# Weather derivatives and hedging the weather risks

Josef TAUŠER, Radek ČAJKA

*Department of International Trade, Faculty of International Relations, University of Economics, Prague, Czech Republic*

**Abstract**: The article focuses on weather derivatives with the aim to present the substance of weather derivatives as relatively new financial products and to discuss their advantages and disadvantages when being used as a tool to diminish the loses coming from these suboptimal weather conditions. We conclude with the findings that weather derivatives have a great potential to develop further. They provide an opportunity to hedge against the suboptimal weather conditions at reasonable costs. However, the hedging effectiveness is the main issue to be analyzed in each specific business case.

**Key words**: weather-related risks, hedging, weather derivatives

Weather and its changes affect different areas of human being. In many fields, these effects are straightforward and "bad" weather may cause serious financial damages to corporations and individuals (see for example Brockett 2005; Chincarin 2011). Although the traditional insurance can be effectively used to avoid high losses coming from the catastrophic events (e. g. hails), it does not provide an adequate solution to mitigate financial loses which are caused by suboptimal weather conditions (Cyr et al. 2010).

One of the main drivers of the weather derivatives market is the convergence of capital markets with insurance markets (Considine 2000). There is a growth in catastrophe bonds issued and catastrophe options traded. The introduction of weather derivatives at the end of 1990s was the next logical step in the weather risk securitization. Utilities have become the main user of weather derivatives, since their business is very often highly dependent on weather and its predictability or "normalcy". According to the CME (2012), nearly 30% of the U.S. economy is directly affected by the weather.

Thus, the aim of this paper is to present the substance of weather derivatives as relatively new financial products and to discuss their advantages and disadvantages when being used as a tool to diminish the loses coming from the suboptimal weather conditions.

## SUBSTANCE OF WEATHER DERIVATIVES – FUTURES

Weather derivatives are contracts, the value and payoff structure of which depend on the specified weather conditions. These contracts are mostly based on the temperature, rainfall, snowfall or wind. Although the basic list contains four weather characteristics only, there are many different ways how to structure the individual contracts. Thus the variety of products available is very high.

We will illustrate the basic idea of weather derivatives using an example of the so- called Weather Heating Degree Day (HDD) Futures which are traded on the Chicago Mercantile Exchange (CME).[1] The contract is standardized in terms of size, trading hours, contract moths and settlement procedures. The value of the contract depends on the CME Degree Days (HDD) Index which is computed as follows:

$$HDD = \max\left[65 - \frac{(Tmax + Tmin)}{2}, 0\right]$$

where:
65 = fixed reference temperature of 65 degrees Fahrenheit,[2]
*Tmax* = maximum temperature of the day,
*Tmin* = minimum temperature of the day.

Supported by the University of Economics, Prague (internal grant VŠE IGS F2/9/2012)

[1]For a detailed product specification see the web pages of Chicago Mercantile Exchange (CMR 2012): http://www.cmegroup.com/trading/weather/temperature/us-monthly-weather-heating_contract_specifications.html
[2]The number is set arbitrary. It is the temperature, from which people usually start to operate their heating devices.

For the purposes of the contract valuation and payoff determination, the index is cumulated over the lifetime of the contract. The price of the contract depends on the supply and demand and generally reflects the expectations about the final value of the cumulative HDD at the end of the contract maturity (Chincarini 2011).

Let us assume that at the beginning of March 2014, the price of the March 14 contract is set at 350, which means that the market expects the cumulative value of the HDD to be 350 at the end of March. Now, the buyer of the contract makes a profit if the cumulative value of HDD exceeds 350 and suffers a loss if it is less than 350. The amount of profit or loss depends also on the size of the contract, which is specified as USD 20 times the monthly index. Thus, if the cumulative value of HDD equals for instance 370, he/she makes:

$(370–350) \times 20 = \text{USD } 400$

We could look at this also from a different perspective. He/she buys the contract for the price of 350, which means that he/she pays USD 7000 (350 times 20). On the maturity day, h/she sells the contract for USD 7400 (370 times 20) which makes a profit of USD 400.

For the seller of the contract, the same logic applies, but vice versa. He/she makes profit if the cumulative HDD is less than 350 on the maturity day and suffers a loss if it is higher. Since the cumulative HDD is the higher the colder are generally the days in March, we can easily come to conclusion that the seller of the contract speculates on a relatively warmer weather or hedge himself/herself against it. And these are usually the heating companies which suffer loses if the weather is relatively warm. For these companies, the HDD Futures are an effective hedging tool.

The contract can be used also by financial institutions and other investors to diversify their investment portfolios. There are some advantages in this respect. There should be, for instance, a relatively low correlation to other investments or there is no risk of misusing the insider information etc. The values of HDD are computed by nationally acknowledged and independent weather stations (for more details, see for example Cristina and Mircea 2011).

It is also not necessary to hold the contract till the maturity. Investors may easily close out their positions by inverse operations on the market prior to maturity. The profit or loss will depend on the actual price of the contract which changes continuously according to the evolution of the HDD index during the lifetime of the contract.

It is also possible to enter into the contracts with more than just one month (Chincarini 2011). For HDD futures, the length of a multi-month period equals, however, to 7 months, because for the HDD only some moths are listed (obviously, these are the months when heating is used).

For the months when the question of cooling arises, there are the Weather Cooling Degree Day (CDD) Futures available. These are the contracts with exactly the same logic, but the opposite way of calculation the CDD (the index rises if the average temperature is more than 65 degrees Fahrenheit). These contracts can be used by energy companies, which want to hedge against losses resulting from a relatively low temperature in summer months under which the air-conditioning is not being used. These companies are, therefore, selling the CDD Futures.

There are many different HDD and CDD Futures on the CME which are specified for different geographical locations of relevant weather stations (including Canada, Australia, Asia, Pacific and Europe).

With a similar logic, we can use also other Futures on the CME to hedge against the excessive or insufficient rainfall and snowfall as well as against the frost and a strong wind. Each contract has its specifics, but the logic is always the same.

## SUBSTANCE OF WEATHER DERIVATIVES – OPTIONS

Options differ from the futures in terms of their flexibility. The option holder has got only the right and not the obligation to exercise his/her option rights. Obviously, he/she will do so only if it is profitable for him/her. On the other hand, he/she has to pay the premium for the option at the beginning. Thus, the losses of the option buyer are always limited by the amount of the premium paid (Hull 2012).

Weather options are both standardized contracts traded on the organized exchange (CME) and individualized contracts traded on the so- called “over-the-counter” markets. Hereinafter, we will deal with the OTC options only to emphasize the differences to the above described weather futures.

Profit and loss function of a weather option on the maturity day depends on the premium paid, the strike measured in some weather index, the current value of the respective weather index on the maturity day and the given financial value of the weather index (Špička 2012).

We will use a simple example to show how the weather options work. Let us assume a farmer who wants to hedge himself/herself against a drought over the next summer month. Thus, he/she may buy a put option on the weather index based on the amount of precipitation over the next month. The strike is set at 4 inches and the compensation equals USD 25 000 per 1 inch of precipitation. The option costs USD 15 000.

Now, if the amount of precipitation over the next month exceeds 4 inches, there is no financial settlement at the end which means that the option buyer has suffered a loss of the premium paid from the contract. However, if the amount of precipitation over the next month is less than 4 inches, the option buyer receives a financial compensation. Let us say, that there was an extremely low precipitation of just 1 inch. Then, he/she would receive USD 75 000, i.e. (4–1) times USD 25 000. This amount of money should compensate the loss which he/she incurs on the corn harvest due to the drought. The paid premium of USD 15 000 should be considered as a cost of hedging.

Once again, the weather indices may be defined in many different ways and on many different weather conditions. The most important variables are the temperature, rainfall, snowfall, speed of wind, length of sunshine periods etc. The substance is, however, always the same – the buyer pays a premium to get the financial compensation if the weather goes in a given direction according to the type of option and the contract specification.

## PRACTICAL ASPECTS OF USING WEATHER DERIVATIVES

The market with weather derivatives is relatively young. First contracts were introduced in 1997 between private companies – the Koch Industries and the Enron. Since then, the market has been rapidly growing. According to the Weather Risk Derivative Survey by the PricewaterhouseCoopers (PWC 2011), the notional value of all contracts amounted to about 11.8 billion of USD in the business year 2010/2011.

The market can be split into the OTC and the organized market (CME). In terms of the notional amounts, the organized market prevails with the total amount of about 9.4 billion of USD in the business year 2010/2011 (PWC 2011). As for the contracts, almost all of the total value is created in the HDD and CDD Futures.

These futures have a high liquidity. Thus, it is relatively easy to buy and sell them according to the individual needs. There are also no premiums to be paid. The trader must only deposit the so- called margin which serves as a collateral to hedge the credit risk of the contract for the exchange (Hull 2012). This margin is returned if the trader makes a profit on a contract or used to cover the eventual loses.

The agreed price of a contract is based solely on the interaction of demand and supply and reflects the general expectations about the future weather conditions (Chincarini 2011). In this respect, the agreed price could be considered as a "fair" one. Thus, the initial investment to enter the contract is low. Due to a high liquidity, the transaction and administrative costs are low as well. The weather index can hardly be manipulated and there is no risk of "insider" trading.

On the other hand, futures are useful just for the a limited number of hedgers since the respective weather indices are naturally defined only for the selected big cities, albeit the number of the covered cities is rising and splitting also into many regions outside the USA. This results in so- called "basis" risk, which simply refers to the fact, that the respective weather index and the real financial flows of the hedger are not well correlated. Thus, the hedging effectiveness is the key question in using the CME futures.

The OTC market is dominant in Europe. In the business year 2010/2011, it amounted to 2.45 billion of USD (PWC 2011). As for the weather indicators used, temperature is visibly the most important one, but there is also an important ratio of rain derivatives.

The OTC options can be customized to find an appropriate weather index and the respective weather station. On the other hand, the hedger must pay the premium at the beginning and it is relatively difficult to find its value. In comparison to the traditional financial options, it is not possible to use the standard valuation methods based on the Black-Scholes-Merton model, because weather cannot be bought and stored and thus the risk-free portfolio cannot be created.

Several methods have been developed to value the weather options (Chincarini 2011; Špička 2012; Mircea 2013). The methods are generally based on the past data, the probability distributions and different simulations. We will illustrate the substance of a simple option pricing model using a CDD option. The model uses the probability distribution fitted to a historical data set of monthly CDDs and integrates the outcome of the probability distribution with the payoff of the option. The theoretical value is then determined by (Considine 2000):

$$E = M \int_{CDD=0}^{\infty} P(CDD)\, Q(CDD) d(CDD)$$

where $P(CDD)$ is the probability distribution of CDDs, $Q(CDD)$ is the payoff of the option in units of CDDs, $M$ is the number of the units of currency (typically USD) specified in the contract per one CDD, and $d(CDD)$ is the differential.

Each pricing model has its advantages and also some drawbacks. For practical reasons, it should be noted that the price of such option contract for the hedger will also contain an important percentage reward for the seller of the derivative.

The basic risk can be limited by individualized conditions of the contract, but still it remains a key question of hedging derivatives. There have been a number of studies on the issue (for example Cyr et al. 2010; Špička 2012; Pelka and Musshoff 2013). Apart from the geographical distance, there is also a "product" dimension of the basis risk which consists of the fact that the impact of weather on financial flows of a hedger is not always straightforward. There are different methods haw to mitigate this problem, but obviously it will hardly be possible to achieve 100% effectiveness.

Apart from the basic risk, the buyers and sellers should bear in mind another complication in the pricing process, which are long-term trends. It implies that a simple distribution should not be fitted directly to the historical data (Considine 2000). Most of the measurement places exhibit long-term trends and variability, which must be accounted for in the model (time series must be detrended).

## HEDGING PROGRAMS

Weather derivatives are receiving an increasing attention both in the academic papers and in the real business. According to the Weather Risk Derivative Survey by the PricewaterhouseCoopers (PWC 2011), the majority of inquires of the potential users of weather instruments comes from energy (46%), construction (23%) and agriculture (12%). The business is growing and there are different providers of hedging programs in the market. These are mainly banks, other financial institutions and also specialized companies. "*To enhance public awareness of the weather risk industry and promote the growth and general welfare of the weather risk market*" even a special institution, the Weather Risk Management Association (WRMA) has been created (WRMA 2014).

The WRMA (2014) describes 3 main types of hedging programs, which are available in this area:

(1) Hedging programs based on the cumulative measures of weather variables in a given period.

(2) Hedging programs based on the number of adverse days during a defined period.

(3) Hedging programs based on adverse events.

The first type of programs has been already illustrated in the previous parts. It is useful if a company wants to hedge itself against a too warm or too cold weather, too much or too little snow, rain, wind etc. during a period of interest. As another example, we may mention the ski regions entrepreneurs, who can protect themselves against the lack of snow during the winter months. They pay a premium and if the cumulative amount of snow is less than agreed, they receive a financial compensation. If the snowfall is heavier than agreed, the paid premium should be perceived as insurance.

The second type of programs is based on the real amount of adverse days in the given period which is then compared to the agreed amount of adverse days (basic threshold). An adverse day may be defined as a day on which the average temperature is higher or lower than a given temperature. This type of programs can be used to hedge against too cold and too hot days in the defined period. It can be, for instance, utilized by the farmers whose financial results could be negatively affected by an extreme cold at the germination and an excessive heat closely prior the harvest (WRMA 2014).

The last type of programs is very similar to the second one. However, the financial compensation does not depend on the difference between the real and contracted number of adverse days. In this case, the financial compensation is paid if an adverse day occurs. As an example, we can mention an open-air festival organizer who wants to hedge against a heavy rain and a strong wind on some particular day.

Furthermore, there are specialized institutions (e.g. the Climate Corporation) in the market, which provide complex products to hedge more specific risks that can, for example, limit the corn yields. The advantage of this solution is its complexity. On the other hand, the price can be higher and the hedging effectiveness remains still the question.

## CONCLUSIONS

Weather conditions may negatively affect the financial results of companies operating in different areas, whereby energy, transportation and agriculture are obviously the most weather exposed businesses. Traditional insurance can be utilized to cover the losses in case of catastrophic events. However, it does not provide a sufficient protection against the risks related to suboptimal weather conditions.

Weather derivatives seem to be a possible solution to minimize the cash-flow variances of companies in different areas whose yields somehow depend on specific weather conditions. Although the market is relatively young, it has been growing rapidly in the past years and now the organized market as well as the OTC market provide various types of weather derivative contracts.

In terms of the notional amounts, the organized market (CME) is significantly larger. The HDD and CDD are the main contracts traded here. These instruments can be utilized to effectively hedge the weather exposures with relatively low costs. However, the scope of the potential users is limited in terms of the geographical dispersion as well as in the terms of business areas.

The OTC market is very important mainly for the European areas. The OTC contracts can be individualized to meet the needs of each potential hedger. On the other hand, it is relatively difficult to value these contracts and the hedging costs will be visibly higher.

The customization should address the basic risk, which is the main problem related to hedging the weather risks. Špička (2012) has demonstrated how a specific contract for sugar beet in a region of the Czech Republic could be designed. He runs the Monte Carlo simulation to test the ability of the proposed contract to reduce the variability of revenues and finds that it decreases by about 12.4% only.

There are also structured products available in the market which enable to hedge against more weather risks in different phases of the business cycles. This solution could save some time to hedgers, but the price would be probably higher. Furthermore, Pelka and Musshoff (2013) show that the mixed indexes do not automatically result in a better effectiveness.

Thus, weather derivatives have a great potential to develop further. They provide the opportunity to hedge against suboptimal weather conditions at reasonable costs. However, the hedging effectiveness is the main issue to be analyzed in each specific business case.

## REFERENCES


Brockett P. L. (2005): Weather derivatives and weather risk management. Risk Management & Insurance Review, *8*: 127–140.

Chincarini L. (2011): No chills or burns from temperature surprises: An empirical analysis of the weather derivatives market. Journal of Futures Markets, *31*: 1–33; DOI 10.1002/fut.20463.

CME (2012): Weather Futures and Options. Chicago Mercantile Exchange, Chicago.

Considine G. (2000): Introduction to Weather Derivatives. Weather Derivatives Group, Aquila Energy.

Cyr D., Kusy M. Shaw A.B. (2010): Climate change and the potential use of weather derivatives to hedge vineyard harvest rainfall risk in the Niagara region. Journal of Wine Research, *21*: 207–227; DOI 10.1080/09571264.2010.530112.

Cristina C., Mircea B.H. (2011): Weather Index- the basis of weather derivatives. Annals of the University of Oradea, Economic Science Series, *20*: 362–369.

Hull J. (2012): Options, Futures and other Derivatives. Prentice-Hall, Boston; ISBN 978-0-13-216494-8.

Mircea B.H. (2013): Weather derivatives: The most common pricing and valuation methods. Annals of the University of Oradea, Economic Science Series, *22*: 961–968.

Pelka N., Musshoff O. (2013): Hedging effectiveness of weather derivatives in arable farming – is there a need for mixed indices? Agricultural Finance Review, *73*: 358–372; DOI: 10.1108/AFR-10-2012-0055.

PWC (2011): Weather Risk Derivative Survey. PricewaterhouseCoopers, May.

Špička J. (2012): Návrh derivátu na počasí pro cukrovku v České republice. (Design of weather derivative for sugar beet in the Czech Republic.) Listy cukrovarnické a řepařské, *128*: 18–21.

WRMA (2014): Managing Weather Risk. Weather Risk Management Association. Available at http://www.wrma.org/risk_managing.html (accessed January 17, 2014).

http://www.climate.com

http://www.wrma.org

http://www.cmegroup.com/



Received: 21st January 2014
Accepted: 6th March 2014



*Contact address:*

Josef Taušer, Radek Čajka, University of Economics, Prague, Faculty of International Relations, W. Churchill Sq. 4, 130 67 Prague 3, Czech Republic;
e-mail: tauser@vse.cz, cajka@vse.cz