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ARE STOCK MARKET PRICES RELATED TO THE WEATHER EFFECTS?

Empirical Evidence from New York City

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ABSTRACT

Several behavioral finance studies have proved that investor psychology fluctuations can explain some anomalies in stock market. Moreover, there are links between weather condition and stock prices via human mood. This thesis investigates the possible relationship between four weather elements (precipitation, snowfall, average daily temperature, and average daily wind speed) and stock prices in New York City. In order to examine the weather effects on stocks, daily weather data of New York City and daily closure stock prices logarithm of NASDAQ Indexes from October 3rd, 1994 (Monday) to October 1st, 2014 (Wednesday) as well as severe events data within this 20 years in New York City are used as the observations in the thesis.

Through applying both individual and combined tests of Ordinary Least Squares (OLS) regressions between weather and stock data, it is found that daily precipitation amount, snowfall amount do not have significant influences on stock prices. Average daily temperature and the dummy variable 1 (good weather) present to have positive influences on stock prices. Both coefficients of them reach the statistically significant level in most of the tests. Besides, the results also prove that average daily wind speed as well as the dummy variable 2 (bad weather) have negative correlations with stock returns. The coefficients of wind speeds are statistically significant in all tests. However, no significant evidence has been found to prove the influence of severe events on the stock market or the existence of Monday or January effect in New York City.

KEYWORDS: weather effects, stock prices, investor moods, OLS model

1. INTRODUCTION

1.1 Problem Background

It is known that traditional financial theory assumes that under the efficient market hypothesis (EMH), investors always evaluate a portfolio by assessing its maxim outcome with "capital asset pricing model" (CAPM) (Sharpe 1964: 425-442). According to these two theories, market information should be fully available for the investors and should be considered by them immediately and rationally (Chang et al. 2008: 1754-1766).

However, there are some anomalies in the stock market. Economists cannot resolve them through the traditional financial theory. Some economists (Lucey & Dowling 2005: 337-355) argue that investors may not always act rationally when they make decisions in the economic market. Some others point out that the investors' psychological movements may affect their decisions (see e.g. Bell & Baron 1976: 18-30; Allen & Fischer 1978: 95-101). Economists decide to do researches to find the influences of investor moods on determination of stock prices (Mehra & Sah 2002: 869-887). Therefore, in order to analyze one of the unexplained abnormal changes in stock prices, behavioral finance, a new area beyond the traditional financial research comes out. It is established based on the inefficient market, psychology and behavior science. The behavioral finance explains the abnormal phenomena that occurred in the stock market through two methods: the first is to analyze the different behaviors of traders and try to figure out if they have any various effects on the stock market or what kind of anomalies they may make. However, the second way comes from the opposite direction. It starts from analyzing a certain anomaly and try to find out the certain behavior which has caused that phenomenon. Among the researchers who prefer the second method, someone has begun to do research on human mood and financial

market. They try to find out the relationship between mood swings and stock returns (see e.g. Saunders 1993: 1337-1345; Elster 1998: 47-74).

There is evidence that human mood and behavior can be influenced by weather conditions (Cunningham 1979: 1947-1956). E. Howarth and M.S. Hoffman point out different weather variables will push people to do some particular actions by affecting their moods (Howarth & Hoffman 1984: 15-23). Saunders (1993: 1337-1345) in his research even finds out that weather can affect people's decision making in the stock market via moods change.

Elster (1998: 47-74) extends the research and finds the relationship between psychological conditions and decision making in the stock market. Mehra & Sah(2002: 869-887) point out that the change of mood may cause swings of investors' preference when they are trading in the market, such as risk preference. These swings may have an influence on stock prices, especially when the investors do not know that their trading behaviors are affected by their mood. Lucey & Dowling (2005: 337-355) even divide the weather into good and bad conditions and analyze if certain kinds of weather have a particular effect on investors' decision making.

1.2 Research Purpose

Based on the findings that weather can affect people's psychological conditions, people's moods affect their behavior and behavior bias may affect the stock market, it is worth to find out if weather effects have some relationship with the stock market. This idea becomes one of the motivations of this thesis. Another motivation is based on the fact that researches have found empirical evidences of weather effects in the stock market in many different countries (see e.g. Cao & Wei 2005: 1559-1573; Garrett, et al. 2005: 291–316; Chang et al. 2008: 1754-1766). Therefore, this thesis focuses on the correlation between weather factors and stock prices in one city: New York City.

Saunders (1993: 1337-1345) have already tested the one single factor of the weather of Wall Street: cloud cover has an effect on stock returns. In this thesis, on the one hand, I plan to test how the four weather factors affect the New York City market stock prices; on the other hand, I also examine the influence of severe events on stock prices. Four weather variables and daily NASDAQ composite stock prices over a long period from 1994 and 2014 are used as the observations. Following the previous studies (Hammami & Abaoub 2010: 7-28), this thesis employs the linear model to test the relationship between weather factors and stock prices in New York City.

This thesis has two limitations: the first is that the weather factors are only collected for New York City. In fact, orders which can change stock prices of NASDAQ come from all over the United States and even from all over the world. It must be different weather at the same day in different order places. The second is that the correlations among the weather factors have been ignored in the thesis.

Despite these limitations, the results of the thesis are still meaningful. The empirical findings can provide information for those who want to trade in the New York City stock market.

1.3 Overview of the Thesis

The content of the thesis is organized as bellow: Chapter one contains the brief introduction including the background and motivation of the thesis. Chapter two introduces the theoretical background and hypotheses related to the thesis, such as theoretical psychology, behavioral finance etc. Chapter three covers the literature review related to the research issue. In this chapter, the previous findings of Efficient Market Hypothesis are introduced. How the mood impacts decision making as well as the link between weather and the stock

market are also reviewed in this chapter. This chapter also explains the Monday and January Effects. Chapter four describes briefly data collection, including the sources, types and period of both weather and stock prices data. Chapter five introduces the previous approach of testing the relationship between weather and stock returns. The applying methodology of this thesis, OLS model, is also introduced in this chapter. Chapter six reports the empirical results from three aspects and chapter seven concludes the thesis.

2. THEORETICAL BACKGROUND

2.1 Environmental Psychology

Weather factors and individual mood have a very close connection. Plenty of studies (see e.g. Goldstein 1972: 786; Young, et al. 1997: 554-562) show that variations of weather factors may change people's moods and thus change people's plan and activities. On the one hand, during such a long time evolution, human beings have evolved to be able to react properly to weather changes due to our instinct which also makes us more adapted to the environment. On the other hand, the adaption does not work every time. Since human body can feel weather factors sensitively, such as our skin which full of sense can receive the feeling of temperature, sunshine, humidity, our throat which can also feel temperature and humidity, our eyes which can see the change of sunlight, and our ears which can feel the change of air pressure, people's psychology conditions are being affected when the change of weather is big enough to break people's self-adjustment. Meanwhile, psychological resistance may also appear (see e.g. Forgas, et al. 2009: 254–257; Denissen, et al. 2008: 662-667; Lu & Chou 2012: 79-93; Page , et al. 2007: 106-112).

Based on these theories, researchers find that people usually have low mood in bad weather and high mood in good weather. For example, in Cunningham (1979: 1947-1956), testers would leave more tips to waitress and be more willing to help others in good sunshine days, but in the days without enough sunshine, the results are opposite.

For the other factor of weather, humidity, researchers use two experiments to test if humidity has any influence on human behavior. The conclusion is that the testers' learning

and recalled ability are better in a proper humidity environment (Allen & Fischer 1978: 95-101).

Some researchers investigate the relationship between weather and shopping patterns (Parsons 2001: 78–84). Parsons finds that rainfall and temperature can influence people's moods and push them to make different shopping decisions.

Temperature is considered as one of the most important factors in Bell & Baron (1976: 18-30). The authors used a very special way to test how the temperature affects human mood and behavior. They divided the testers into two groups: one group was kept in a comfortable cool environment and the other in an uncomfortable hot environment. Then the researchers asked the testers to use the electric shock to retaliate the strangers who had evaluated them. The result indicates that temperature indeed affect mood and behaviors.

Digon and Bock (Digon & Bock 1966: 279-286) find that different barometric pressure has an influence on people's psychological conditions. Syeonidis also finds that cloud cover can affect mood (Symeonidis 2010: 214-223).

Howarth and Hoffman confirm the relationship between temperature, humidity, sunshine hours and mood by sending mood questionnaires to 24 college students (Howarth & Hoffman 1984: 15-23). The results show that temperature and sunshine hours have a positive influence on mood, while humidity has negative correlations with mood.

2.2 Mood and Decision Making

Investors are not always rational because of the mood movements, especially when they are making decisions.

There are some literatures about the relationship between mood and decision making (see e.g. Simonsohn 2007: 143-152; Isen 1984; 534-537). Someone believes that when people are in good mood, they can make decisions faster than they are in bad mood. This phenomenon occurs because good mood can shorten testers' progress of message reading and acceptance. However, some researchers (Hirshleifer & Shumway 2003: 1009-1032) consider that this kind of shortening may be because good mood makes testers' cognitive ability become lower or it indeed makes the testers understand the message effectively. Through the experiments made by Johnson and Tversky (Johnson & Tversky 1983: 20-31), it can be found that no matter what causes the human mood bias, people's decision making are affected by mood bias.

William F Wright and Gordon H Bower provide three findings about feelings and decision making. According to their experiments, different mood may have different influences on people's cognitive power and judgment of the stuff they did not know before. They divide mood into three conditions: happy, neutral and sad. When people experience or focus on the happy or sad events, they will have a consistent good or bad mood effect. This effect would affect their decision making consistently. The researchers point out that during the tests, people in good mood behave more optimistically, whereas people in bad mood are more pessimistic (Wright & Bower 1992: 276–291).

Schwarz points out in "mood-as-information" theory that people would like to make the decisions based on their feeling or mood, even if the mood has nothing to do with what they are going to decide. This result predicts that mood can help people make decisions quickly. Meanwhile, he also believes that good mood makes people less critical when they make decisions (Schwarz 1990: 527-561).

2.3 Weather and Stock Prices

After the discussion of weather, mood and decision making, how the weather impacts stock prices is going to be talked next.

Saunders (1993: 1337-1345) finds the correlation between weather factors and stock returns by analyzing the 62 years' data from 1927 to 1989 of stock prices in New York Stock Exchange (NYSE) and cloud cover data in Manhattan. He finds the stock returns are negatively related with cloud cover and implies that the stock prices are higher in sunny days. This result echoes the Wright & Bower (1992: 276–291) research that good mood helps people make optimistic judgment and bad mood makes people pessimistic.

Hirshleifer & Shumway (2003: 1009-1032) examine the results of Saunders (1993: 1337-1345). They analyze the data over a period from 1982 to 1997 from 26 countries. They investigate not just sunshine's influence on stock returns, but some other factors of weather as well, such as rain and snow. Finally, they confirm the relationship between certain weather factors and stock returns. They admit that sunshine does affect stock prices. In the meantime, they point out that rain and snow is not related to stock prices.

According to researches (see e.g. Cao & Wei 2005: 1559-1573; Keef & Roush 2003: 61-79), temperature is negatively correlated to stock prices. However, Yoon and Kang (Yoon & Kang 2009: 682-690) believe that a positive effect on stock prices exists when temperature is below a certain level.

Although not all studies obtain the same results regarding weather effects, it is still a popular topic in behavioral finance, such as if weather have any influence on stock prices, what weather variables affect stock prices and what cannot, etc.

2.4 Efficient Market Hypothesis

Since behavioral finance is based on the abnormal phenomena that cannot be explained in Efficient Market Hypothesis (EMH), it is beneficial to understand what EMH is.

In 1965, traditional economist Eugene Fama firstly presented the efficient market theory and pointed out that in an efficient market, investors are all rational and can get entire information easily (Fama 1965: 55-59). He proposed the three forms of Market Efficiency in 1970 (Fama 1970: 383–417).

EMH theory assumes that the financial markets are informational efficient which means all information should be available for the investors and moreover investors are rational on average. Due to the efficiency, investors cannot get extra returns. EMH has three forms. The first one is the Weak-Form Market Efficiency, which assumes that market prices can reflect all historical trading information, including trading price, trading volume etc. In other words, if the Weak-Form Market Efficiency holds, technical analysis of stock prices does not work at all. The second one is the Semi-Strong-Form Market Efficiency, according to which prices reflect all the public information and even the operating prospects information of the company. The information includes trading price, volume, profit forecast, financial statement etc. In this case, neither technical nor fundamental analysis works. Investors can earn extra returns only if they can get some insider information. The third one is the Strong-Form Market Efficiency, which states that prices have already reflected all the information about the company, including all the public and hidden (insider) information. If the strong form holds, by no means can investors get extra returns.

Although EMH has been widely used in financial models, there still exist researchers who have different views. Black puts forward that the financial markets are not always efficient. He also presents the noise theory that defines "Noise is what makes our observations imperfect." (Black 1986: 529-543.) The existence of anomalies in the stock market has also been proved in many studies (see e.g. Jacobs & Levy, 1988, pp. 28-39; Keim, 1983, pp. 13-32). Fama and French even examine the factors which can explain the asset pricing anomalies (Fama & French, 1996, pp. 55-84). The researchers point out that abnormal returns are usually associated with firm characteristics; structural factors like behavioral bias, government regulation etc., and calendar effects. The calendar effect is one of the asset pricing anomalies. It occurs in particular day of the week, particular time of the month or year. Similar to weather effects, calendar effects behave differently in different days and also have different influences on stock prices. The Monday and January Effects are the two typical examples of calendar effects.

2.5 The Monday and January Effects

The Monday effect means that the stock returns on Monday follow the trend of last Friday. Put simply, if the stock prices went up on previous Friday, they would go up as well on Monday. In 1930, Fred C. Kelly firstly put forward the Monday effect (Kelly, 1930). He finds that investors tend to sell stocks on Monday. After him, researchers began to pay attention to this interesting phenomenon. Frank Cross finds that stock prices changes on Friday and Monday are not random (Cross 1973: 67-69). Jeffrey Jaffe and Randolph Westerfield provide more international examples of weekend effect (Jaffe & Westerfield 1985: 433–454). Despite the evidence of this kind of consistent trend in the stock market, no one can explain the Monday effect precisely (French 1980: 55–69).

The January effect is a hypothesis that stock prices will always increase in January. The growth rate is higher than in other months. In this seasonal event, investors can earn extra

returns by buying stocks at a lower price before January and selling them at a higher price in January. Kinney and Rozeff provide more evidence by analyzing 70 years data from New York Stock Exchange from 1904–1974. They find that except the years 1929–1940, stock returns increase in January much more than in any other month (Kinney Jr. & Rozeff 1976: 379-402).

There are, however, some different views towards the January effect. Sullivan, Timmermann and White argue that calendar effects do not really exist in the stock market. They collect 100 years stock data and analyze stock returns on some particular days, weeks and months. Finally they get the result of "once evaluated in the context of the full universe from which such rules were drawn, calendar effects no longer remain significant." (Sullivan, et al., 2001, p. 249–286.)

3. LITERATURE REVIEW

As mentioned above, how weather influences human mood as well as their decision making and hence affects stock prices has become a popular topic in financial area. More and more economists begin to do researches to investigate the correlation between them. They present plenty of empirical evidences from all over the world to examine if weather effects exist in their cities or countries. However, according to the previous studies which have been selected into this thesis, not all of them gain same results of weather effects.

In Europe, half of the studies do not find any significant evidence to prove weather effects. Lucey & Dowling (2005: 337-355) confirm the positive correlation between stock returns and two weather factors: "CLOUDLESS25%" and humidity. They also prove the negative influences of "CLOUD100%", precipitation and geomagnetic storm on stock returns. Floros provide the significant evidence of negative relation between temperature and stock returns (Floros 2011: 5-13). In Americas, most studies use cloud cover and temperature as weather observations. Only two of them do not find cloud cover's influence on stock markets, all the others confirm negative effects of cloud cover or temperature on stock returns. Previous studies of Asia present to have consistent results with results of Americas. Temperature, cloud cover and humidity show the negative correlation with stock prices. Kang, et al. (2010: 91-99) make some groups in his paper and get both positive and negative effect of different groups. In Oceania, Keef and Roush point out that temperature, cloud cover and wind speed are negatively correlated with stock returns in New Zealand. However, they only confirm the negative correlation with temperature in Australia. Andrew (2009: 148-154) does not find any weather effects in Australia. Hammami & Abaoub (2010: 7-28) finds that sunshine hours and temperature are positively related with stock returns while rain, humidity and wind speed have negative influence on stock returns. For the international evidence, both of the studies confirm significant existence of weather effects.

They find negative effects of cloud cover or temperature on stock markets. Some relevant literatures are presented below to show the connection between weather and stock prices in different continents.

3.1 Empirical Evidence from Europe

Plenty of studies argue that weather can affect investor's mood and behaviors, which can be reflected in stock prices. Some of them have already found the significant correlation between weather and human behaviors (see e.g. Howarth & Hoffman 1984: 15-23; Kamstra et al. 2000: 1005-1011; Hirshleifer & Shumway 2003: 1009-1032). Pardo and Valor decide to do the similar research in order to test if the weather effects also work in Spanish market (Pardo & Valor 2003: 117-126). They select almost 20 years financial data of daily closure price during the period of 1981 to 2000 from a special index called Madrid Stock Exchange (MSE). MSE only open at some fixed time to let the traders trading before 1989 and after that changed trading system to computer assistant trading. This change helps the researchers test the data more accurately in different periods. They collect two factors of weather data: humidity and sunshine hours. They believe these two factors are the most relavent variables of weather which can affect investors' behavior in the stock market. Since MSE changed the trading method in 1989, Pardo and Valor divide the data into two periods and do statistical tests separately. According to the results of both parametric and non-parametric tests, it can be found that sunshine and humidity have no impact on stock returns in Spanish market whatever kind of trading systems are used there. The empirical evidence shows that weather effects do not work in Spain.

Similar study appeared in Germany and Turkey (see e.g. Kramer & Runde 1997: 637-641; Tufan & Hamarat 2004: 117-126). In order to examine the findings of Saunders (1993: 1337-1345), Kramer and Runde do the experiments in Germany and analyze the stock returns in the Frankfurt stock market from 1960 to 1990. They propose that whether the

weather effects exist or not depends on how the data are dredged and classified. They believe that no significant relationship between weather variables and stock returns exists in the Germany market. Tufan and Hamarat want to investigate the influence of cloud cover on the stock market in Turkey. They find that cloudy days have no influence on stock returns and also admit the weak form efficiency in the Istanbul stock market.

In spite of the different conclusions Pardo & Valor (2003: 117-126), Tufan & Hamarat (2004: 117-126) made, there are still some economists trying to examine weather effects in their own countries. Motivated by Loewenstein (Loewenstein, et al. 2001: 267-286) who argues that feelings impact decision making, Lucy and Dowling, for instance, analyze data in the Irish stock market and try to prove the existence of weather effects (Lucey & Dowling 2005: 337-355).

They believe that weather is not the only proxy factor which can affect investor moods, but biorhythms and beliefs are also the important factors. Based on this point, they collect almost 13 year's data from 1988 to the end of 2000 and examine 8 variables including 4 weather variables. The 4 factors are rain, cloud, humidity and geomagnetic storm. All factors are analyzed both individually and combined. The authors make 2 dummy variables: good and bad weather, with these 4 factors. They analyze the data by running OLS regressions, Least Absolute Deviation (LAD) and Trimmed Least Squares (TLS). These three methods give the same results, concluding that weather condition indeed has a significant impact on stock returns, to varying extent though. To be more specific, they find out that the relationship between humidity and stock returns is positive. They also reveal that when investors perform well in the stock market, this weather effect and influence of mood appear more obviously. It is also consistent with psychology theory believing that weather and other external factors may affect investors' decision choice more easily if they have a good mood which comes from good performance of investment (Mackie & Worth 1991: 201-219).

In Portugal, researchers investigate not only the significant relationship between temperature and stock prices, but also prove the existence of the January effect and trading month effect (Floros 2011: 5-13). Christos Floros collects daily stock prices as well as temperature of Portugal from 1995 to 2007. In order to check the temperature effect on Portugal's stock and the existence of "calendar-related anomalies" in Portugal, the author ignores if the tradings come from electronic way or not and applies the GARCH model under some different assumptions. The results indicate that temperature has a negative impact on stock returns of PSI20 index. Moreover, all the parameters are significant in the model. The January effect proves to be true in this study, the empirical evidence show that stock returns are higher in January when the temperature is low. The results also prove the trading month effect that during the first two weeks of a month, stock prices are higher than other periods.

The summary of previous studies' empirical evidences in Europe is presented in table 1.

Table 1 Summary of previous studies in Europe.

Author	Location	Stock data	Main weather factors	Correlation with stocks
Pardo & Valor (2003)	Spain	Daily closure price of Madrid Stock Exchange from 1981 to 2000	Humidity Sunshine hours	No correlation
Kramer & Runde (1997)	Germany	Stock returns of Frankfurt Stock Exchange from 1960 to 1990	Cloud cover Humidity Atmospheric pressure Rainfall	No correlation
Tufan & Hamarat (2004)	Turkey	Stock returns of Istanbul Securities Market from 1987 to 2002	Cloud cover	No correlation
Lucey & Dowling (2005)	Ireland	Daily stock returns of Irish Stock Exchange Official Price Index and FTSE All-World Index from1988 to 2001	Cloud cover (100 percent cloud cover) (cloud cover less than 25%) Precipitation Humidity Geomagnetic storm	 Negative Positive Negative Positive Negative
Floros (2011)	Portugal	Daily stock returns of Lisbon Stock Exchange from 1995 to 2007	Temperature	Negative

3.2 Empirical Evidence from Americas

Researchers from America also provide some empirical evidence of weather effects in their countries and cities. They believe that weather effects exist in New York City and claim that weather condition is highly related to stock prices (see e.g. Saunders 1993: 1337-1345; Stecklow 1993: 1; Trombley 1997: 11-21; Koretz 1994: 20; Loughran & Schultz 2004: 343-364; Goetzmann & Zhu 2005: 559-578; Chang 2008: 1754-1766; Schneider 2014: 27).

One of the famous researches is Saunders (1993: 1337-1345). This research discovers the relationship between mood fluctuation induced by weather and stock returns. He collects the stock data from Dow Jones Industrial Average which covers the time from 1927 to 1989. For the value weighted and equally weighted data, he uses indices of New York Stock Exchange /American Stock Exchange from 1962 to 1989. New York City's daily weather data have been used as the observations in the research as well. The author expects that good weather which he defines as clear days induces good mood, and thus leads to a higher stock return in market. Likewise, bad weather which he defines as cloudy days induces bad mood and leads to a lower stock return. After the analysis, he finds out the significant correlation between cloud cover and stock. He concludes that, when the level of cloud cover is 100%, the stock returns are lower than the mean value, but when the cloud cover is less than 20%, the stock returns become higher than the mean value.

According to Saunders (1993: 1337-1345), psychology influences asset prices and may cause an irrational security market. In order to examine the results from Saunders, Trombley (Trombley 1997: 11-21) uses the data from Dow-Jones Industrial Average from 1927 to 1992, which is similar to what Saunders used. However, he applies an improved approach which is different than Saunders'. He provides an additional evidence of the relationship between weather and stock prices of New York City. The result is that the relationship is not as clear as Saunders describes. In addition, he finds out that stock returns have no big difference in New York Stock Exchange, whether it is sunny or cloudy. He

believes that the significant correlation that occurred in Saunders (1993: 1337-1345) is probably due to the different returns the author used in the analysis.

Similarly, Trombley, Loughran and Schultz are also inspired by Saunders (1993: 1337-1345) and Hirshleifer & Shumway (2003: 1009-1032). These studies motivate them to do research on weather and stock returns in the United States. Meanwhile, they find out the limitations of those previous studies: local weather factors may not be a good proxy to test the stock prices, since the orders come from all over the world (Loughran & Schultz 2004: 343-364). They apply a different approach to check the impact of cloud cover on stock returns of localized trading. They collect stock data from NASDAQ Stock Index because they consider this data are more suitable to the analysis. They believe companies listed in NASDAQ are affected by more local weather (see e.g. Coval & Moskowitz 1999: 2045-2073; Loughran & Schultz 2004: 343-364). They sort out 25 largest cities based on the number of companies that are located in the cities. Then they get prices, returns and trading volumes of 4949 stocks from The University of Chicago's Center for Research in Security Prices (CRSP). For the weather, they use hourly cloud cover data of each city which are collected from National Oceanic and Atmospheric Administration (NOAA), as Hirshleifer & Shumway(2003: 1009-1032) did.

By analyzing local weather conditions and stock prices, Loughran and Schultz finally get the result that there is no evidence to prove the relationship between cloud cover at companies' locations and companies' stock returns. Although the result is different from what previous studies find, they find another phenomenon that New York City's weather condition indeed has a slight relation with NASDAQ stock returns. The stock returns which have been analyzed in the study are lower in cloudy days in New York City. Although the coefficient of New York City cloudiness is very small, which is only -0.038, the author cannot deny its impact on stock return.

With the same aim of testing the existence of weather effects in the United States, Goetzmann and Zhu start in a different way. They conduct the analysis on investors

according to their locations (Goetzmann & Zhu 2005: 559-578). All the data are provided by a discount brokerage company in the United States. The data include investors' personal information, such as characteristics, securities identification and also some trading information, such as trade date, price, volume etc. The data cover 80000 investors, 5 cities in the United States and almost 6 years from 1991 to 1996. For the weather data, they collect hourly Total Sky Cover (SKC) from NOAA. They examine both the relations between stock returns and weather which is SKC in this study and between weather and investors' trading behavior. They do not find link between local weather condition and investors' trading behavior which means investors do not appear to buy more or less in cloudy days than other days. However, they still find the weather effects through the data. In cloudy days, the stock spreads become wider. They point out that if the weather effects indeed affects stock returns, the responder should be some other large investors rather than the individual ones, such as market makers, agents etc. They are physically located in stock exchange cities and have bigger power to impact the stock returns. Therefore, individual investors' influence tends to be insignificant compare to them.

There are also some researchers who discover the significant relationship between weather and stock. For instance, in Chang et al. (2008: 1754-1766), they examine if intraday patterns of NYSE stocks are influenced by weather condition in New York City. They collect 10 years stock data covering the period from 1994 to 2004. The data include stock prices, volume, bid-ask quotes, quotes size as well as shares outstanding and the market value etc. Following (Chordia, T., et al. 2002: 111-130), they set some filters in their data to make the errors be the least. They use the same weather data source as Hirshleifer & Shumway (2003: 1009-1032) and Loughran & Schultz (2004: 343-364) which is National Climatic Data Center. Both stock and weather variables are hourly recorded. In order to check the influence of weather during market open hours, the researcher divides a trading day into 8 periods and analyzes stock data and weather data in each period. They calculate price range, standard deviation and other variables and finally get the result. They discover that stock returns are lower in cloudy days than other days. They also find out that the more cloud in the sky, the more seller-initiated trades occur. The further finding is that spread

and turnover ratio can impact volatility and market depth. It has a positive correlation with the former one but a negative correlation with the latter one. They go further to claim that these findings can happen not only during the market opening hours but the whole day as well. Their findings are consistent with previous studies which believe psychology condition affects stock returns and also indicate that weather has a significant impact on investors trading behavior by influencing their mood.

Besides Chang et al. (2008: 1754-1766), Akhtari (Akhtari 2011: 51-70) finds high correlation between weather and stock as well. He uses weather data from NOAA and stock data from Dow Jones Industrial Average (DJI). Both the two types of data are collected from 1948 to 2010. After analyzing, he finds out that sunshine hours in New York City indeed affect stock prices. This result is consistent with some of the previous studies (Hirshleifer & Shumway 2003: 1009-1032). He also points out that the correlation has increased little by little during last 50 years.

The summary of previous studies' empirical evidences in Americas is presented in table 2.

Table 2 Summary of previous studies in Americas.

Author	**Location**	**Stock data**	**Main weather factors**	**Correlation with stocks**
Saunders (1993)	New York City	Daily percentage changes in the Dow-Jones Industrial Average and New York Stock Exchange/ American Stock Exchange indexes from 1927 to 1989	Cloud cover	Negative

Table 2 Continued.

Author	Location	Stock data	Main weather factors	Correlation with stocks
Trombley (1997)	New York City	Daily stock returns in the Dow-Jones Industrial Average from 1927 to 1992	Cloud cover	No correlation
Loughran & Schultz (2004)	The United States	Stock prices, returns and trading volumes of companies in NASDAQ	Local cloud cover New York weather	No correlation Negative
Goetzmann & Zhu (2005)	The United States	Investors' personal information; Trading information: price, volume etc. from 1991 to 1996	Cloud cover	Negative
Chang et al. (2008)	New York City	Stock prices, volume, bid-ask quotes, quotes size, shares outstanding and the market value etc. of New York Stock Exchange from 1994 to 2004	Temperature	Negative
Akhtari (2011)	New York City	Daily index return of the Dow Jones Industrial Average from 1948 to 2010	Cloud cover	Negative

3.3 Empirical Evidence from Asia

In Asia, some researchers provide plenty of empirical evidence of correlation between weather and the stock market as well (see e.g. Prasad, et al. 1994: 53–63; Chang et al. 2006: 343–354; Shu 2008: 96-102; Yoon & Kang 2009: 682-690; Kang, et al. 2010: 91-99; Lu & Chou 2012: 79-93; Wang & Lin 2012: 695-703; Brahmana, Rayenda , et al. 2014: 175-190).

With the aim of testing if mood fluctuations induced by weather effects can really work in the Taiwan stock market and checking if these fluctuations can impact investors' evaluations of stocks and equities, Chang et al. (2006: 343–354) conducts empirical researches of weather conditions and stock data in the Taiwan market. They collect weather data from 1997 to 2003. The data include daily temperature in Celsius degree, humidity and cloud cover information of Taipei City. For the stock data, they choose the same time period as weather. To make the research more targeted, they use daily closing stock prices of the Taiwan stock market. In order to investigate stock prices and weather factors relation, they calculate the stock returns as the logarithmic difference. They use the difference of log form between today's stock price and yesterday's as the stock returns.

Following the previous studies, Chang et al employ two types of the unit root test: the traditional unit root test and non-linear one (KSS test) in their paper (Kapetanios, et al. 2003: 359–379). They firstly use this model to test the null and alternative hypothesis. In the second step, they apply a developed econometric method to examine the data, which is a non-linear threshold model with GJR- GARCH process. Although the previous studies are more likely to use linear model, Chang et al. (2006: 343–354) believe that non-linear model is the better examine method.

According to the results of both the unit root test and threshold model with GJR- GARCH，the author finds out that both temperature and cloud cover are important factors which influence stock returns in Taiwan. As long as the temperature becomes above or below a certain threshold (it can be either too hot or too cold), stocks present lower returns than in

other days. This finding supports the previous studies which argue that weather is an important factor which can affect investors' mood and behaviors (see e.g. Saunders 1993: 1337-1345; Hirshleifer & Shumway 2003: 1009-1032). Moreover, they point out that very high or low temperature may cause people fret and impatient, disturb their investment behavior, and finally affect the stock returns. Besides temperature, results show that cloud also has a significant impact on stocks in Taiwan. The stock returns are lower in cloudier days. This finding also supports some psychologists' arguments that human tend to be unhappy and depressed when they do not have enough sunshine (McAndrew, 1993).

Shu (Shu 2008: 96-102) has examined the results of Chang et al. (2006: 343–354) and he obtains similar results. He points out that good weather and stock returns have a positive correlation in the Taiwan Stock Market. Meanwhile, he puts forward that good weather can bring good mood to individual investors and hence the stock returns tend to be higher. These three factors are highly correlated. He also compares the reaction to the weather of individual investors and institutions. The results indicate that individual investors are more easily influenced by weather than are institutions. In another word, individual investors are more likely to make irrational decisions than institutions.

Researchers also find similar evidences in Korean (Yoon & Kang 2009: 682-690). The authors analyze almost 16 years data from 1990 to 2006. Daily closing prices of stocks are collected from Korea Composite Stock Price Index 200. Based on these closing prices, the authors calculate the descriptive statistics and apply the unit root tests. They collect weather data with the same time period as stock prices. Three daily weather factors are taken into analysis in this paper: temperature, humidity and cloud cover in Seoul. They create dummy variables with these three weather factors and apply a linear autoregressive (AR) model with the GJR-GARCH(1,1) process. They also divide the whole observations into two periods with 1997 financial crisis being the dividing point. Empirical evidence shows three main results of weather effects in the Korean Stock Market. The first one is that stock returns are higher in very low temperature days and lower in very high humidity days during the pre-financial crisis period. The evidence also indicates that very heavy cloud has

a negative influence on the Korean stock market. This finding proves that people's investment decisions are affected by weather effects in Korea. The second one is that weather effects becomes weak after 1997 financial crisis, the authors attribute this to the establishment of the electronic trading system resulting in reduced limitations to foreign investors. The third one is that the conditional volatility becomes higher when bad news are released. Overall, Yoon & Kang (2009: 682-690) believe that the weather effects indeed exists in the Korean stock market before financial crisis, especially in the extreme hot or cold days.

Kang provides another study of weather effects empirical evidence (Kang, et al. 2010: 91-99). Motivated by the studies mentioned above, the authors research the Shanghai stock market. Their aim is not only to examine the weather effects on stock returns, but also to investigate the relationship between weather and volatility of stocks. Since Shanghai stock exchange trades both A-share and B-share, which represent the domestic board and a foreign board, respectively. The authors collect daily stock prices for both the two shares from the beginning of 1996 to the end of 2007. It is noteworthy that B-share has been open to domestic investors since 2001. For weather data, they only use daily temperature, humidity, and sunshine duration in Shanghai. Because weather data are seasonal factors, the authors convert them into dummy variables according to different season. They follow the methodology of Yoon & Kang (2009: 682-690) and use 31-day moving average (MA) and moving standard deviation (MSD) methods. They consider both 21-day and 31-day methods. Based on the hypothesis which argues that local weather has more influence on domestic investors than on foreign investors, the authors obtain two main results from the analysis. First, weather effects work on A-share market both pre and post- opening of B-share. It only impacts B-share after the opening. This means that this opening makes domestic investors able to enter the B-share market and lead to the weather effects. Second, weather conditions affect strongly the volatility of both A and B share. Overall, the evidence proves the existence of weather effects in the Shanghai stock market.

A recent paper with empirical evidence in Malaysia also provides the significant association between weather and investor's behavior. (Brahmana, Rayenda , et al. 2014: 175-190) find out that there are not so many studies about the behind pushing factors of anomalies in the stock market (see e.g. Chin & Abdullah 2013: 5-18; Kudryavtsev, et al. 2013: 33-53). In order to give some empirical analysis of this unsolved problem, Brahmana and Rayenda collect Malaysian stock prices from 1999 to 2010 and consider it to be the dependent variable. They collect three stations daily temperature of Malaysia and calculate daily average temperature from 9 am to 5 pm which are trading hours of the three stations. The calculation is similar to (see e.g. Kramer & Runde 1997: 637-641; Saunders 1993: 1337-1345). After applying DOWA model (French 1980: 55–69), they get the results that temperature does affect investors' mood and this can cause anomalies in the stock market. In conclusion, mood fluctuations induced by temperature is one of the causes of The Monday effect in Malaysia. The summary of previous studies' empirical evidences in Asia is presented in table 3.

Table 3 Summary of previous studies in Asia.

Author	**Location**	**Stock data**	**Main weather factors**	**Correlation with stocks**
Chang et al. (2006)	Taiwan	Daily closing stock prices of the Taiwan Stock Market from 1997 to 2003	Temperature (Extremely hot or cold temperature)	Negative
			Cloud cover	Negative
			Humidity	No correlation
Shu (2008)	Taiwan	Daily stock returns in the Taiwan Stock Exchange	Good weather	Positive
			Bad weather	Negative

Table 3 Continued.

Author	Location	Stock data	Main weather factors	Correlation with stocks
Yoon & Kang (2009)	Korea	Daily closing prices of Korea Composite Stock Price Index 200 from 1990 to 2006	Temperature	Negative
			Humidity	Negative
			Cloud cover	Negative
Kang, et al. (2010)	China	daily stock prices of Shanghai Stock Exchange from 1996 to 2007	Extreme weather (low temperature + high sunshine)	Positive
			(low temperature +low sunshine)	
			(high temperature)	
			(high humidity + low sunshine)	Negative
			(low temperature + low humidity)	
			(low temperature)	
Brahmana, Rayenda , et al. (2014)	Malaysia	Stock prices of Malaysian Stock Exchange from 1999 to 2010	Temperature	Negative

3.4 Empirical Evidence from Oceania

There are some scholars in Oceania who provide plenty of empirical evidence of the stock prices fluctuations induced by weather effects. Stephen P. Keef and Melvin L. Roush, even do the research of the same location with different data. In 2003, Keef and Roush analyzed the New Zealand stock market firstly (Keef & Roush 2003: 61-79). Then, they extended their research 2 years later (Keef & Roush 2005: 415–437). After that, in order to examine their previous results, they collected Australian data and analyzed more about weather effects on Australian stock in 2007 (Keef & Roush 2007: 173-184). Aiming to give further evidence of the role that cloud cover plays on stock returns, they do another research of the international data (Keef & Roush 2007: 324-338).

Keef & Roush (2003: 61-79) is motivated by two strands studies: one has empirical evidence from psychology science that weather factors affect human's mood and behavior (see e.g. Hirshleifer & Shumway 2003: 1009-1032; Loughran & Schultz 2004: 343-364), the other one provides evidence from economics to show that mood fluctuations induced by weather affect stock returns (see e.g. Saunders 1993: 1337-1345; Trombley 1997: 11-21; Pardo & Valor 2003: 117-126). The authors collect stock data from 1986 to 2002. The stocks are all domestic companies and the index is value-weighted. The authors choose this data set as observations in their paper because it does not include the overseas companies. The weather data are collected for Wellington City with the same time period as stocks. They apply factor analysis based on eight weather variables. The most important variables in weather data are temperature, wind speed and cloud cover. The authors use both OLS model and Bootstrap tests to analyze the data. The results indicate that temperature does have an impact on stock returns in New Zealand but the influence is very slight. However, wind speed appears to exert a strong effect on stock returns. Cloud cover does not show any relationship with stock returns.

Keef and Roush want to extend the research of Keef & Roush (2003: 61-79). Firstly, they extend the financial data field: adding two financial securities including bank bills, and government bonds Secondly, they transform the weather data into 4 independent factors for 2 big cities: Wellington and Auckland. The factors are temperature, sunshine, wind in each city. Finally, they get the result that bank bills and sunshine have positive a correlation, while stock return and wind speed from Wellington have a negative correlation (Keef & Roush 2005: 415).

In order to examine if weather effects have universality, Keef and Roush decide to continue to analyze their neighbor Australia. They collect daily stock data of two stock indices in Australia and then use weather data of Sydney. As they did in their previous study, they keep using temperature; wind speed and cloud cover as the weather variables. Based on the regression analysis, the results show that in the Australian stock market, wind speed and cloud cover do not have an effect on stock returns, but temperature has been proved to have a negative correlation with stock returns (Keef & Roush 2007: 173-184).

Besides Keef & Roush (2007: 173-184), (Andrew 2009: 148-154) do a similar research of the Australian stock market. They are inspired by the behavioral finance studies which investigate the existence of weather effects in equity markets (see e.g. Mehra & Sah 2002: 869–887; Lucey & Dowling 2005: 337-355). The stock data are collected from 1958 to 2005 from Australian Securities Exchange (ASX) and Sydney Stock Exchange. The data contain 92% domestic companies in Australia. The weather data contain information of two stations of Sydney. There are 8 elements of weather used in the paper which includes precipitation, evaporation, humidity, temperature (both maximum and minimum), sunshine hour, wind speed and direction of maxim wind etc. The authors apply regression model to check the weather's influence on stock. However, they do not find any evidence to prove the relationship of these 8 elements with stock returns in Australia.

The summary of previous studies' empirical evidences in Oceania is presented in table 4.

Table 4 Summary of previous studies in Oceania.

Author	Location	Stock data	Main weather factors	Correlation with stocks
Keef & Roush (2003)	New Zealand	Daily stock returns in New Zealand Stock Exchange from 1986 to 2002	Temperature	Negative
			Sunshine hours	No correlation
			Wind speed	Negative
Keef & Roush (2005)	New Zealand	Daily stock returns, bank bills, government bonds in New Zealand Stock Exchange from 1980 to 2002	Sunshine hours	Positive
			Wind speed	Negative
Keef & Roush (2007)	Australia	Daily stock returns in Australian Stock Exchange from 1992 to 2003	Temperature	Negative
			Cloud cover	No correlation
			Wind speed	No correlation
Andrew (2009)	Australia	Daily closing prices from the Australian Securities Exchange and Sydney Stock Exchange from 1958 to 2005	Precipitation	No correlation
			Evaporation	
			Humidity	
			Temperature	
			Sunshine hour	
			Wind speed	
			Direction of maxim wind	

3.5 Empirical Evidence from Africa

Motivated by some researchers who believe that human moods can affect people's decisions and by the argument that when it comes to future event which people not very sure of, this effect appears to be more obvious (see e.g. Trombley 1997: 11-21; Loughran & Schultz 2004: 343-364; Tufan & Hamarat 2004: 117-126), Fatma Hammami and Ezzeddine Abaoub do a research in Tunisian Market and try to find the relationship between weather factors and daily stock prices to see if weather effects also works in Tunisian (Hammami & Abaoub 2010: 7-28).

They select five weather variables which they believe can impact investors' mood. The variables are sunshine, temperature, humidity, rain and wind. In order to make the test more relavent, all the weather data are daily and the location is the nearest place from exchange market. For stock prices, they choose daily closure prices. Both weather data and stock prices are collected from 1999 to 2006. Five variables are applied in Ordinary Least Squares (OLS) individually and combined. In the individual OLS test, the relationship between single weather variables and stock prices has been tested. The results show that each of the variables has high or low correlation with Tunisian stock prices. According to the regression, there is a positive correlation when sunshine is over 75%, while a negative one when sunshine is below 25%. Temperature, as the second variable, shows similar results as sunshine: coefficient is positive when temperature over 20 ° and negative coefficient when it is below 10 °. This also confirms the findings of previous studies by Lucey & Dowling (2005: 337-355). The regression result also presents a correlation of humidity and stock prices: it is a negative coefficient when humidity is over 94%. The same results also happened to the fourth and fifth variables: rain and wind have negative correlation with the stock market when they are above the normal level. Through the combined regression, they find that results are similar with individual ones. It is worth to be noticed that the dummy variables they created, good weather and bad weather, are significantly correlated with stock prices. Good weather with positive coefficients and bad

weather with negative coefficients. The empirical evidence from Tunisian proves the weather effects.

The summary of previous studies' empirical evidences in Africa is presented in table 5.

Table 5 Summary of previous studies in Africa.

Author	**Location**	**Stock data**	**Main weather factors**	**Correlation with stocks**
Hammami & Abaoub 2010	Tunisia	Daily closure prices of BVMT and TUNINDEX indexes from 1999 to 2006	Sunshine	Positive
			Temperature	Positive
			Humidity	Negative
			Rain	Negative
			Wind	Negative

3.6 International Empirical Evidence

As mentioned above, some economists prefer to analyze the international weather and stock data rather than focus on one country. They believe multiple countries' data are more convincing, especially when it comes to weather effects (see e.g. Hirshleifer & Shumway 2003: 1009-1032; Cao & Wei 2005: 1559-1573).

Motivated by Saunders (1993: 1337-1345), Hirshleifer & Shumway (2003: 1009-1032) extend the research to the global one. They collect weather data from 26 financial centers in different countries in the world. To be more specific, they calculate the daily average cloud

cover and weekly average cloudiness value. Meanwhile they also use rain and snow to be the observations. The observation time is 15 years from 1982 to 1997. To find the dependent variable, they use daily stock returns from the target countries which provide weather data of the same time period. Instead of time series data, they use panel data. After examining the world sunshine effect, they find the significant global correlation between weather and stocks. They find that the cloud has shown an negative effect on equity returns in 18 cities 4 of which have a significant effect. In a word, the authors believe that the high level of cloud may leads to the low stock returns and this phenomenon is global.

In 2005, Cao & Wei (2005: 1559-1573) re-test the international data to see if some other elements of weather still can affect stock returns. After analyzing weather and stock data from more than 20 countries, among which 8 countries are examined deeply, they find a negative correlation between temperature and stock returns. They believe that low temperature makes people more aggressive, which can help investors to make risky decision and lead to a higher stock returns. Although the result is significant, it cannot be taken as a widespread effect.

The summary of international empirical evidence of weather effects is presented in table 6.

Table 6 Summary of international empirical evidence of weather effects.

Author	Location	Stock data	Main weather factors	Correlation with stocks
Hirshleifer & Shumway (2003)	26 cities	Daily stock returns from 1982 to 1997	Cloud cover	Negative in 18 cities
Cao & Wei (2005)	20 countries	Daily stock returns, from 1962 to 2001	Temperature (average of daily maximum and minimum temperature)	Negative

4. DATA

In order to find the correlation between weather factors and stock prices, I use two data sets. One is the weather data of the United States, and to be more specific New York City. The other one is the stock prices.

4.1 Weather Data

Weather elements are the most important variables which can affect investors' mood in the stock market in this thesis. In order to find the most appropriate data to be analyzed, I collect daily weather data from National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA) (www.ncdc.noaa.gov) of New York City, LaGuardia airport station. LaGuardia airport station is the closest climate collected station to New York Stock Exchange in geography. The source is the same as used by Hirshleifer & Shumway (2003: 1009-1032) and Loughran & Schultz (2004: 343-364). The daily weather data include five weather variables: Precipitation, Snowfall, Maximum temperature, Minimum temperature and Average daily wind speed, over a period from October 3rd, 1994 (Monday) to October 1st, 2014 (Wednesday), totally 7304 days. I use the average value of maximum temperature and minimum temperature as the average daily temperature. Since the stock market is closed on weekends and holidays, I match the weather data with daily stock prices. Finally, 5036 days are selected as the effective observations days.

Meanwhile, 199 severe events in New York City have been recorded in NCDC within the same time period mentioned above. According to the Storm Events Database of NCDC, 23 types of severe events include tornado, blizzard, flood, heavy snow, storm, heavy rain, fog, thunderstorm wind etc., occurred in New York City and caused lots of deaths and injuries.

Saunders points out that "extreme weather affect returns considerably more." (Saunders 1993: 1337-1345). Akhtari (2011: 51-70) also creates two extreme weather dummy variables like Saunders in his study. Since these researchers believe extreme weather conditions have more effects on stock prices, it is worth to investigate if severe events, which contain most extreme factors of weather, have any special effects in the stock market.

After the match with stock date, 118 severe events are left as the effective observations. The severe weather data contain the information of Deaths, Injuries and Property Damage. Table 7 presents the summary information of severe events.

Table 7 Summary information of severe events.

Events		**Number of days of attacks**	**Quantity**
Event Types	23		
Deaths		12	28 People
Injuries		22	24 People
Property Damage		20	451500 Dollar

I assign 5 levels of each daily weather variable. The detail information of these variables is presented in Figure 1~4. As can be seen from the figure, there are 3339 days with daily precipitation equal to 0 which accounts for more than 66% of total 5036 observation days, and only 69 days with precipitation over 40 millimeters per day which is less than 2% of total. Similar to precipitation, daily snow fall equal to 0 takes more than 96% of the total observation days. Only 59 days with daily snow fall over 5 millimeters. As for the average daily temperature of New York City, it is distributed more uniformly than other variables. 4572 days are found to have the daily average temperature between 20 ℃ to 30 ℃ which

takes more than 90% of total, the days with extreme temperature: below 10 ℃ or above 30 ℃, only takes the other 10%.

For the last daily variable of weather, it can be found that wind speed between 3 to 5 meters per second is the largest proportion wind data, with 3481 days and takes more than half of total observation days. Strong wind days with speed over 7 meters per second only take no more than 3% of total.

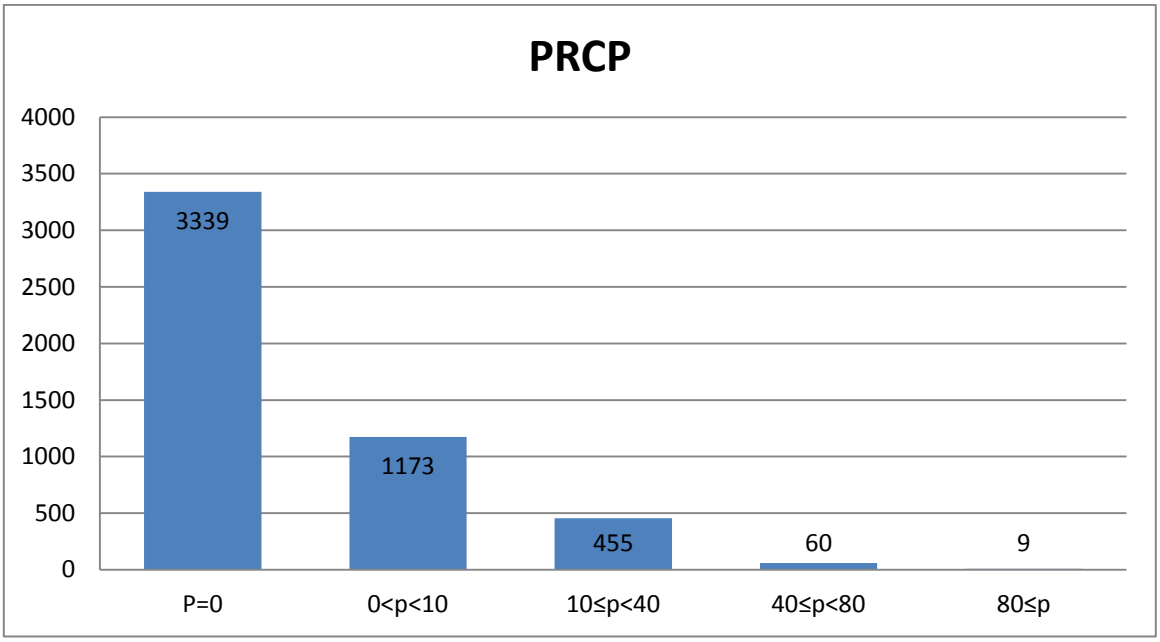

Figure 1 Daily precipitation distribution.

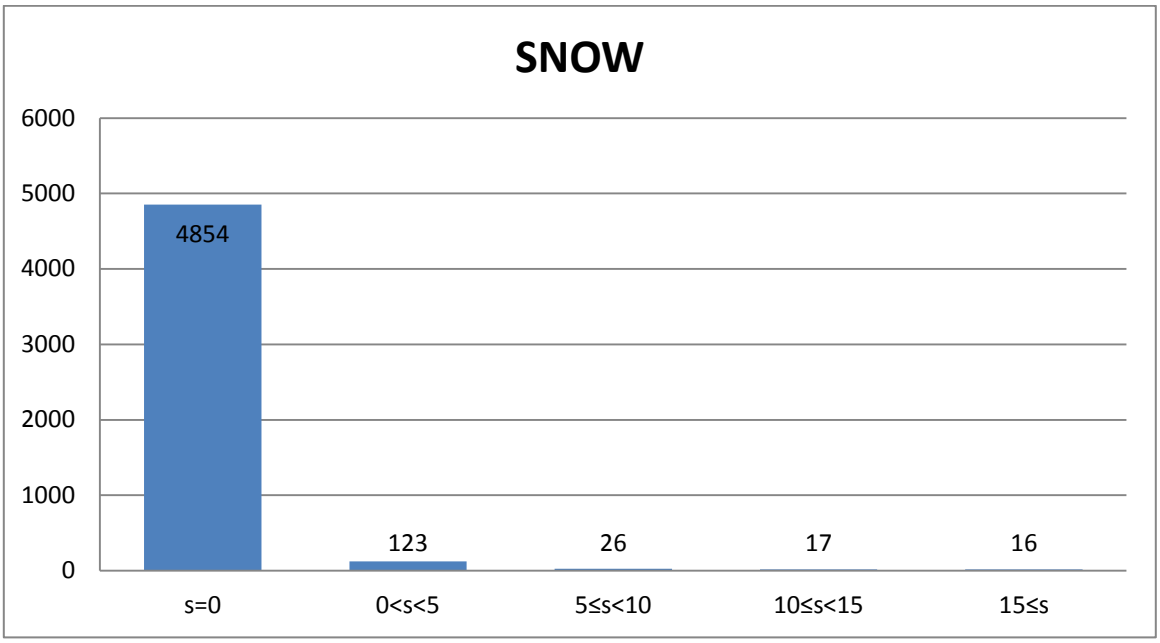

Figure 2 Daily snowfall distribution.

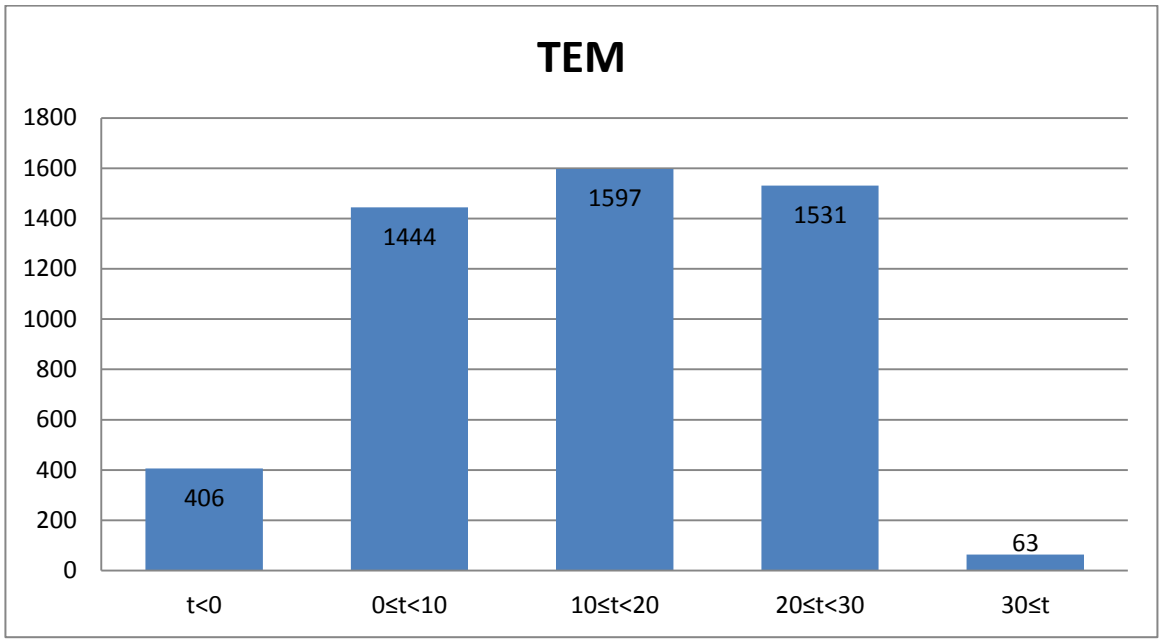

Figure 3 Average daily temperature distribution.

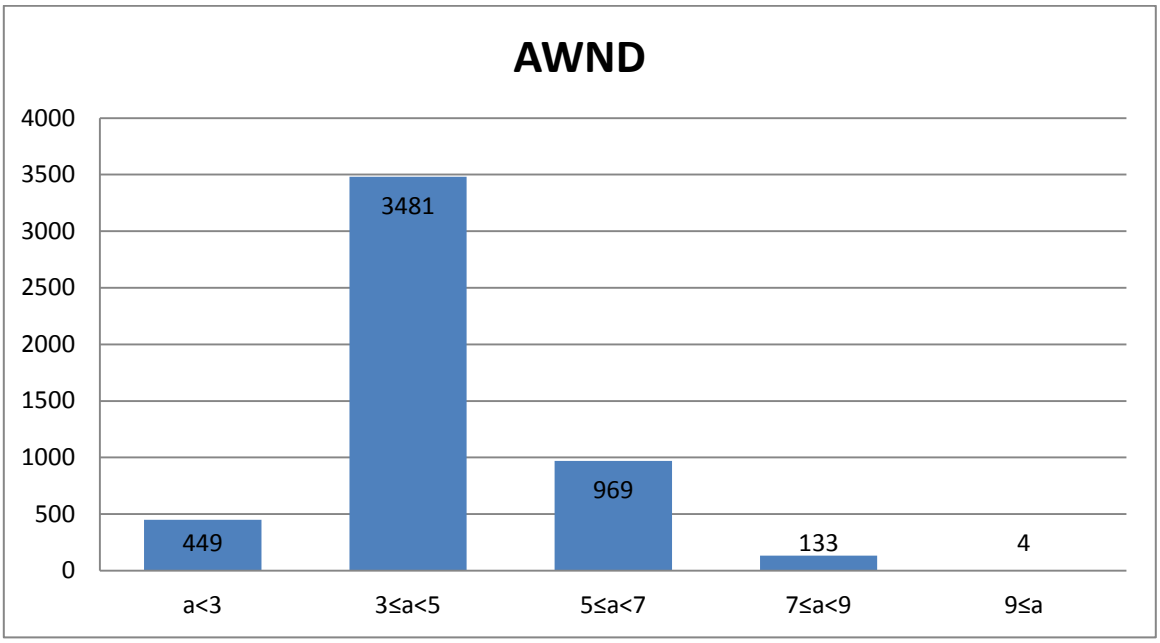

Figure 4 Average daily wind speed distribution.

4.2 Stock Market Data

The stock data employed in this thesis are daily closure stock prices logarithm. I collected daily closure stock prices of National Association of Securities Dealers Automated Quotations (NASDAQ) Index from Yahoo Finance over the period from October 3st, 1994 to October 1st, 2014, totally 5036 days. Companies registered in NASDAQ are smaller than the companies listed in New York Stock Exchange (NYSE). I choose NASDAQ data because its price appears to be easier affected by local weather compare with other stock indexes. According to Coval & Moskowitz (1999: 2045-2073), fund managers may have biases when they make investments. These biases appear graver in small companies than big companies. Moreover, Zhu (Zhu 2002) also find a similar phenomenon when he investigates the individual investors. Besides the size of company, the list time of company in NASDAQ is another reason for NASDAQ index to be used in this thesis. It is well known that share ownership will scatter over time. Companies in NASDAQ are newer listed and this makes their shareholders are closer to the companies' location. Table 8

presents the definitions and units of measure of daily weather variables, severe events variables and stock variables.

Table 8 Definitions and measure units of weather data and stock data.

Variable	Definition and Measure unit
PRCP	Amount of daily precipitation measured in Millimeters (mm)
SNOW	Amount of daily snowfall measured in Millimeters (mm)
TEM	Average daily temperature of the day measured in Degrees C
AWND	Average daily wind speed measured in Meters per second
G	Good weather
B	Bad weather
Dth	Deaths number in the severe event
Inj	Injuries number in the severe event
PrD	Property Damage in the severe event measured in Dollar
R	Daily closure stock prices logarithm of NASDAQ Composite Index

The trends of these stock variables are presented in Figure 5 and Figure 6. The highest closure stock price of NASDAQ Composite Index was 5048.62 which occurred on March 10th, 2000 and the lowest one was 719.05 on Dec. 9th, 1994. It is easy to find out in figure 2 that after the 1998 financial crisis, the stock prices began to rise. However, 2 years later, the prices went down until the beginning of 2003. There was another drop of the stock market in 2008 while after that, stock prices keep raising.

Figure 6 indicates the movements of stock prices of NASDAQ composite index. As can be seen, the highest return occurred in 2000, to be more specific 13 April 2000. The lowest return occurred in 2001, on 2ed January 2001 actually. The stock prices volatility presents

really high during 1998 and 2008 financial crisis. More detailed descriptive statistics of both daily weather variables and stock returns are presented in Table 9.

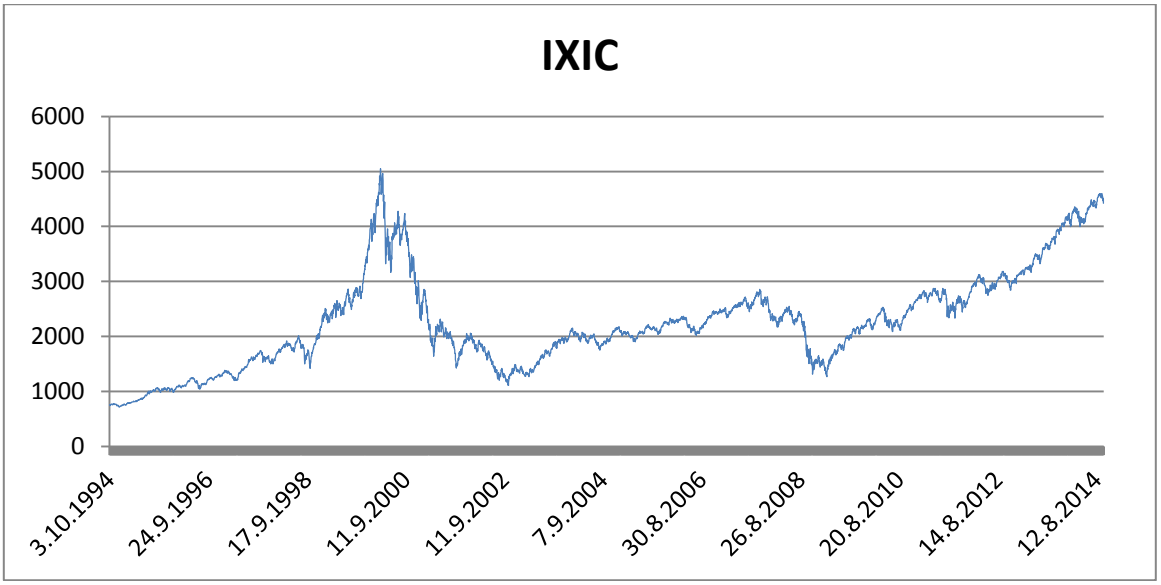

Figure 5 Daily closure stock price of NASDAQ Composite Index, 1994-2014.

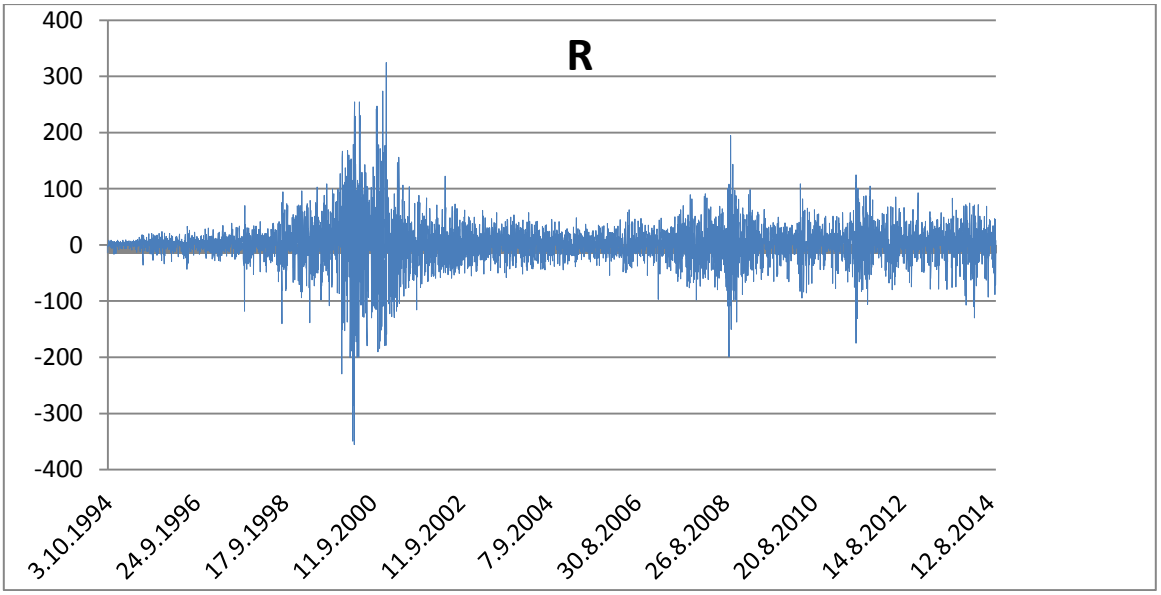

Figure 6 Daily stock returns of NASDAQ Composite Index, 1994-2014.

Table 9 Descriptive statistics of daily weather variables and stock prices.

	PRCP	**SNOW**	**TEM**	**AWND**	**R**
Mean	3.25	0.18	13.65	4.84	7.64
Median	0.00	0.00	13.85	4.50	7.67
Maximum	133.60	26.40	34.70	13.20	8.53
Minimum	0.00	0.00	-11.15	0.00	6.58
Std. Dev.	9.20	1.45	9.48	1.73	0.40
Skewness	5.19	10.73	-0.16	1.00	-0.34
Kurtosis	41.38	133.42	2.07	4.04	2.97
Jarque-Bera	331756.00	3665583.00	202.94	1068.46	98.98
Probability	0.00	0.00	0.00	0.00	0.00
Sum	16351.30	910.00	68729.40	24370.60	38485.75
Sum Sq. Dev.	426327.80	10574.20	452529.80	15070.83	796.75
Observations	5036	5036	5036	5036	5036

5. METHODOLOGY

5.1 Previous Approach

In order to examine the relationship between weather and stock, plenty of methods have been used in previous studies. Some traditional approaches, such as Ordinary Least Squares (OLS) regression is used in many studies (see e.g. Keef & Roush 2003: 61-79; Lucey & Dowling 2005: 337-355). In Keef & Roush (2003: 61-79), the authors apply both OLS and Bootstrap tests as the approaches to analyze the data. They find the different influences of temperature, cloud cover and wind on stock prices in the New Zealand stock market.

Lucey & Dowling (2005: 337-355) use three approaches in their paper: OLS, Least Absolute Deviation (LAD) and Trimmed Least Squares (TLS). Through those tests, Lucy and Dowling confirm the positive relationship between humidity and stock prices in the Irish stock market.

Unit root test is also a popular method to be used to examine a relationship. Not only the traditional unit root test, but also the non-linear unit root test are employed in Chang et al. (2006: 343–354). The author creates the non-linear unit root test equation according to KSS test (Kapetanios, et al. 2003: 359–379). Moreover, threshold model with GJR- GARCH(1,1) model is also been used in his paper. According to those two tests, the authors prove that temperature and cloud cover can affect stock prices in Taiwan market. Same with Chang, Yoon & Kang (2009: 682-690) also apply a linear autoregressive (AR) model with the GJR-GARCH(1,1) process in their paper. They divide the whole observations into two periods by 1997 financial crisis and get different results according to the dividing point.

Floros (2011: 5-13) make a change on GARCH model with some assumptions for the errors, such as normal, Student's-t and GED. Through this AR(1)-TGARCH(1,1) model, he

find the empirical evidence of weather effects, the January effect and trading month effects in the Portugal stock market.

Besides GARCH model, DOWA model is another method which is used in literatures commonly. Brahmana et al. (2014: 175-190) adapt this model from French (1980: 55-69), they create another four models based on DOWA by adding some dummy variables according to their demands. After analyzing, they prove that investors' moods affect their decisions in the stock market and may cause the Monday effect in the Malaysia stock market.

5.2 Applying Methodology

The main empirical methodology used in this thesis is OLS Regression Model, which is inspired by Hammami & Abaoub (2010: 7-28). Basically I use daily stock prices logarithm as dependent variable. There are two sets of independent variables. One set is the four factors of daily weather data: Precipitation (PRCP), Snowfall (SNOW), Average daily temperature (TEM), and Average daily wind speed (AWND). The other one is the three factors of severe events: Deaths, Injuries and Property Damage.

With the aim of checking influences of different weather variables on stock prices, several tests are applied in the thesis. Individual weather variable test is used to find the correlation of each weather factor and stock prices. Combined weather variable test is used to check the influences of different type of weather on stock prices. Severe events test is used to investigate the influences of special weather events on the stock market. Robustness Checks is used to check other anomalies in the stock market, such as the Monday effect and the January effect.

5.2.1 Daily Weather Variables Tests

The linear relationships between each daily weather variable and daily stock prices of NASDAQ composite index have been checked in the thesis. The precipitation varies between 0 millimeters and 133.6 millimeters per day. Hypothesis 1 and equation have been written as follows:

H1: Great precipitation amount corresponds to low stock prices.

(1) $R_t = a + \beta_p PRCP_t + \varepsilon$

where R_t represents the daily stock prices logarithm of IXIC at day t, $PRCP_t$ represents the daily precipitation at day t.

In order to have a further examination of precipitation, one dummy variable has been created: PRCP>3.25 when the daily precipitation is more than 3.25 millimeters (the daily mean precipitation), it equals to 1, 0 otherwise. PRCP>3.25 represents negative weather. The equation is written as follows:

(2) $R_t = a + \beta_p PRCP_t^{>3.25} + \varepsilon$

The snowfall variable varies between 0 millimeters and 26.4 millimeters per day. Hypothesis 2 and the equation have been created as follows:

H2: Great snowfall amount corresponds to low stock prices.

(3) $R_t = a + \beta_s SNOW_t + \varepsilon$

A dummy variable of snowfall has been created: SNOW>0.18 when the daily snowfall is more than daily average snowfall: 0.18 millimeters, it equals to 1, 0 otherwise. It represents negative weather. The equation is written as follows:

(4) $R_t = a + \beta_s SNOW_t^{>0.18} + \varepsilon$

As for the temperature variable, I calculate the average daily temperature according to the original data: maximum and minimum temperature. The average daily temperature varies between -11.15℃ to 34.7℃. The Hypothesis 3 and equation have been created as follows:

H3: High temperature will be associated with high stock prices.

(5) $R_t = a + \beta_{tem} TEM_t + \varepsilon$

Same with precipitation and snowfall, I have created two dummy variables to check the influence of the average daily temperature on stock prices, these two dummies are: TEM>20 when the average daily temperature of a day is over 20℃, it equals to 1, 0 otherwise; TEM<10 when the average daily temperature is lower than 10℃, it equals to 1, 0 otherwise. They represent positive and negative weather situation respectively. The equation is written as follows:

(6) $R_t = a + \beta_{tem1} TEM_t^{>20} + \beta_{tem2} TEM_t^{<10} + \varepsilon$

For the last variable: average daily wind speed, it varies between 0 meters and 13.2 meters per second. The Hypothesis 4 and equation have been written as follows:

H4: High wind speed levels correspond to low stock prices.

(7) $R_t = a + \beta_a AWND_t + \varepsilon$

According the wind data, 5 meters per second is calculated as the average wind speed. The dummy variable is created as bellow: AWND>4.84 when the average daily wind speed is no more than 4.84 meters per second, it equals to 1, 0 otherwise. It represents negative weather situation. The equation is written as follows:

(8) $R_t = a + \beta_{awnd} AWND_t^{>4.84} + \varepsilon$

In addition to the individual tests, two kinds of combined tests of daily weather variables are employed in the thesis. In the first one I combine all the independent variables into a single regression as follows:

(9) $R_t = a + \beta_p PRCP_t + \beta_s SNOW_t + \beta_{tem} TEM_t + \beta_a AWND_t + \varepsilon$

In the second combined test, I create two dummy variables of weather: good weather (G) and bad weather (B). It is assumed that the day with temperature over the daily average 13.65℃, and the average daily wind speed less than 4.84 meters per second, the day is recognized as good weather and this Good Weather dummy equals 1 and 0 otherwise. For the Bad Weather, I assume that the day with daily precipitation over 40 millimeters, or the snowfall over 10 millimeters, or average temperature below 0℃, or average daily wind speed exceed 4.84 meters per second, the day is recognized as bad weather. This Bad Weather dummy equals 1 and 0 otherwise. For the first step, I put each of them into one regression to see their influence individually. Then I apply these two dummies into one regression as independent variables to check the relationship between them and the stock prices. Based on these two dummy variables, the Hypothesis 5 and equations are written as follows:

H5: Good weather leads to high stock prices and bad weather cause low stock prices

(10) $R_t = a + \beta_g G_t + \varepsilon$

(11) $R_t = a + \beta_b B_t + \varepsilon$

(12) $R_t = a + \beta_g G_t + \beta_b B_t + \varepsilon$

5.2.2 Severe Events Tests

As mentioned above, several studies point out that extreme weather conditions have more influences on stock returns (Saunders 1993: 1337-1345). Some researchers (Kang, et al. 2010: 91-99) create several dummy variables of extreme weather and get different results. The authors prove that 3 of the dummy variables have significant positive relationship with stock returns and the other 3 present significant negative correlations with stock returns. If extreme weather have such influence in the stock market, storms or other severe events probably have more significant effects on stock returns.

Since there are almost 200 sever events recorded in New York City, it is worth to examine the influences of these sever events of New York City on stock prices. Two steps are applied in this thesis. First, I match the stock prices days with severe events days and finally get 118 effective observations. Second, I create the OLS regression based on the stock prices and three variables (Deaths, Injuries and Property Damage). Similar with daily weather variables tests, I apply both individual test and combined test of severe events. The regressions are written as below:

(13) $R_t = a + \beta_d Dth_t + \varepsilon$

(14) $R_t = \mathrm{a} + Inj_t + \varepsilon$

(15) $R_t = \mathrm{a} + PrD_t + \varepsilon$

(16) $R_t = \mathrm{a} + \beta_d Dth_t + \beta_i Inj_t + \beta_{prd} PrD_t + \varepsilon$

5.2.3 Robustness Checks: The Monday and January Effects

Besides weather effects, calendar effects are another important anomalies in the stock market. In order to find a comprehensive relationship between those anomalies and stock prices, I employ the robustness checks of two famous calendar events: The Monday and January effects. In the robustness checks, I create another two dummy variables: the first one is Monday (M) and the second one is January (J). It is assumed that when the day is Monday, the dummy equals 1 and 0 otherwise. For January dummy, I assume if the observation day is a day of January, the dummy equals 1 and 0 otherwise. I combine them into (9) and (12) respectively, the equations are written as follows:

(17) $R_t = \mathrm{a} + \beta_p PRCP_t + \beta_s SNOW_t + \beta_{tem} TEM_t + \beta_a AWND_t + \beta_m M_m + \beta_j J_j + \varepsilon$

(18) $P_t = \mathrm{a} + \beta_g G_t + \beta_b B_t + \beta_m M_m + \beta_j J_j + \varepsilon$

6. EMPIRICAL RESULTS

6.1 Daily Weather Variables Tests

As mentioned above, daily stock prices logarithm of NASDAQ composite index are used as dependent variables, daily weather factors and dummy variables: good weather and bad weather are used as independent variables. The results of daily weather variables tests are presented in Table 10.

Table 10 Results of weather factors and stock prices regressions.

Equation No.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
1	C	7.639813	0.005944	1285.275	0.0000
	PRCP	0.000713	0.000609	1.169784	0.2421
2	C	7.641758	0.006234	1225.881	0.0000
	PRCP>3.25	0.001932	0.014255	0.135524	0.8922
3	C	7.641806	0.005649	1352.677	0.0000
	SNOW	0.001777	0.003869	0.459417	0.6460
4	C	7.642670	0.005710	1338.451	0.0000
	SNOW>0.18	-0.015013	0.030037	-0.499835	0.6172
5	C	7.613751	0.009815	775.7233	0.0000
	TEM	0.002079	0.000591	3.520097	**0.0004**

Table 10 Continued.

Equation No.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
6	C	7.635096	0.009789	779.9496	0.0000
	TEM<10	-0.010493	0.013464	-0.779293	0.4358
	TEM>20	0.035585	0.014085	2.526507	**0.0116**
7	C	7.733518	0.016598	465.9274	0.0000
	AWND	-0.018885	0.003230	-5.847323	**0.0000**
8	C	7.662236	0.007319	1046.896	0.0000
	AWND>4.84	-0.048407	0.011356	-4.262774	**0.0000**
9	C	7.713689	0.022738	339.2441	0.0000
	PRCP	0.001035	0.000620	1.670352	**0.0949**
	SNOW	0.004770	0.003968	1.201998	0.2294
	TEM	0.000891	0.000653	1.364237	0.1726
	AWND	-0.018173	0.003554	-5.113105	**0.0000**
10	C	7.621745	0.007032	1083.823	0.0000
	G	0.055484	0.011603	4.782093	**0.0000**
11	C	7.660541	0.007495	1022.110	0.0000
	B	-0.041658	0.011273	-3.695399	**0.0002**
12	C	7.629162	0.012555	607.6473	0.0000
	G	0.048183	0.015474	3.113713	**0.0019**
	B	-0.010713	0.015021	-0.713157	0.4758

As can be seen from table 10, no evidence proves the significant correlation between precipitation and stock prices in the individual tests. According to the results of equation 1 and 2, precipitation presents a positive correlation with stock prices. None of the coefficients reach the significance level because all the t-statistic values and p values of them are not significant. Consequently, the daily precipitation of New York City may not be a stable sign of stock prices of NASDAQ composite index. The results imply that precipitation cannot be used to predict stock prices.

In addition to precipitation, similar results can be found from the results of equation 3 and 4. The results indicate the correlation between daily snowfall amount and stock prices in New York City. Although the coefficient of daily snowfall is positive, the snowfall over 0.18 millimeters shows a negative correlation with stock prices. Moreover, neither the t nor p value is significant. Daily snowfall amount is proved as an inappropriate proxy to forecast the stock trend of NASDAQ composite index in New York City. The results of precipitation and snowfall are consistent with some previous studies (Pardo & Valor 2003: 117-126; Kramer & Runde 1997: 637-641).

As expected, temperature is discovered to have a close relationship with stock prices. Broadly speaking, the results of equation 5 and 6 indicate that daily average temperature of New York City has a significant positive correlation with stock prices of NASDAQ composite index. To be more specific, temperature below 10℃ presents a negative correlation while the temperature over 20℃ presents a positive one. The coefficient of temperature below 10℃ is not significant at all, but the coefficient of temperature over 20℃ is statistically significant at the level of 1%. According to the results, it can be conclude that temperature affects stock prices positively. As a result, higher temperature may cause higher stock prices and lower temperature may lead lower stock prices. The results are well confirmed hypothesis 3 in this thesis and are consistent with previous study (Hammami & Abaoub 2010: 7-28).

The examinations of equation 7 and 8 provide a consistent result with hypothesis 4. Average daily wind speed has been found highly related with stock prices and as expected, the coefficient is negative. Furthermore, both of the coefficients reach the statistical significance level at 1%. The results indicate that the higher wind speeds are, the lower stock prices are in NASDAQ. The conclusion is consistent with some studies in Oceania and Africa (Keef & Roush 2003: 61-79; Keef & Roush 2005: 415–437; Hammami & Abaoub 2010: 7-28)

In the first combined test, correlations between weather variables and stock prices are same with individual tests. However, the coefficient of precipitation becomes positively significant at the level of 5%, although the influence of precipitation is very small. The coefficient of daily average temperature becomes insignificant. In fact, the results of equation 9 indicate that only one weather factor has significant effect on stock prices: daily average wind speed. Consistent with previous researches, the coefficient is negative and approaches at statistically significance level 1%. The correlations among the weather factors have been ignored in this thesis and this could be the reason for the different results and insignificant coefficients of weather variables in this combined test.

For other combined tests, regressions present consistent results with the expectation in hypothesis 5. Both results of equation 10 and 11 are statistically significant at 1% level. Results of equation 12 show that compare with bad weather variable, good weather variable presents more obviously influence on stock prices. Besides, all three equations' results provide positive coefficients of good weather and negative coefficients of bad weather. In conclusion, good weather is one of the reasons of higher stock prices and bad weather may cause lower stock prices. The results are consistent with most of the previous researches (Shu 2008: 96-102; Hammami & Abaoub 2010: 7-28)

6.2 Severe Events Tests

Similar with daily weather variables tests, in severe events tests, daily stock prices logarithm of NASDAQ composite index are used as dependent variables and severe events variables are used as independent variables. The results of these tests are in table 11 and figure 7. As none of the variables is statistically significant, it can be concluded that the severe events may not have any stable relationship with stock prices.

Table 11 Results of severe events and stock prices.

Equation No.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
13	C	7.623322	0.035083	217.2941	0.0000
	DTH	0.021386	0.026569	0.804930	0.4225
14	C	7.636459	0.035050	217.8756	0.0000
	INJ	-0.039092	0.032998	-1.184680	0.2386
15	C	7.629144	0.034919	218.4813	0.0000
	PRD	-1.82E-07	1.23E-06	-0.148371	0.8823
16	C	7.631865	0.036107	211.3674	0.0000
	DTH	0.022370	0.026654	0.839286	0.4031
	INJ	-0.039997	0.033202	-1.204680	0.2308
	PRD	-1.49E-07	1.23E-06	-0.121075	0.9038

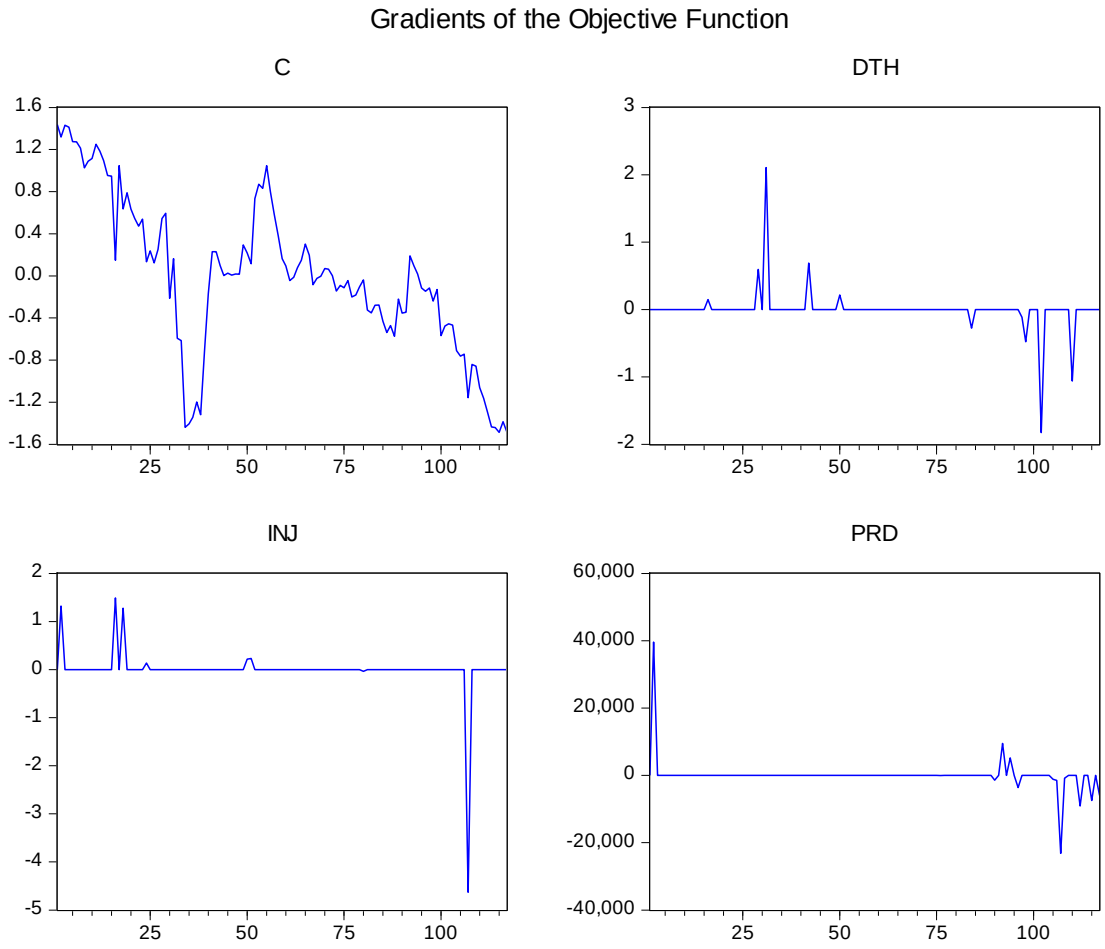

Figure 7 Gradients of severe events variables.

6.3 Robustness Checks: The Monday and January Effects

The OLS regressions are run to check other anomalies in the stock market, such as the Monday effect and the January effect. The results of the regressions are showed in table 12. As can be seen from the table, all correlations of daily weather variables and stock prices are consistent with previous findings in the thesis. To be more specific, precipitation, snow, temperature and good weather have positive correlations with stock prices. Furthermore,

wind speed, bad weather have negative correlation with stock prices. However, only wind speed and good weather present to have highly significant influence on stock prices. All the other variables' coefficients are neither very small nor insignificant. The results indicate that the Monday effect and the January effect are not always effective. At least they are not effective in New York City.

Table 12 Weather variables and calendar anomalies.

Equation No.	**Variable**	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
17	C	7.709942	0.023702	325.2877	0.0000
	PRCP	0.001037	0.000620	1.674028	**0.0942**
	SNOW	0.004684	0.003970	1.179872	0.2381
	TEM	0.001090	0.000702	1.553327	0.1204
	AWND	-0.018100	0.003557	-5.088243	**0.0000**
	M	-0.003855	0.014291	-0.269785	0.7873
	J	0.017380	0.022249	0.781143	0.4348
18	C	7.628127	0.013159	579.6804	0.0000
	G	0.049630	0.015682	3.164822	**0.0016**
	B	-0.010914	0.015029	-0.726167	0.4678
	M	-0.002313	0.014314	-0.161577	0.8716
	J	0.012655	0.021021	0.602016	0.5472

7. CONCLUSIONS

Some studies claim that climate change or fluctuation of weather factors may cause human moods bias. Furthermore, this moods bias may lead people to making different decisions in the stock market (see e.g. Howarth & Hoffman 1984: 15-23; Kramer & Runde 1997: 637-641; Kamstra, et al. 2000: 1005-1011; Pardo & Valor 2003: 117-126; Tufan & Hamarat 2004: 117-126). In order to provide more information for the investors who want to earn abnormal returns in the New York stock market, I write this thesis to find some empirical evidence of weather effects in New York City. The thesis analyzes how weather conditions affect human behavior and how the human mood fluctuations induced by the four weather elements in New York City affect stock prices of NASDAQ. Through running OLS regressions, 20 years data of both weather and stock prices are analyzed. I have discovered some statistically significant relationships between weather factors and stock prices.

Specifically, daily precipitation amount and snowfall amount present no significant influence on the stock market. Neither the values of precipitation nor snowfall reach the significant level. In individual tests, daily average temperature has statistically significant positive influence on stock prices. However, the temperature appears the same correlation in the combined tests but with an insignificant coefficient. The dummy variable: good weather, presents the same results as temperature. It is also highly positively related to stock prices in NASDAQ composite index. It reaches statistically significant level at 1%.

Another important element which has been found to have the closest relationship with stock prices is the wind speed. Average daily wind speed is proved to have negative correlation with stock prices in NASDAQ composite index. In addition, all coefficients of wind speed reach the statistically significant level at 1%, no matter be it in individual tests or combined tests. The results indicate that the average daily wind speed in New York City can be used as a clear sign to predict the stock prices of NASDAQ. The dummy variable: bad weather

also proves to have negative correlation with stock prices. However, compared with “good weather”, the coefficients of bad weather do not seem to be as significant as good weather, especially in the combined tests. For other tests, no significant evidence has been found to prove the influence of severe events on the stock market or the existence of the Monday and January effect in New York City.

Despite the two limitations in this thesis: the unmatched locations of weather and orders; the ignored correlation among weather factors, the empirical findings are still meaningful in the finance industry. The results of this thesis support the point in behavioral finance that psychologically condition should be taken into consideration in asset pricing model. In addition, this thesis has proved that investors’ decisions in the New York stock market can be affected by the fluctuations of investors’ mood induced by weather condition. Investors who want to forecast stock prices of NASDAQ and earn excess returns may benefit from this thesis. This evidence encourages us to do more research on predicting stock prices in the New York stock market.

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