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On Weather Derivatives and Temperature Swapping In Japan

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Abstract.
Until recently, the meteorological disturbances to the management of economic entities had to be simply accepted; however, several financial tools have been developed, with which we can cancel out the adverse influence of meteorological events. This paper will intend to examine 2 types of tools, weather derivatives and temperature swapping, which have been shown to work in Japan.

Key Words: financial engineering, catastrophe risk, HDD(heating degree days), CDD(cooling degree days)

１． Introduction

In Japan, we have a saying that nobody can control the weather; it is an “Act of God”. The weather can exercise a great influence on the output of industry or firms, especially in the field of agriculture. Of course, while such entities can not control the weather, they can protect themselves from the potential bad influence of the weather by using any risk management tools.

Until recently, however, there have been no such effective tools. As Mizushima (2006) has emphasized, the insurance system does not work well in weather-related risky situation because the fluctuation of income due to changes in the weather almost always falls into the category of “speculative risk,” which is impossible to insure; and because, in most cases, changes in the weather are not subject to law of large numbers, on which the insurance system is based.

In recent years, weather derivatives have been developed in order to overcome such a limitation of insurance. In their earliest appearance, ENRON and Koch developed “energy derivatives” in August, 1997(cf. Hijikata(2000)). In June 1999, the Himalaya Co. of Japan signed a contract with the Mitsui-Sumitomo Marine & Fire Insurance Co. for a “Snow Depth Index Option.” After 3 more years, the scale of this market had expanded to an annual trade of ￥30 billion, and it continues to expand even more rapidly today.

There are 2 reasons why we focus on these new financial tools. First, on the supply side, financial engineering has made great advances. Here, financial engineering is defined as the quantitative method, with which investor can make various financial tools (so to speak “derivatives” such as option, swap, etc.) in order to hedge his risk and attain more gain with certainty. Second, on the demand side, not only expected profit but also its stability are highly valued, related to investor relations (IR), which has recently become one of the most important concepts in the securities market. In order to set stock value to the high level, any stock company must now keep its profit stabilized.

This paper will review two representative types of financial tools that help offset risks due to meteorological disturbances.

２． Scheme of Weather Derivatives

Generally speaking, if insurance becomes functionless against any risks, then ART (alternative risk transfer) emerges, which is a mode of risk transfer other than insurance. For example, in Fig.1, the

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alternatives are substitutes or complements for each other.

Fig.1. Classification of ART
Source: Swiss Reinsurance Company(2003), fig.4.

Here we follow the definition of weather derivatives given by the Japan Meteorological Agency(2002): “financial goods that compensate profit shortfalls because of extreme weather trends.” There are many types of trends(rain, snow, humidity, wind, etc.), but most are dominated by temperature (see Table. 1).

Table.1. Trades by Type of Contract, National Value of Contracts(Including CME)
Source: Results of the 2005 PwC Survey, Presentation to Weather Risk Management Association by John Stell, November 9, 2005.p.21(Price Watherhouse Coopers)

Thus, we will focus only on weather derivatives that use temperature as an index. For our temperature-related indexes, heating degree days (HDDs) and cooling degree days (CDDs) are defined as follows:

$$\text{daily HDD} \equiv \text{Max}(0,\ 65^{o}\text{F} - \text{daily average temperature}) \quad (1)$$

$$\text{daily CDD} \equiv \text{Max}(0,\ \text{daily average temperature} - 65^{o}\text{F}) \quad (2)$$

Here, daily average temperature
≡(maximal temperature from 0:00 to 24:00+minimal temperature from 0:00 to 24:00)/2

Equations (1) and (2) mean that we shall choice the larger variable out of the two in the right bracket. The temperature of 65 ^{o}F (ahrenheit) is equal to 18.33℃ (elsius),which is the most comfortable temperature for the average American and also “the benchmark which is the fork of hotness and coolness”(Hijikata(2000),p.19).

Equations (1) and (2) are calculated on a daily basis, but very often temperature derivatives are used on a cumulative basis. Transferring equations (1) and (2) into cumulative formulas, we obtain:

cumulative HDD
$$= \Sigma\, \text{Max}(0,\ 65^{o}\text{F} - \text{daily average temperature}) \quad (1)'$$

cumulative CDD
$$= \Sigma\, \text{Max}(0,\ \text{daily average temperature} - 65^{o}\text{F}) \quad (2)'$$

There are two types of weather derivatives: the option type and the swapping type. Here, we devote our attention only to the former; the latter will be reviewed in Section 3 below.

Fig. 2. Payoff of weather derivative (temperature put option) in a hypothetical refreshment drink company.
Source: Hijikata (2000), Fig.1-1.
Note: a little retouched

In Figure 2, we set the cumulative CDD to the horizontal axis, just like the market price of underlying assets in an option pricing model (OPM;

Black and Scholes (1973)). Both variables are "exogenous," meaning that no one can control them arbitrarily.

Now, let us review the CDD put option scheme by Hijikata (2000), which is used to protect the option-holder against a cool summer. First, we assume that during a cool summer, a hypothetical refreshment drink company will earn only half of its expected sales in July and August. Second, let us set the premise, based on existing records, that the company's balance sheet will be in the red of $15,000/CDD only if the average temperature is less than 78.7 ^{o}F. In this case, the company (option-holder) buys the put option, which is indemnified such that the option-writer will pay the holder $15,000/CDD only if the cumulative CDD is less than 850 ^{o}F (=31days x 2 months x (78.7 ^{o}F -65 ^{o}F)) from the beginning of August until the end of September. Here, we assume the upper limit of the option-writer's indemnity to be $3 million and the option premium be $0.5 million.

On the one side, the option-holder obtains the composite position, which is produced from a (vertical) summation of the original payoff (a straight line that passes the cumulative CDD of 850 ^{o}F with a tangent at 45^{o}) and the payoff of this put option, which is located in the cumulative CDD from 650 ^{o}F -850 ^{o}F as a fixed cost of $0.5 million in the 4th quadrant. In other words, this company's gain becomes stabilized. Here, we must take note of a kinking of the payoff line of this put option at cumulative CDD 650 ^{o}F. There are two reasons for this: (1) the option-holder can save option premium; (2) based on the past experience, it is rare for a cumulative CDD to be less than 650 ^{o}F. On the other side, the favorable composite position, at which the cumulative CDD is over 850 ^{o}F, takes the form of the 45^{o} angle and from the original payoff payment, i.e., an option premium equal to $0.5 million down.

３． Temperature Swap Scheme

In Section 2 above, we saw that the option-holder (risk-hedger) must pay a premium as a reward to the option-writer (risk-taker) in weather derivative trade. In contrast, no payment is performed ex ante in the swap transaction. Let us consider the interesting example of a temperature swap contract between the Tokyo Electric Power Company (TEP) and the Tokyo Gas Company, signed in July 2001 in Japan (Mizuho(2003), pp.49-50). The former had faced the risk of an unusually low demand for electric power for air conditioning because of a cool summer, while the latter had faced the risk of unusually low demand for gas to heat water because of a hot summer. Therefore, the two parties have conflicting interests with regard to summer temperature.

Here, we assume that the two companies reach to a break-even point in a moderate summer. Given this background, they establish a scheme of swapping the risk of an excessively hot summer with that of an excessively cool summer. The outline of the scheme is as follows:

1. The companies concerned directly (i.e., not through an intermediary) swap their own risks, by which
2. One of them shall make up for the other's deficit of excessive temperature by their respective gain.
3. They calculate the equivalent risk and make the transaction at no cost.
4. Their income and outflow are then theoretically cancelled out in the long-term contract.

Following this scheme, the TEP has selected the Tokyo Gas Co. as its partner. According to the "Response Analysis of Ordinary Profit" of these companies, it was determined that the profit structure showed a distinct reverse correlation, especially in summer, as shown in Figure 3.

Fig.3.Comparison of the revenues structure of the Tokyo Electric Power Co.and the Tokyo Gas Co.

Source: Mizuho(2003), p.78.

Therefore, these companies agreed upon a contract for swapping temperature risk, with the following details:

1. Term of contract: August 1, 2001 to September 30, 2001 (61 days)
2. Index: average temperature per day according to the Tokyo district meteorological observatory
3. Reference temperature: 26 ℃
4. Payment temperature on the side of the TEP: reference temperature+0.5 ℃ (=26.5 ℃)
5. Receivable temperature on the side of the TEP: reference temperature -0.5 ℃ (=25.5 ℃)
6. Maximal exchange amount: approximately ¥ 0.7 billion (reference temperature ±2.0 ℃)

This contract states that if the average temperature is higher than 26.5 ℃, the TEP must make a payment to the Tokyo Gas; inversely, if it is lower than 25.5 ℃, the Tokyo Gas must pay the TEP. The summer had cool temperature, so at the time when the contract expired, the Tokyo Gas paid the TEP ¥0.32 billion.

Fig. 4. Payoff line of temperature swapping of the Tokyo Electric Power
Source: Mizuho(2003). p.78.

Thus, as shown in Fig.4, the payoff line of the TEP with hedging has approached a horizontal line. This means that with the temperature swap contract, the gain of the TEP was stabilized with respect to temperature variance.

４. Conclusion

In the paper, we have reviewed two types of weather derivatives created in order to raise the value of an enterprise by stabilizing profit. We can not in this space estimate the prospects of these derivatives in the future, but we have had favorable reactions to date, both at home and overseas.

Let us cite here finally the comment of the Swiss Reinsurance Company (2003,p.40): "Weather derivatives were adopted mainly in energy sectors. These financial tools markets are vastly wide. The sales in the areas of agriculture, construction, sightseeing, clothing, foods and soft drink depend very greatly on the weather. According to some estimation, 33% of the U.S. Economy, i.e., $3.3 trillions, is influenced by the weather. As the weather derivatives market is growing up, more industries will become to make use of those derivatives, in order to hedge their undesirable outcome, which will be brought by meteorological variations."

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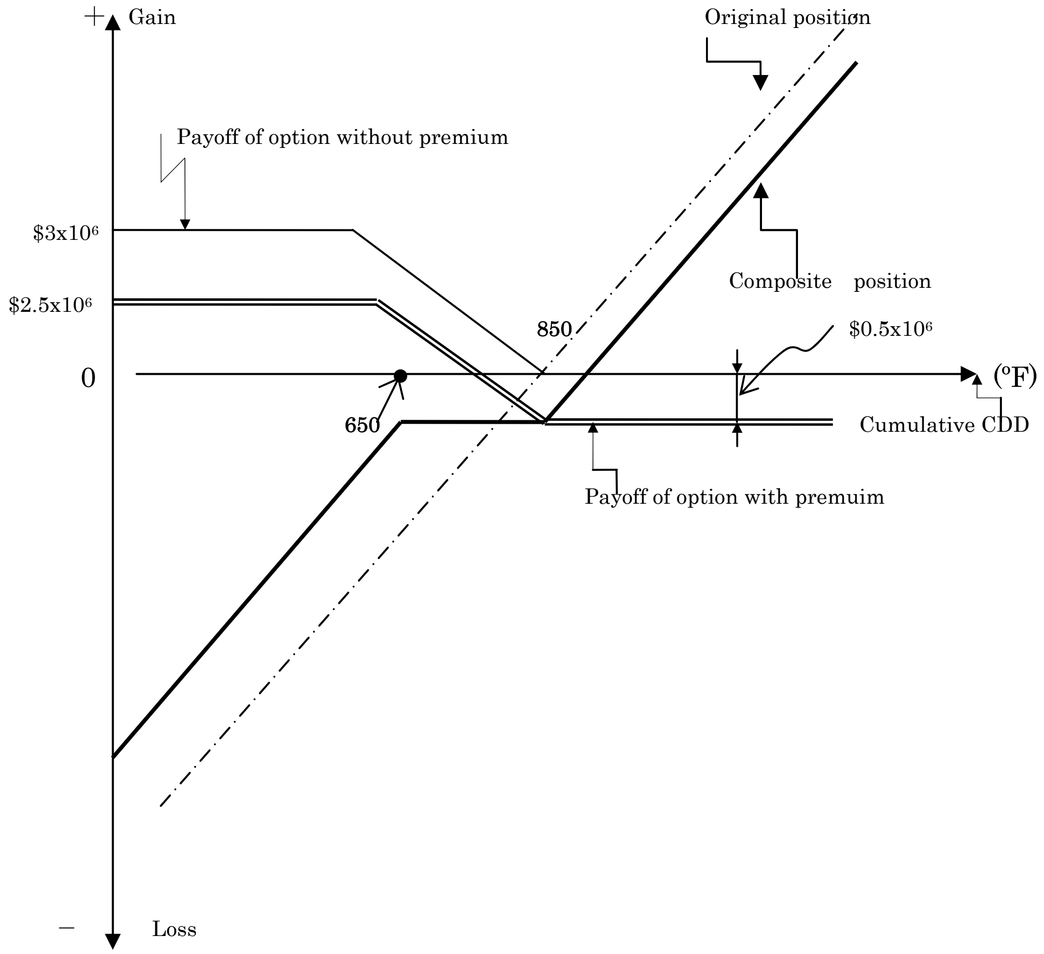
Fig. 1:

- alternative
  - risk carrier
    - self insurace/captive
    - risk retension group
    - pool
    - capital market
  - solution
    - finite risk (re-) insurance
    - contingent capital
    - MMP,MPT
    - new asset risk solution
    - weather derivatives
    - securitization/insurance-linked-security

Table 1.

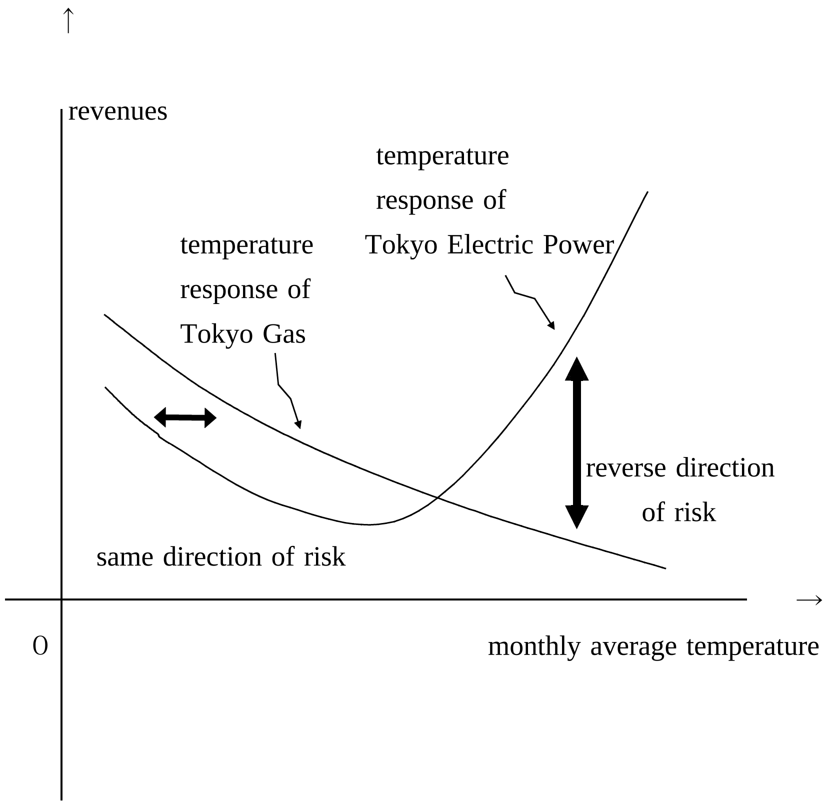
item that became to object	market share(%)	
date	2003/4	2004/5
HDD	57	56
CDD	19	35
Other Temperature	20	7
Other	4	2
Total	100	

Fig. 2：



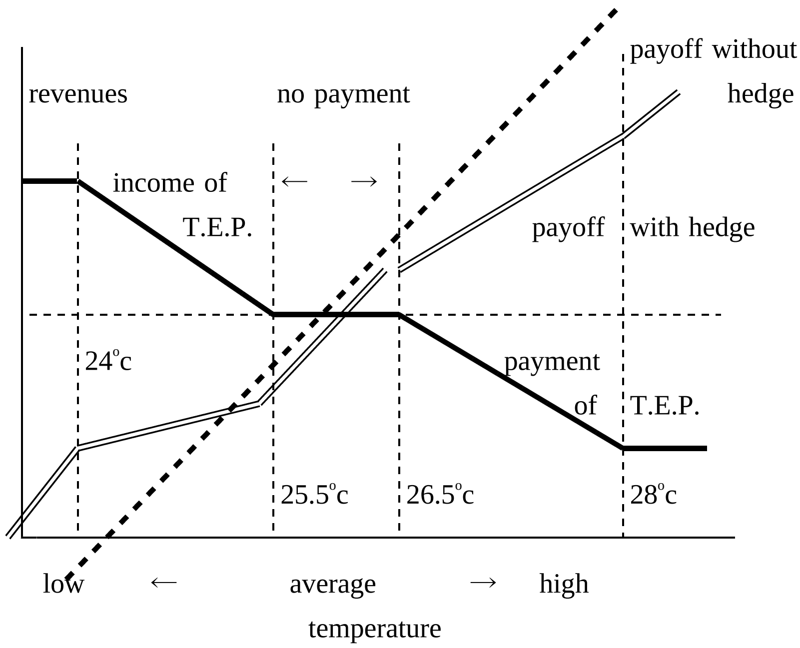
+
Gain
Original position
Payoff of option without premium
$3x10⁶
$2.5x10⁶
Composite position
850
$0.5x10⁶
0
(°F)
650
Cumulative CDD
Payoff of option with premuim
−
Loss

Fig. 3



revenues
temperature
response of
Tokyo Electric Power
temperature
response of
Tokyo Gas
reverse direction
of risk
same direction of risk
0
monthly average temperature

Fig. 4


revenues
no payment
payoff without
hedge
income of
T.E.P.
payoff with hedge
24°c
payment
of T.E.P.
25.5°c
26.5°c
28°c
low
average
high
temperature