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Effects of weather on stock market returns

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Abstract

This study investigates the weather effects on returns of the Hong Kong Exchange and the Shenzhen Exchange. In doing it so, this study considers extreme weather condition dummies generated by using the 11-day moving average and its standard deviation. Empirical analysis provides two key results regarding weather effects. First, the Hong Kong stock market is insensitive to weather effects on the returns, whereas there's a significant weather effect on the returns of Shenzhen index. This result implies that the Shenzhen stock market is less efficient than its counterpart. Second, accounting for the QFII plan, the returns of Shenzhen A-share in the pre-opening period which traded only by domestic investors show the strong weather effect, but there is no weather effect in the post opening period. This evidence indicates that the Shenzhen A-share stock market is becoming efficient after QFII plan due to the increase in foreign institutional investors.

Keywords: *MA-MSD method, Investment sentiment, Financial market openness, QFII plan, Efficient market hypothesis*

1. Introduction

It is well known that weather effect is interpreted as one of market anomalies, closely related to investors' mood and sentiment. For example, weather conditions affect an individual's emotional state or mood, which obstructs people from making rational or optimal decisions. If the existence of weather effects affects investors' decision making, various weather conditions might influence on the movement of stock returns.

In light of the efficient market hypothesis (EMH) that share prices are justified by firms' fundamental values, there is no weather effect on their returns. However, behavioral finance theory has argued that, to some extent, stock market anomalies can be the result of relevant

weather factors.[1] As a result, the existence of a weather effect has raised some questions as to the validity of the EMH.

As far as behavioral finance concerned, the Chinese stock markets provide a unique source for examining weather effects. There are two typical stock indexes: one is domestic board (A-share) and the other is a foreign board (B-share). Most of the ownership of A-share is restricted to foreign investors,[2] while that of B-share was restricted to residents of domestic investors. However, starting from 9th July, 2003, foreign investors were allowed to trade A-shares. The investment decisions of domestic investors might be affected by Chinese local weather factors, so the weather effect might exist in the stock market. Thus, this distinctive market structure allows us to test the existence of weather effect on stock returns before or after the market openness.

To date, the market openness and globalization increase the proportion of foreign investors in local stock markets, which can lead to weaken weather effects in markets. With the development of electronic-trading system and communication technology, arbitrageurs can make international portfolio strategies using program trading. This development can also lead to weaken weather effects and make stock market efficient.

This paper primarily examines the weather effect using three indexes of Hong Kong and Shenzhen Exchanges; Hang Seng Index (HSI), Shenzhen Composite (SSZ) and Shenzhen A-share (SSZA). In doing it so, we consider daily index returns over the period of 1999-2008 using four weather proxies; temperature, humidity, cloud cover and sunshine duration. We also consider whether the addition of foreign investors in the Shenzhen A-share market reduces the extent of weather effect following 9th July, 2003. In order to analyze the openness of A-share market to foreign investors, we divide the A-share index series into two groups of sub-period and compare the impact of weather effect between the two periods.

The rest of this paper is organized as follows. Section 2 discusses prior research regarding the weather effect on stock markets. Section 3 provides the statistical characteristics of the stock returns and weather data. Section 4 discusses the extreme weather dummy variables and methodology using the 11-day moving average and its standard deviation. Section 5 examines the relationship between weather and stock returns, and compares the results for the two sub-periods. Final section summarizes the most relevant conclusions.

2. Literature reviews

Psychologists have long interested in the influence of sunshine on individual's behavior (Bell and Baron, 1976; Allen and Fischer, 1978; Cunningham, 1979; Howarth and Hoffman, 1984). They asserted that the degree of sunshine influences an individual's mood or sentiment, which can create the predisposition to engage in particular behaviors; i.e., the mild sunshine positively

[1] For example, Saunders (1993), Hirshleifer (2003), Kamstra, Kramer and Levi (2000, 2003), Garrett, Kamstra and Kramer (2005), Keef and Roush (2002, 2005, 2007), Dowling and Lucey (2005, 2008), Cao and Wei (2005), Chang et al. (2006), Yoon and Kang (2009).

[2] From July, 2003 foreign investors have begun to trade A-shares restrictively as QFII (Qualified Foreign Institutional Investor) plan.

attributes to consumer's behaviors and encourages people to give an interview (Cunningham, 1979).

With regard to this perspective, weather conditions can affect an individual's emotional state or mood, which holds back people from making rational or optimal decisions. If so, the weather effect can have strong influence on the stock market investors' decisions.

Regarding this perspective, research into the weather effect has focused on the influence of cloud cover (or lack of sunshine) on stock returns. Saunders (1993) and Hirshleifer and Shumway (2003) reported that cloud cover was negatively correlated with the daily stock returns. Some recent studies have considered multiple weather conditions. Keef and Roush (2002, 2005) examined the weather effect on the returns of New Zealand financial securities using three local weather factors: cloud cover, temperature and wind. Dowling and Lucey (2005, 2008) also investigated the weather effect on stock returns using multiple weather proxy variables. Keef and Roush (2007) and Cao and Wei (2005) and found a negative correlation between temperature and returns in the Australian stock market. Chang et al. (2006) reported that temperature and cloud cover had a negative effect on returns in the Taiwan stock market. Yoon and Kang (2009) investigated the influence of weather effect on the Korean stock returns using temperature, humidity and cloud cover.

Several empirical studies have done on the weather effect in the Chinese market. Yi and Wang (2005) evidenced the weather effect (humidity and wind) in the Shanghai composite stock index. Han (2005, 2006) and Han and Wang (2005) found the significant impact of weather in the Shanghai and Shenzhen stock markets. Kang et al. (2010) considered the influence of opening of Shanghai B-share market to domestic investors and compared the weather effect between the pre-opening and post-opening periods. They found the post opening period only shows the strong weather effect on B-share returns, indicating that the increase in the proposition of domestic investors can result in the weather effect. The above findings can be interpreted as casting doubt on the validity of the EMH in the Chinese stock market.

3. Data and descriptive statistics

The sample data used in this study comprise the three daily stock indexes of the Hong Kong Exchange (Hang Seng Index (HSI); and the Shenzhen Exchange (SSE Composite Index (SZZ); SSE A-Share Index (SZZA)) from January 1999 to December 2008.3 The Shenzhen stock market had been segmented with domestic investors trading A-share and foreign investors trading B-share. Since 9th July 2003, A-share market has been available to foreign investors. In order to analyze the openness of A-share market to foreign investors, we divide two sub-samples as a cut off date of 9th July 2003.

Daily returns are calculated as $r_t = \ln(P_t / P_{t-1}) \times 100$ for $t = 1, 2, \cdots, T$, where P_t is the current index and P_{t-1} is the previous day's index. Fig. 1 shows the fluctuations of daily nominal percentage return series for both HSI and SSZ. Both return series display volatility clustering as shown in Fig. 1. The dynamics of SSZ is more volatile over the time than that of HSI, indicating that the Shenzhen Exchange is less stable than the Hong Kong Exchange.

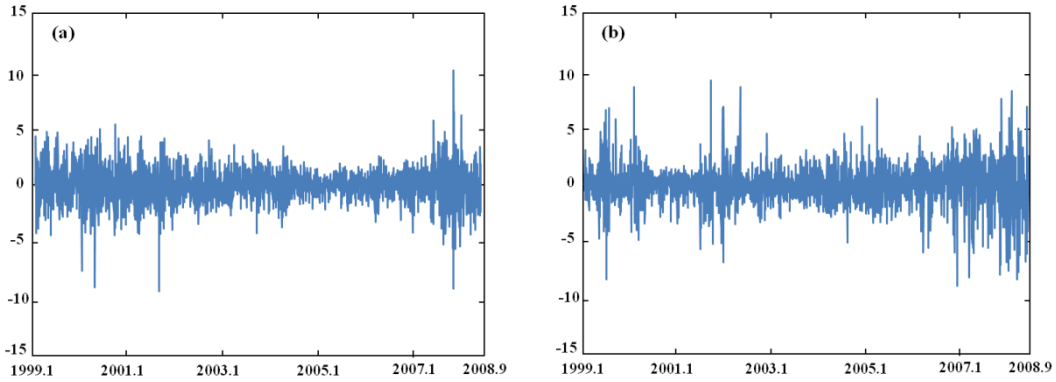

Fig. 1. Dynamics of daily returns: (a) HSI; (b) SZZ

We explored the daily weather data for temperature (TEMP), humidity (HUMI), cloud cover (CLOUD) and sunshine duration (SUNSH) in the city of Hong Kong from January 1999 to December 2008, obtained from the Hong Kong Observatory (http://www.weather.gov.hk/). The temperature variable is measured in degree Celsius. The humidity variable is the percentage relative humidity. The cloud cover variable is the percentage. The sunshine duration variable represents the hour of sunshine duration.

Tables 1-2 summarize the descriptive statistics for the stock returns and weather variables, respectively. In Table 1, the distribution of all sample returns shows non-normality, as indicated by the skewness, kurtosis, and the Jarque-Bera test. In Table 2, the descriptive statistics of weather variables show an identical weather condition because both Hong Kong and Shenzhen Exchanges are geographically closed each other. The distribution of all weather variables is not normally distributed due to the significance of the value of Jarque-Bera (J-B) test statistic.

[3] All sample data are obtained from the RESSET Financial Research Database.

Table 1

Descriptive statistics

Variables	Obs.	Mean	Max.	Min.	Std. Dev.	Skew.	Kurt.	Jarque-Bera
HSI	2382	0.03	10.18	-9.29	1.48	-0.20	6.85	1487.1***
SZZ	2316	0.03	9.24	-8.93	1.77	-0.25	6.83	1436.2***
SZZA	2316	0.03	9.24	-8.93	1.77	-0.25	6.83	1438.3***

Note: *** indicates a rejection of the null hypothesis at the 1% significance level.

Table 2

Weather variables

Variables	Obs.	Mean	Max.	Min.	Std. Dev.	Skew.	Kurt.	Jarque-Bera
Panel A: Hong Kong								
TEMP	2382	23.6	31.8	8.2	5.00	-0.57	2.33	172.9***
HUMI	2382	78.1	98.0	27.0	10.06	-1.05	5.18	908.6***
CLOUD	2382	67.7	100.0	0.0	24.86	-0.95	2.90	359.8***
SUNSH	2382	5.2	12.4	0.0	3.91	0.00	1.53	214.7***
Panel B: Shenzhen								
TEMP	2317	23.7	31.8	8.2	4.92	-0.58	2.36	168.2***
HUMI	2317	78.2	98.0	27.0	10.02	-1.08	5.30	962.8***
CLOUD	2317	67.9	100.0	0.0	24.80	-0.96	2.94	356.0***
SUNSH	2317	5.2	12.4	0.0	3.91	-0.01	1.53	209.2***

Note: *** indicates a rejection of the null hypothesis at the 1% significance level.

4. Methodology

4.1. Weather variables

To examine the weather effect on the returns, the four weather variables are converted to dummy variables because they contain a seasonal factor. For example, the 15°C is a warm temperature in the winter, whereas this is relatively considered as a cold temperature in the summer. It seems that using raw weather data generates biases to measure weather effect on the stock market. In this reason, we recalculate weather variables following the study of Yoon and Kang (2009) which use moving average (MA) and moving standard deviation (MSD) approaches. In particular, the technique of 11-day MA and MSD is used as follows:

$$MA(W_t) = \frac{1}{11}(W_{t-5} + \mathrm{L} + W_t + \mathrm{L} + W_{t+5}), \quad (1)$$

$$MSD(W_t) = \sqrt{\frac{1}{10}\sum_{i=-5}^{5}\left(W_{t+i} - MA(W_t)\right)^2}, \quad (2)$$

where W_t is the daily value of four weather variables (TEMP, HUMI, CLOUD and SUNSH) at time t. Assuming that extreme weather conditions might lead to more significant effects on stock returns than normal weather conditions, we generated two dummy variables for each weather factor, depending on extreme above-average and extreme below-average weather conditions, as follows:

If $W_t < \left[MA(W_t) - MSD(W_t)\right]$, then $WLD_t = 1$; otherwise, $WLD_t = 0$. And

if $W_t > \left[MA(W_t) + MSD(W_t)\right]$, then $WHD_t = 1$; otherwise, $WHD_t = 0$. (3)

Table 3

Descriptions of weather dummies

Weather dummies	Descriptions
tmL	Extremely low temperature
tmH	Extremely high temperature
hmL	Extremely low humidity
hmH	Extremely high humidity
cloL	Extremely low cloud
cloH	Extremely high cloud
snL	Extremely low sunshine duration
snH	Extremely high sunshine duration

In the above equation, WLD_t is a dummy variable for extreme below-average weather, whereas WHD_t is a dummy variable for extreme above-average weather. The various weather dummies used in this study are summarized in Table 3.

4.2. Model framework

Using the above weather dummy variables, we define the model to analyze the weather effect on the returns. We first adopt two linear regression models as follows:

Model 1:

$$R_t = \mu + \theta\ JAN + \psi\ MON + \gamma_1 tmL + \gamma_2 tmH + \gamma_3 hmL + \gamma_4 hmH + \gamma_5 cloL + \gamma_6 cloH + \gamma_7 snL + \gamma_8 snH + \varepsilon_t . \quad (4)$$

Model 2:

$$\begin{aligned} R_t = {} & \mu + \theta\ JAN + \psi\ MON \\ & + \gamma_1 tmL + \gamma_2 tmH + \gamma_3 hmL + \gamma_4 hmH \\ & + \gamma_5 cloL + \gamma_6 cloH + \gamma_7 sunL + \gamma_8 sunH \\ & + \lambda_1\, tmL * hmL + \lambda_2\, tmL * hmH + \lambda_3\, tmL * snL + \lambda_4\, tmL * snH + \lambda_5\, tmL * cloL \\ & + \lambda_6\, tmL * cloH + \lambda_7\, tmH * hmL + \lambda_8\, tmH * hmH + \lambda_9\, tmH * snL + \lambda_{10}\, tmH * snH \\ & + \lambda_{11}\, tmH * cloL + \lambda_{12}\, tmH * cloH \\ & + \lambda_{13}\, hmL * snL + \lambda_{14}\, hmL * snH + \lambda_{15}\, hmL * cloL + \lambda_{16}\, hmL * cloH \\ & + \lambda_{17}\, hmH * cloL + \lambda_{18}\, hm H * cloH + \lambda_{19}\, hm H * snL + \lambda_{20}\, hm H * snH \\ & + \lambda_{21}\, cloH * snH + \lambda_{22}\, cloH * snL + \lambda_{23}\, cloL * snH + \lambda_{24}\, cloL * snL + \varepsilon_t , \end{aligned} \quad (5)$$

where R_t is the daily returns of the Hong Kong and Shenzhen Exchange at time t; *JAN* and *Mon* represent the dummies of January effect and Monday effect, respectively; γ_i is coefficients for weather dummies; λ_i represents the interact effect of four weather dummies.

In the next step, we consider the nonlinear problem in the sample regression using a simple GARCH (1,1) model:

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}, \quad \varepsilon_t = z_t \sigma_t, \quad z_t \sim N(0,1), \quad (6)$$

where stochastic error ε_t is normally distributed; h_t is conditional variance; all parameters (ω, α and β) must be positive; the sum of $\alpha + \beta < 1$ quantifies the persistence of shocks to volatility.

5. Empirical results

5.1. Weather effect in Hong Kong and Shenzhen stock markets

Table 4 displays the simple weather effect on the returns of HSI and SZZ using simple regression (Equation (4)) and the GARCH (1,1) model (Equation (6)), while Table 5 reports the interaction of weather condition on the returns of HSI and SZZ using simple regression (Equation (5)) and the GARCH (1,1) model (Equation (6)). Both tables show the values of parameters (ω, α and β) in the GARCH model are positive and the sum of $\alpha+\beta<1$, which satisfy the non-negativity constraint and stationarity in conditional variances, respectively. Additionally, the returns of SZZ show the calendar effect of January (Jan), indicating that there exists a market anomaly in the Shenzhen Exchange.

Table 4

Weather effect on the returns using model 1

	HIS		SZZ	
	Coef.	t-value	Coef.	t-value
μ	0.048	1.45	0.038	0.99
Jan	0.022	0.19	0.479	3.58***
Mon	0.074	1.33	-0.007	-0.12
tmL	0.024	0.33	0.010	0.14
tmH	-0.057	-0.71	-0.047	-0.60
hmL	-0.014	-0.20	-0.171	**-2.19****
hmH	0.081	1.04	-0.020	-0.23
$cloL$	0.064	0.85	0.144	1.68
$cloH$	-0.073	-0.75	0.247	**2.61*****
snL	-0.041	-0.44	-0.185	**-2.05****
snH	-0.079	-0.97	-0.176	**-1.89***
ω	0.009	2.94***	0.046	5.34***
α	0.054	8.93***	0.120	12.49***
β	0.942	141.5***	0.872	101.6***

Note: *, ** and *** indicate the rejection at the 10%, 5% and 1% significance level, respectively.

Table 5

Weather effect on the returns using model 2

	HIS		SZZ	
	Coef.	t-value	Coef.	t-value
μ	0.033	0.92	0.002	0.06
Jan	0.068	0.55	0.500	3.62***
Mon	0.073	1.30	0.005	0.09
tmL	0.038	0.35	0.241	**2.03****
tmH	0.020	0.18	-0.009	-0.08
hmL	-0.074	-0.65	-0.164	-1.25
hmH	0.178	**1.70***	-0.014	-0.11
$cloL$	0.135	1.30	0.083	0.67
$cloH$	-0.197	-1.23	0.062	0.36
snL	0.066	0.46	-0.013	-0.10
snH	-0.008	-0.06	0.018	0.11
$tmL * hmL$	-0.009	-0.04	0.076	0.34
$tmL * hmH$	-0.124	-0.63	-0.263	-1.22
$tmL * snL$	-0.112	-0.52	-0.327	**-1.75***
$tmL * snH$	0.234	0.29	-0.801	-1.60
$tmL * cloL$	-0.466	-0.61	0.058	0.12
$tmL * cloH$	0.338	1.41	-0.023	-0.10
$tmH * hmL$	0.148	0.77	0.162	0.74
$tmH * hmH$	-0.329	-0.90	0.241	0.77
$tmH * snL$	-0.183	-0.27	-0.943	-1.64
$tmH * snH$	-0.149	-0.63	-0.755	**-3.29****
$tmH * cloL$	-0.197	-0.87	0.433	**1.90***
$tmH * cloH$	0.233	0.34	0.616	0.98
$hmL * snL$	0.116	0.40	-0.598	**-2.13****
$hmL * snH$	0.039	0.22	-0.093	-0.43
$hmL * cloL$	-0.011	-0.06	-0.095	-0.44
$hmL * cloH$	0.244	0.63	0.878	**2.57****
$hmH * cloL$	0.550	0.45	-1.117	-0.69
$hmH * cloH$	0.135	0.58	0.249	1.10
$hmH * snL$	-0.165	-0.68	0.005	0.03
$hmH * snH$	-0.711	-0.89	0.290	0.47
$cloL * snH$	-0.054	-0.32	0.086	0.42
$cloH * snL$	-0.120	-0.56	0.044	0.22
ω	0.008	2.86***	0.043	4.69***

α	0.055	8.81***	0.121	12.12***
β	0.941	138.0***	0.872	97.09***

Table 6

Numbers of significant weather dummy on the Hong Kong and Shenzhen Exchanges

	HSI	SSZ
Model 1	0	4
Model 2	1	6

As shown in Table 4, in case of HSI, there is no evidence of weather effect due to the insignificance of the t-value. However in case of SSZ it is apparent that the t-statistics of various weather dummies are statistically significant, implying that the extreme weather conditions do influence on the returns of SZZ. Namely, using the 11-day MA-MSD method (Table 4), the t-value of four variables ($cloH$, hmL, snL, snH) are significant at least 10 % level. Thus, we conclude that the weather effect exists in the Shenzhen Exchange, but there is no evidence of weather effect in the Hong Kong Exchange.

Table 5 identifies the interaction effect of weather condition on the returns of HSI and SZZ. We found the strong evidence of weather effect on the returns of SSZ due to six significant weather variables ($tmL, tmL*snL$, $tmH*snH$, $tmH*cloL$, $hmL*snL$, $hmL*cloH$). In contrast, it is evident that there was weak evidence of weather effect on the returns of HSI because only the extremely high humidity (hmH) variable are significant at the l0% level.

Table 6 calculated the number of significance of weather dummy variables using model 1 and model 2 with the GARCH (1,1) model. The returns of HSI show the only one number of significance of weather condition, while there are the six numbers of significance of weather condition in the returns of SSZ (in case of Model 2). As a result, we conclude that there is weak evidence of weather effect in the Hong Kong Exchange, but the Shenzhen Exchange shows strong evidence of weather effect.

5.2. Weather effect on the returns of the SSZA

In this section, we further consider the opening date of the Shenzhen A-share market to foreign investors, who are less sensitive to local weather conditions than domestic investors. For this purpose, this study divides the whole period of A-share data into two sub-periods at the date of 9th July 2003; (1) the pre-opening period composed of only domestic investors and (2) the post-opening period composed of both foreign and domestic investors.

Tables 7 and 8 report the test results of the weather dummy and interaction effect on the SSZA returns over different time period, respectively. Let's focus the estimation results of Table 8, because the implication of the results of Tables 7 and 8 is similar.

As shown in Table 8, the January effect (Jan) presents its significance in all three sample periods. The t-values of whole sample period of SZZA show strong evidence of weather effect

due to the significance of seven weather variables. For example, three weather conditions (tmL, $tmH*cloL$ and $hmL*cloH$) have a positive relationship with the returns of SZZA, while four weather conditions ($tmL*snL$, $tmH*snL$, $tmH*snH$, and $hmL*snL$) shows a negative impact on the returns of SZZA.

In the pre-opening period, eight various weather conditions have strong impact on the returns. For example, the t-values of three weather conditions (tmL, $cloL$, $hmL*cloH$) are positively significant, but the t-values of five weather conditions ($tmL*snL$, $tmH*snL$, $tmH*snH$, $hmL*snL$, $hmL*cloL$) are negatively significant. Thus, before the market opening, the decision making of domestic investors is affected by extreme local weather conditions. However, in the post-opening period, the t-value of only one weather variable ($tmH*snH$) is statistically significant, implying that the weather effect becomes weaker after the market openness to foreign investors.

Importantly, the pre-opening period of SZZA market has more significant weather dummies than the post-opening period. It supports our hypothesis that the weather effect on the SZZA returns becomes disappear following the openness of SZZA market to foreign investors. Due to the market openness, the SZZA market is attracted by more foreign investors, who are generally less sensitive to local weather condition than domestic investors.

Table 7

Weather effect on the SSZA returns using the model 1

	Whole period		Pre-opening		Post-opening	
	Coef.	t-value	Coef.	t-value	Coef.	t-value
μ	0.035	0.92	0.010	0.21	0.065	1.03
Jan	0.473	3.53***	0.270	1.45	0.647	2.56**
Mon	-0.009	-0.16	-0.110	-1.40	0.162	1.68*
tmL	0.012	0.16	0.067	0.74	-0.059	-0.46
tmH	-0.053	-0.68	-0.011	-0.10	-0.030	-0.25
hmL	-0.171	**-2.21****	-0.187	**-1.84***	-0.093	-0.74
hmH	-0.021	-0.24	0.002	0.02	0.006	0.04
$cloL$	0.144	**1.69***	0.202	**1.65***	0.019	0.15
$cloH$	0.243	**2.58*****	0.249	**1.89***	0.189	1.25
snL	-0.182	**-2.04****	-0.108	-0.97	-0.335	**-2.24****
snH	-0.172	**-1.85***	-0.147	-1.02	-0.230	**-1.65***
ω	0.044	5.30***	0.078	4.28***	0.032	2.68***
α	0.122	12.58***	0.214	8.65***	0.074	7.24***
β	0.870	101.9***	0.775	36.72***	0.919	90.08***

Table 8

Weather effect on the SZZA returns using the model 2

	Whole period		Pre-opening		Post-opening	
	Coef.	t-value	Coef.	t-value	Coef.	t-value
μ	0.001	0.03	-0.031	-0.59	0.055	0.78
Jan	0.496	3.60***	0.344	1.78*	0.648	2.63***
Mon	0.001	0.03	-0.108	-1.27	0.173	**1.79***
tmL	0.236	**1.98****	0.288	**2.12****	0.097	0.45
tmH	-0.029	-0.27	-0.067	-0.39	0.005	0.03
hmL	-0.169	-1.31	0.037	0.25	-0.310	-1.44
hmH	-0.018	-0.15	-0.149	-0.98	0.116	0.61
$cloL$	0.093	0.76	0.410	**2.59*****	-0.180	-0.91
$cloH$	0.057	0.34	-0.180	-0.56	0.026	0.10
snL	-0.005	-0.04	0.043	0.24	-0.247	-1.05
snH	0.020	0.12	0.154	0.72	-0.096	-0.38
$tmL*hmL$	0.086	0.38	-0.058	-0.20	0.408	1.10
$tmL*hmH$	-0.251	-1.17	0.041	0.17	-0.519	-1.40
$tmL*snL$	-0.339	**-1.82***	-0.398	**-1.66***	-0.124	-0.37
$tmL*snH$	-0.813	-1.62	-1.737	-0.10	-1.022	-1.41
$tmL*cloL$	0.077	0.16	1.033	0.06	-0.001	0.00
$tmL*cloH$	0.003	0.01	0.329	1.04	-0.128	-0.35
$tmH*hmL$	0.182	0.84	0.093	0.35	0.375	0.97
$tmH*hmH$	0.246	0.79	0.533	1.33	-0.049	-0.10
$tmH*snL$	-0.968	**-1.68****	-1.911	**-1.81***	-0.413	-0.47
$tmH*snH$	-0.711	**-3.14*****	-0.589	**-1.69***	-0.763	**-2.15****
$tmH*cloL$	0.412	**1.82***	0.452	1.38	0.317	0.85
$tmH*cloH$	0.662	1.06	0.910	0.69	0.293	0.34
$hmL*snL$	-0.612	**-2.20****	-1.340	**-3.54*****	0.051	0.09
$hmL*snH$	-0.083	-0.38	0.202	0.67	-0.106	-0.32
$hmL*cloL$	-0.099	-0.46	-0.543	**-1.74***	0.154	0.48
$hmL*cloH$	0.870	**2.57*****	1.492	**2.81*****	0.387	0.57
$hmH*cloL$	-1.060	-0.65	-4.292	-0.18	-0.486	-0.13

$hmH * cloH$	0.225	1.00	-0.022	-0.07	0.441	1.25
$hmH * snL$	0.016	0.08	0.327	1.18	-0.140	-0.37
$hmH * snH$	0.281	0.48	4.564	0.14	0.015	0.02
$cloH * snL$	0.039	0.20	0.203	0.61	0.099	0.30
$cloL * snH$	0.070	0.34	-0.378	-1.32	0.326	1.01
ω	0.041	4.68***	0.077	3.72***	0.032	2.56***
α	0.123	12.18***	0.244	8.15***	0.078	7.14***
β	0.870	97.18***	0.750	31.09***	0.915	84.2***

Table 9 figures out the numbers of significant weather dummies in the returns. As shown in this table, the pre-opening period of A-share market has more significant weather dummies than the post-opening period. It supports our hypothesis that the weather effect on A-share returns becomes disappear following the openness of A-share market to foreign investors. This finding implies that the A-share market becomes more efficient after the market openness.

Table 9

Numbers of weather dummies which are significant (10% below significance level)

	A-share (SZZA)		
	Whole period	Pre-opening	Post-opening
Model 1	5	3	2
Model 2	7	8	1

6. Conclusions

It is well known that weather conditions affect an individual's emotional state or mood, which prevents people from making rational or optimal decision. Supposed that the existence of weather effects affect the investor's decision making, various weather conditions may influence the movements of stock returns.

This study investigates the weather effect on the returns of Hong Kong and Shenzhen Exchanges using extreme weather conditions calculated by the 11-day MA-MSD approach. Additionally, this study also considers the QFII plan which allows the ownership of foreign investors in the Shenzhen A-share market. Importantly, it is assumed that domestic investors are more sensitive to the local weather of Shenzhen than foreign investors. Empirical analysis in this study provides two key results regarding weather effects on returns.

First, the comparison of weather effects between the Hong Kong and Shenzhen Exchanges, the Hong Kong stock market is insensitive to weather effects on the returns, whereas there is a

significant weather effect on the returns of Shenzhen index. This result implies that the Shenzhen market is less efficient than its counterpart.

Second, accounting for the QFII plain on July 9, 2003 as a cutoff point in the sample data, the returns of Shenzhen A-share in the pre-opening period which traded only by domestic investors show the strong weather effect on the returns, but there is weak weather effect in the post-opening period. This evidence indicates that the Shenzhen A-share stock market is becoming efficient after QFII plan due to the increase in foreign institutional investors.

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