-2.77E-11 (3.59E-11)
Hum_t	1.41E-02 (6.34E-02)	2.92E-07*** (1.21E-07)	5.26E-03 (4.24E-02)	-1.68E-07 (1.39E-07)	5.94E-04 (3.71E-04)	8.10E-13 (1.12E-11)
$Cloud_t$	4.13E-02 (5.48E-01)	-5.67E-06*** (1.08E-06)	7.42E-02 (7.30E-01)	-9.94E-06*** (1.04E-06)	-1.45E-01*** (1.23E-02)	-2.45E-09*** (8.30E-11)
R_{t-1}	1.93E-01 (4.18E-01)		7.48E-03 (9.13E-01)		2.21E-02 (1.02E-02)	
R_{t-2}	-8.92E-02 (4.40E-01)		1.66E-02 (5.56E-01)		2.30E-03 (1.03E-02)	
Model diagnosis						
$Q(6)$	3.6529		7.9983		1.8747	
$Q^2(6)$	0.8650		6.6089		2.1773	

Notes: *** significance at the 1% level, ** significance at the 5% level. All coefficients are multiplied by ten thousand. $Q(6)$ and $Q^2(6)$ are the Ljung-Box Q statistic for the returns and the squared returns lagged 6 trading days and its critical value at 5% significant level is 12.5916.

Source: Authors' estimation.

Table 5 Weather Effects of Taiwan, Hong Kong and Japan Stock Market with Bull Market

Parameter	Taiwan		Hong Kong		Japan	
	Returns	Volatilities	Returns	Volatilities	Returns	Volatilities
C	8.44E-02 (7.63E+01)	5.16E-05 (2.88E-05)	-2.83E-01 (2.17E+01)	8.07E-07** (3.54E-07)	-1.91E+01 (2.82E+02)	5.45E-04 (2.68E-04)
$Temp_t \times Bull_t$	-1.58E-03 (2.43E+00)	7.86E-06*** (2.10E-07)	-4.20E-03 (4.39E-01)	9.21E-08*** (2.50E-08)	-4.94E-02 (3.13E+00)	1.15E-04*** (8.55E-06)
$Hum_t \times Bull_t$	2.06E-03 (2.34E+00)	-2.62E-06*** (2.56E-07)	-2.92E-02 (3.91E-01)	-6.48E-08*** (2.25E-08)	8.24E-04 (8.59E-01)	-1.26E-05*** (4.54E-06)
$Cloud_t \times Bull_{t_t}$	-5.42E-02 (3.62E+01)	2.37E-05 (1.41E-05)	1.07E-01 (9.73E+00)	4.95E-07*** (1.75E-07)	1.50E+00 (2.96E+01)	5.49E-04*** (1.15E-04)
R_{t-1}	2.56E-02 (8.88E+00)		3.11E-02 (9.29E+00)		-9.14E-01 (2.08E+01)	
R_{t-2}	-6.00E-02 (2.44E+01)		1.12E-01 (6.17E+00)		-3.88E+00 (5.93E+01)	
Model diagnosis						
$Q(6)$	4.5694		8.9280		1.2908	
$Q^2(6)$	3.8786		4.2553		0.4169	

Notes: *** significance at the 1% level, ** significance at the 5% level. All coefficients are multiplied by ten thousand. $Q(6)$ and $Q^2(6)$ are the Ljung-Box Q statistic for the returns and the squared returns lagged 6 trading days and its critical value at 5% significant level is 12.5916.

Source: Authors' estimation.

Table 6 Weather Effects of Taiwan, Hong Kong and Japan Stock Market with Bear Market

Parameter	Taiwan		Hong Kong		Japan	
	Returns	Volatilities	Returns	Volatilities	Returns	Volatilities
C	5.86E+00*** (2.13E+00)	-3.19E-06 (2.28E-06)	-5.99E-01*** (6.93E-02)	-1.77E-10 (1.54E-10)	-7.24E-01*** (9.32E-02)	-7.92E-10*** (1.78E-10)
$Temp_t \times Bear_t$	6.09E-03 (9.44E-02)	-1.19E-07*** (2.83E-08)	9.86E-03 (4.35E-03)	2.74E-11 (1.78E-11)	-2.25E-02*** (2.83E-03)	-1.25E-13 (2.14E-11)
$Hum_t \times Bear_t$	-2.64E-02 (1.14E-01)	1.64E-07*** (4.29E-08)	8.32E-03** (3.15E-03)	-1.46E-11 (1.51E-11)	1.62E-02*** (2.32E-03)	-3.49E-13 (7.22E-12)
$Cloud_t \times Bear_t$	-3.38E+00*** (1.25E+00)	2.88E-06*** (1.14E-06)	1.22E-01*** (3.51E-02)	3.09E-10*** (7.77E-11)	-8.28E-02 (4.42E-02)	7.84E-10*** (1.04E-10)
R_{t-1}	3.15E-01 (6.17E-01)		-5.21E-03 (2.61E-02)		6.17E-02 (3.50E-02)	
R_{t-2}	-1.67E-02 (6.05E-01)		-8.90E-02*** (2.25E-02)		1.07E-01** (5.43E-02)	
Model diagnosis						
$Q(6)$	2.9644		5.6066		0.6774	
$Q^2(6)$	3.3470		7.0524		2.7275	

Notes: *** significance at the 1% level, ** significance at the 5% level. All coefficients are multiplied by ten thousand. $Q(6)$ and $Q^2(6)$ are the Ljung-Box Q statistic for the returns and the squared returns lagged 6 trading days and its critical value at 5% significant level is 12.5916.

Source: Authors' estimation.

4. Conclusion

This study aims to determine whether the stock market is affected by the weather. Thus, we selected three weather variables, namely temperature, humidity, and cloud cover, to test the influence of weather changes on returns and volatilities of the stock market. Moreover, this study also examined the market trends under weather effects. The empirical results of our study show that the effect of the weather on the stock market is insignificant and cannot be distinguished between market trends; however, the weather still has influence on the volatilities of the stock market. The possible reasons for this may be that the stock market reflects a large amount of information, and a variation from good news to bad news is unsystematic if the market trend is not distinguished. From the perspective of the volatilities of returns in the stock market, the weather does not affect investors' moods, and thus, only indirectly affects the volatilities of the stock market. As a result, our study separated market trends to explore the effects of weather on the stock market returns; and we found that in a bear market, weather variables have significant effect on market returns. This proves that investors are relatively pessimistic in a bear market and that stock market returns change along with the weather. Finally, we found that weather factors have a stronger impact on stock market returns in a bear market than in a bull market, and this can be attributed to different investor moods amid different market sentiments.

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