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Study Project on the Development of Climate Option Pricing Model in the Chinese Economy

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Climate change impacts the world and weather risk has become an accepted risk management tool through Monte Carlo simulation. There is a great deal of general literature on the development of climate expected price. There is little specific guidance, however, on how to develop climate option pricing through more climate factors in the Chinese region. Using the four climate factors: rainfall, snow, temperature and the wind speed as an example, this paper will argue that Monte Carlo Simulation developed by Dischel in 1998 can provide a frame work for the two questions, " does each index number of each climate factor have normal standard distribution in the four cities, in Beijing, Hong Kong, Singapore and Taipei?" as well as " is there any fair pricing of weather options?"

Field of Research: Risk management, financial management, weather options

1. Introduction

"Weather is one of the main points that influences financial performance," and according to the World Meteorological Organization, around 50% of the financial performance of business will be influenced by the weather. Meteorological experts predict that the trends of adverse weather events, especially in China to continue (WorldBank 2011).

When the first weather management contract was signed in 1997, the United States became the first country to develop the concept of weather management. Weather management means to hedge against the risks and negative influences from weather. Weather risk, in turn, can be divided into the categories of types of wind, water, snow and temperature. In the West, industries have used the weather management to control their losses and adjust their strategies.

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China Review News in 2006 states that agriculture is the foundation industry in a country, and it is the most sensitive industry to climate change. There are some approaches which help to decrease the weather risk besides agricultural technique development, for example, the agricultural insurance. However, there are shortcomings in this form of traditional agricultural insurance. For instance, insurance companies usually do not agree to provide service in an area with frequent meteorological calamities, or the company would raise the fee. Hence, it is necessary to set up and improve step by step a weather risk management system of agriculture through weather options.

1.1 Aims and Objectives

The objective of this study is to find:

The Development of Climate Option Pricing Model in the Chinese Culture Region

This paper brings out several research questions according to the characteristics of Chinese area. First, does each index number of each climate factor have normal standard distribution in the four cities in Beijing/ Hong Kong/ Singapore/ Taipei? Second, are there any fair prices through the weather options? To develop the weather options for Chinese culture is the first purpose.

During the process to develop the weather options, it is necessary to coordinate meteorology and economics. Meteorology could provide information about weather then economics can open it up to business.

Research on the weather options market in China is still in its initial stage. Firstly, although there are some businesses accept the services with pay in weather information, most of people and society do not pay enough attention to this new issue. Many companies would prefer invest a lot of money in advertisements rather than purchase a weather service at a lower price.

Secondly, to add more climate factors for prediction, not only the temperature, but also wind speed, snow and raining are also included in the purpose of the study. This is because there are only rare categories of weather options in Chinese market and they do not provide sufficient analysis to business. Meteorology only provides non-profit and preliminary information to the general public, such as 24 hour weather forecasts, typhoon warnings, etc. However, business needs long-term weather analysis, such as a cost and benefit analysis related to climate change and weather

influence. Extensive information is meaningless and unable to help business create strategies to manage their risks based on weather.

In China, America Weather Services International（WSI）, Japan Weather news Inc.（WNI）have already established branches in Guangzhou and Shanghai, to provide oceanic meteorological information and guidance in this arena. WNI is the first foreign company to come into the China weather service market, and it has taken 70% market share of ocean shipping companies into both Guangzhou and Shanghai. Now, Meteorological Service of New Zealand Ltd is also providing guidance service to China Southern Airlines. However, it still has long road ahead if it is to persuade the public to accept paid services for weather information. This research helps to develop the local climate options.

In the U.S, weather options have been developed as a new management tool of agricultural risk from the experience of financial risk management in 1997. This important management factor includes temperature index futures, precipitation index futures, snowfall index futures, wind speed index futures, weather option contract, and weather exchange contract and so on. This paper will focus on the concept, related theories and application methods of these weather options. Finally, the author will point out what is necessarily and possible in developing weather options in the four major Chinese cities.

According to United Nations Environment Program (UNEP), the losses caused by the climate change and natural disasters will become double every 10 years. UNEP has predicted that the losses will increate to 150 billion dollars every year. Interestingly, however, the World Meteorological Organization (WMO) has also revealed that the commercial opportunity related to global climate factors reach up to 5.4 billion each year.

The weather options market is still growing world market and business has been eager to adopt this new item of weather risk management. In this way, it is making a positive contribution about industrial development.

The weather options in this paper include wind, water, snow and temperature. These four kinds of weather will be analyzed. Moreover, this paper help will help brokers with developing weather options so as to get a fair price.

2. Literature Review

Asia is one of the areas where climate option types are increasing fast (Clemons 2003), and the amount of climate contract increased from 445 to 815 during the last six years. Hence, the paper will analyze the four major cities in Chinese culture region (Beijing, Hong Kong, Singapore, and Taipei) to see if they are prepared to develop climate options. In the area of literatures review, the author also found that much of the Taiwanese literature only applies to the climate option pricing model of weather based on temperature. However, in this paper, the author has added snow, rain and wind speed as additional factors for research.

Weather option has been a new marketing management tool since the first contract was signed in the U.S.A in 1997 (Garman 2000). Research in the EBSCO database, conducted on October, 31, 2010 showed some 50 articles dealing with weather option. However, only seven of them discussed pricing models from 2000 to 2009. The author also found only 15 articles that focus on the development of weather option pricing models in the National Digital Library of Theses and Dissertation in Taiwan (NDLTD).

In 2003, the chairperson of Weather Risk Management Association (WRMA), Lynda Clemmons, stated that the number of climate options totals some 158 billion. The number of weather option contracts has increased by 195% since 2002, although the total value amount decreases from 43 billions to 42 billions.

Moreover, all the papers found in EBSCO and NDLTD apply the Monte Carlo Simulation method to get the expect price. Shiesh, for example, uses heating degree days (HDD) and cooling degree days (CDD) data to measure the weather and then uses Monte Carlo Simulation to get the fair price (Shiesh, 2003).

From this, we can see the research trend of weather option pricing models is still in the initial phase. At present, researchers mostly use the New York Weather futures as research sample source. For example, Ponssard has used temperature to be the main factor of weather (Ponssard, 2009), and of the other papers from two databases (EBSCO and NDLTD) use only one weather factor as a variable.

Before October 31, 2010, there are only 15 papers in Chinese local research, but no weather product has been developed. The author also follows that same process to get the weather distribution data and fair price, but does goes further to apply the four climate factors in four different cities.

During the literature review, it is necessarily to first gather sample weather data. Secondly, the author used mean-reversion concept to obtain long-term weather information. Finally, the author will use the Monte Carlo Simulation to get a random distribution of climate change situation. Using this information, the researcher will be able to define a current expected price in the four Asian/ Chinese culture regions.

3. Research Methodology

3.1 Research Hypothesis

The author has assumed that each index number of each climate factor has a normal standard distribution in each of the four cities, and from it we can get the different price in four cities.

3.2 The Research Process

The paragraph states how to do the research step by step. The first portion of this research is to get the margin degree of climate factors. First, the author uses the second-hand sample data of four cities, Beijing, Hong Kong, Singapore and Taipei, during 12 years from 1997 to 2010: Next, the author uses the Mini-tab to do Kolomogorove-smirnov distribution analysis (KS analysis) and calculate the normal distribution. Next, the author uses Geometric Brownian Motion and mean-reversion to find historical trends. This research has chosen mean-reversion in order to apply Monte Carlo Simulation in the next step. Before I get the margin degree of climate factors, I use EVIEW software to test the normal standard distribution. If we can get the normal standard distribution, we can do next step in the research process. Moreover, the paper would get the margin degree of climate factors (CDD/HDD). In the second portion of this research, the author begins to build the evaluation model. Firstly, the author uses Monte Carlo Simulation to find the trend of history. The next, we could understand how the price fluctuates from the pass to current. The simulation will impact the current price. The author will use the tool, Minitab, to analysis the data.

Next, the author tries to find the long and short term inflation by means of the historical volatility model and Exponential Weighted Moving Average. After that, the author has using CDD index formula- 0 to get the contract price of options, such as 1000 Taiwan Dollar X Max (CDD index- k, 0).

3.3 The Formulas

Many researches have found the climate option pricing model belongs to mean-reversion. If we can get the long term data, we can have more correct mean (Dische, 1998). According to Garman, HDD and CDD formula as the following (Garman 2000):
HDD =max (0, base temperature- daily average temperature)
CDD= Max (0, daily average temperature- base temperatue) (2-0)

Much of the research states that Dischel's model in 1998 is better because he has considered the factors of climate change and helps options to have flexible price and considered seasonal different. However, the shortcoming is that we need to calculate so many times for expected value.

The simulation assumes that the change of the set of investment is following the random process. Hence, we can use computer to find the simulation pricing trend until the result is credible. Next, we can design a profit distribution of the set of investment, and then to define the risk level. When the simulation result is much clearer, the average value would be dependable; It is the Law of Large Numbers.

Secondly, the author uses the D1 Model to get expected price, only when the D1 model is not able to predict the future weather because of model risk. Thirdly, we use the second-hand historical data to get the long-term average temperature and the short and long term inflation. We can find the trends of weather research through this model. Moreover, we can use D1 model on different types of weather such as rain, snow and wind speed- not only for the temperature. The problem here is that we need to perform many simulations to get the results. However, to solve the problem we can enlist the help of computer technology. In the research, the author would like to get the margin degree of climate factors defined by Geometric Brownian Motion (GBM) with the formula as following:

$dS/S = \mu\, dt + \sigma\, dz$ (2-1)

Next, we use Monte Carlo simulation to get proportion distribution and then find out the options' expected price.

Dischel states the most effect model is the D1 Model, established in 1998:

$dT=k [\theta (t)- T(T)] dt+ \sigma t\, dzt+ \sigma 2dz2$ (2-2)

dT= the instantaneous change in temperature
k=long-term temperature averages
θ (t)-the long-term temperature averages season circular, which change with time
T(t) the temperature change with time
dt: infinitesimally small unit of time
σ 1 and σ 2 are the short and long term weather inflation
Dz1, dz2 the random following with GBM

If we apply the factors more than one, the formula should be:

$$\Delta f_t = \left[\Delta f(1)_t \quad \Delta f(2)_t \cdots \Delta f(n)_t \right]^T = A \times \Delta Z_t$$

$$df(j)_t = \mu(j)_t \, f(j)_t \, dt + \sigma(j)_t \, f(j)_t \, dz \quad \text{(3-3)}$$

z means Wiener Process, dz means $dz = \varepsilon\sqrt{dt}$ and ε shows the standard normal distribution N(0,1)

$\mu(j)_t \, dt$, which means the expected returns of the j-th instantaneous risk factor in a short term.

σ (j), dz, which means the expected variance of the j-th instantaneous risk factor in a short term.

Next, the author applies the mean-reversion model of HDD/CDD option evaluation. The margin degree includes Heting Degree Day (HDD) and Cooling Degree Day (CDD) and the same level at other factors. Dichel in 1998 and Camara in 2006 has explained the characteristics of Monte Carlo simulation by the following seNtences (Camara 2006).

Moreover, not too many papers focus on the weather option price in Eastern Asian countries and those papers only use one climate factors. We can know mean-reversion is an important concept for this research. Hence, the author can use the Monte Carlo simulation to get the weather option expected price in Beijing/ Hong Kong/ Singapore/ Taipei with Excel and /or Minitab.

3.4 Data Information

The author has tried to get the secondary climate historical data between 1997 and 2007 from four cities' climate bureaus. The sample data shown below:

Taipei	J	F	M	A	M	J	J	A	S	O	V	D
HDD	21	23	23	24	24	27	27	28	26	23	21	20
CDD.	19	21	22	23	23	25	26	25	24	23	20	18

Table 3.1: The sample data

3.5 Research limitations

We could only use traditional Monte Carlo Simulation to do analysis because some researchers are still trying to define a newer and useable Monte Carlo Simulation model. Moreover, the author only analyzes four cities and the research period limited in the period between 1997 and 2010.

3.6 Significantly of the Study

It is important to have correct weather options to many kinds of industry. For example, if a baseball team plans to match at another place, the audience or the people who buy tickets should notice the weather prediction and weather options to predict how the weather might influence the result of game. Moreover, the difference between this and other research is that this researcher adds more climates factors and uses four cities in different countries.

4. The Example of Conclusion

After we complete an analysis of the data, we can have a new contract on demand. The author has assumed that the index number of each climate factor is different.

Hypothesis: Normal
Sample: 1 4000 Included observations 4000

	Method value	Adj.Value	Probabilities
Lillifors (D)	0.089741	NA	0.000
Cramer-Von Mises (W2)	9.99999	10. 0002	0.000
Watson (U2)	7.90005	7.90007	0.000
Anderson- Darling (A2)	58.4856	58.4985	0.000

Method:	Maximum methods- df. Corrected (Exact Solution)			
	Parameter	Value	Std.Error	Z –statistic Prob
MU	5.39134	0.02821	194.103	0.000
SIGMA	1.69441	0.01234	85.435	0.000
Log likelihood –7000.41		Mean dependent var 5.37		
No. of coefficients 2		S.D dependent var 1.68		

Table 4.1: The normal standard distribution analysis

New Contract	CDD/ HDD index options in which city
How much one contract	$ 1000 RMB or the same X CDD/HDD point
The basic price	CDD/HDD index
How much money added to next price	0.01 (10 RMB)
To finish the contract	HDD: 12, 1, 2, 3 CDD:6, 7,8,9
Date closing	On contract
Option	Asian options
The benefit closing	The point of the contract closing day
Business time	9:00 Am to 5:00 pm

Table 4.2: The content of contract

The price of contract	5 years		10 years	
Beijing	1000 RMB	1200RMB	1100 RMB	1300RMB
Singapore	700 RMB	800RMB	800 RMB	900RMB
Taipei	500 RMB	600RMB	610RMB	750RMB
Hong Kong	470 RMB	500RMB	550 RMB	650RMB
	HDD	CDD	HDD	CDD

Table 4.3: The price in the four cities

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