WEATHER INDEX- THE BASIS OF WEATHER DERIVATIVES

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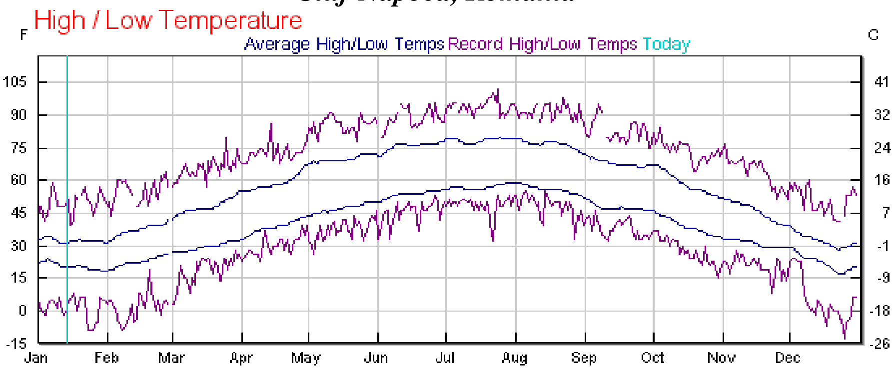
This paper approaches the subject of Weather Derivatives, more exactly their basic element the weather index. The weather index has two forms, the Heating Degree Day (HDD) and the Cooling Degree Day (CDD). We will try to explain their origin, use and the relationship between the two forms of the index.
In our research we started from the analysis of the weather derivatives and what they are based on. After finding out about weather index, we were interested in understanding exactly how they work and how they influence the value of the contract. On the national level the research in the field is scares, but foreign materials available.
The study for this paper was based firstly on reading about Weather Derivative, and then going in the meteorogical field and determining the way by which the indices were determined. After this, we went to the field with interest in the indices, such as the energy and gas industries, and figured out how they determined the weather index. For the examples we obtained data from the weather index database, and calculated the value for the period. The study is made on a period of five years, in 8 cities of the European Union.
The result of this research is that we can now understand better the importance of the way the indices work and how they influence the value of the Weather Derivatives.
This research has an implication on the field of insurance, because of the fact that weather derivative are at the convergence point of the stock markets and the insurance market.
The originality of the paper comes from the personal touch given to the theoretical aspect and through the analysis of the HDD and CDD index in order to show their general behaviour and relationship.

Keywords: Weather derivatives, Weather index HDD, CDD
JEL: G22

Weather index - the basis of Weather Derivatives

In order for giving protection against the consequences of extreme weather events, Weather derivatives have as underlying assets a variety of weather variables. Weather Derivatives can be structured accordingly to one or more variables. The most common used variable is *temperature*, either hourly, daily minimum or maximum, or as a daily average. By international consensus, in most countries, the average daily temperature is the arithmetic mean of the maximum and minimum temperatures recorded for a period. In some countries, however, the average daily temperature is calculated as weighted average of values recorded per two day. The time of day when the recording of these temperatures takes place, the method of determining these temperatures can also vary from a country to another. To participate in the weather derivatives market transactions it is needed to examine in detail the meteorological measuring system practiced by each of the country in which weather derivatives are composed and then traded. It is generally known that in the U.S. the measurements are made in Fahrenheit degrees, and in the rest of the countries they are made on Celsius scale.
As an example of heat minimum and maximum values, the chart below shows the minimum, maximum and daily average recorded in Cluj-Napoca, Romania, in 2008.

Chart 1. Evolution of daily minimum, maximum and average daily temperatures, in 2008 in Cluj-Napoca, Romania



Source: Data processed by author using information available on www.wunderground.net

In this chart we graphically illustrated thermal maximum and minimum records in Cluj-Napoca in the year 2008. The dark blue line shows the average temperature in its two forms, maximum and minimum. The purple line stands for the daily fluctuations of the temperatures and turquoise vertical line, represent the value in the day that the data were extracted.

This chart shows the evolution of the minimum and maximum daily values, and also of the daily average, thus we are able to observe the trend manifested by the weather indices. For Cluj-Napoca, the temperature reaches its highest level in July (about 40C) and the minimum is recorded in late December (approx.-24C).

Alongside the temperature, wind and rain measurements can also underpin weather derivatives. Protection against **wind currents**, for example, are of interest to wind ”farms” that want to contract these weather derivatives to protect themselves against the decline in wind speed, or in the construction industry, which would have to stop work in the winds blows too strong(e.g. for “sky-scrapers”). These contracts can be also used to replace traditional insurance policies for events such as damage caused by powerful winds, protection of future investments against events as *abundant rainfall* in the agricultural sector or *drought* for the hydro-electric industry. Protection of these events are relevant as are heavy snow falls of interest to mountain resorts, municipalities that must clean the roads in winter, but also for companies that sell products related to the cold-season, such as sport equipment or winter car-tires.

These are contracts that are based on such variables as *the number of sunny hours in the day, the temperature of sea water or river flows.*

In order to plan and build such a weather derivative we require accurate and reliable weather data.

Correlation between relevant meteorological variables and their impact on economic activity that needs protection will vary from one weather event to another and from a company to another. Thus, the contracts will be individualized and constructed on indices that accurately reflect both probability of occurrence and its effects.

Meteorological indices can be defined as the number and characteristics attributed to a phenomenon, process or other complex weather events. Indices that are most commonly used as base for weather derivatives contracts are indices of daily temperature, average temperature index, average cumulative index and heat index weather event. In this paper we will explain the importance of daily temperature index.

Daily temperature index

Using Daily indices is rooted in the energy industry and they are so constructed as to show domestic demand for heating or cooling. Weekly and monthly records of the index can be used also for monitoring and planning further needs, its costs and the heating cost for buildings which have performing air-conditioning systems. Annual records may help in predicting future expenditure for this purpose.

It should be noted that the United States, where the temperature is measured on the Fahrenheit scale, the core temperature (base temperature) for contracts is of 65F (18.33C), and in other countries, where they use the Celsius scale, the basis temperature is set at 18C (64.44F).

Heating Degree Days (HDD)

The Heating Degree Days is a measure designed to reflect the daily need of heating of a home or office space, and thereby is a way of measuring how cold it is (if it is colder the heat demand is higher). There are a variety of ways of defining HDDs used by the energy industry, thus reflecting the differences in consumption between cities, showing that there is a correlation between the ways of defining heat necessity and how well the index reflects the demand. The most common definition of the HDD index for the weather market is:

$$z_i = \max(T_0 - T_i, 0) = (T_0 - T_i, 0)^+ \qquad (1.1)$$

Where: Ti- the average temperature in day i

T0- base temperature [11]determined by the contract

During this paper we will assume that the formula depicted above is the calculating formula for HDDs. On a period of Nd days is defined as the sum of daily HDDs during the study:

$$x_{HDD} = \sum_{i=1}^{Nd} z_i \qquad (1.2)$$

The daily heat is higher in winter and weaker, almost zero, during summer. In many locations where the heat daily index is of interest, average temperature are recorded in certain periods do not exceed the 18C/65F limit, so the HDD index is always positive.

[11] Base temperature= temperature that by its variation determines the Heating Necessity or Cooling Necessity. This temperature is often regarded of having the optimal value of 18C(65F)

Table 1 Monthly average number of HDD used in the period 01.01.2006 to 31.12.2010, for 8 European cities. Data are related to a contract with the base temperature of 18C.

Month/City	London	Amsterdam	Stockholm	Paris	Vienna	Budapest	Bucharest	Sofia
January	374	475.2	581.2	Id[12]	505.8	494	547.6	535
February	335.8	421.2	496.6	Id	401.4	389.2	411	442.6
March	315.2	383.8	444.2	Id	323.8	287.8	302.8	339.2
April	245.4	246.2	290.8	Id	176.2	148.8	154.4	183
May	173.2	190	187.6	37.2	119.2	84.2	67	101.2
June	79.8	96.2	125	12.6	44.4	33	17	42.4
July	39.6	44.8	61	3.2	26.4	21.2	6	28
August	59	95.8	89.8	9.4	42.6	30.4	8.2	28.6
September	108.8	127.4	257.8	19.8	129.4	162	131.6	95.2
October	200	231.6	409.8	41.6	305.8	274	263.6	271.8
November	308.4	315	474.6	66.8	363.4	340.6	413	322.6
December	423.4	473	596.2	111.8	501.2	511.2	561	505.6

Source: Authors processing data available on www.degreeday.net

[12] ID – Incomplet Data

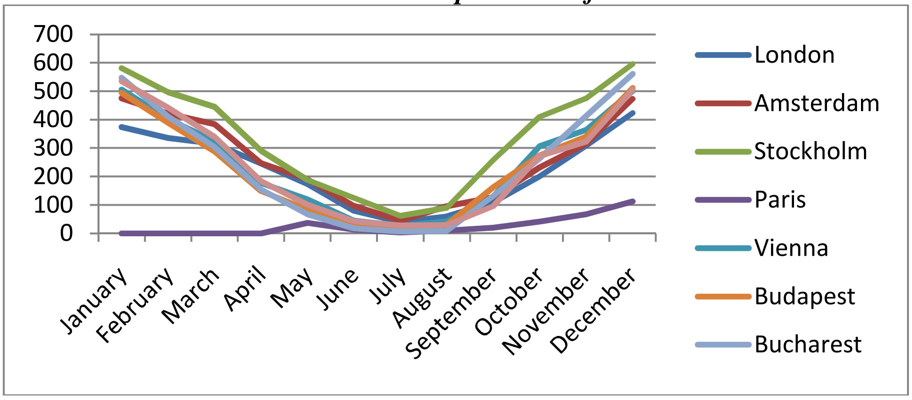
Our purpose is to highlight the monthly HDD values. In the study we chose to analyse cities from Europe, in order for the information to be relevant to the study. The data from (Tabel1) shows eight cities from the EU. In the selection process we tried chose the cities in such a way to minimize errors from the calculations. The period of study is of five years, from 01.01.2006 to 31.12.2010,

Processing the data presented difficulties for Paris, because of the lack of data for this location, only the data of 2010 are available. This lack of data explains why the general data for Paris are less than for the cities nearby, one such example is London.

We can also see that the highest values were recorded in January and December.

From (Chart2), we note that this index is at maximum level in Stockholm in December. At the opposite point is London, which presents the lowest values for all the studied period. Although the graph shows that Paris would have the lowest value, we can't prove it because of lack of data.

Chart2. Chart interpretation of Tabel1.



Source: Data processed by the author using information available on www.degreeday.net

The use of HDDs in the construction and trading of weather derivatives are used in the USA and Europe, and rarely in Japan.

Cooling Degree Day (CDD)

The daily cooling requirement is mainly used to measure summer energy demand for cooling, so determining how hot is (if it is warmer, the CDD need is higher). Heating systems are powered by electricity or gas, but cooling systems are mainly powered by electricity. This is one reason why CDD's are more relevant to the electricity market. Because electricity is generated recently from natural gas, the CDD's are becoming relevant to the gas industry also. The number of days that require CDD's is calculated:

$$z_i = \max(T_i - T_0, 0) = (T_i - T_0, 0)^+ \qquad (1.3)$$

As for the HDDs, the index is the sum over a period Nd of CDDs during the studied period.

$$x_{CDD} = \sum_{i=1}^{N_z} z_i \qquad (1.4)$$

Tabel3. Monthly average CDD numbers for eight European cities, in the 01.01.2006-31.12.2010 period. Data is consistent for contract with a base temperature 18C

Month/City	London	Amsterdam	Stockholm	Paris	Vienna	Budapest	Bucharest	Sofia
January	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0.2	0.4
March	0	0	0	0	0.4	0.6	1.2	2.4
April	4.6	4.2	2.8	4	10.2	16.6	23.2	16.6
May	17	8.8	7.4	7.6	27.2	46	64.4	59.8
June	36.8	32.8	27.6	25.2	64.6	78	145	103
July	50.6	63.4	76	75.8	121.8	151.2	194	145
August	38.6	38.6	32.6	36.8	91	122.6	239.6	152
September	12.2	8.2	2.6	12.4	23	28.2	73.4	59.2
October	1.6	2	0	5.4	3	4.2	5.4	9.4
November	0	0	0	0	0.2	0	3.2	3.4
December	0	0	0	0	0	0	0	0.4

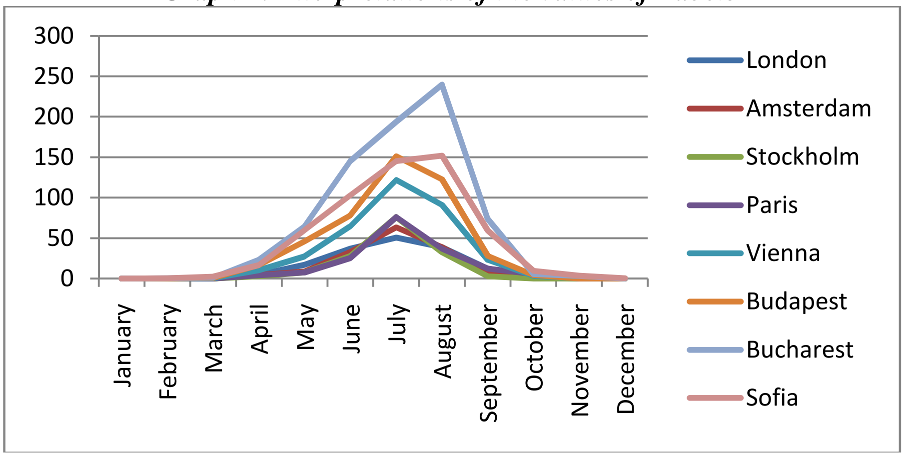
Source: Data processed by the author using information available on www.degreeday.net

In this analysis we used the same location as for the Heating degree days. London is the main market for weather derivatives in Europe; thus taking into account the nearby cities that show interest in these derivative contracts, as Paris and Amsterdam. I chose Stockholm to exemplify the developments and use of thermal indices in Scandinavia. Vienna, Budapest, Bucharest and Sofia have been selected because they are located in Central-Eastern Europe.

(Tabel3) emphasizes that the daily allowance of coolness, the figures show the opposite then in the case of the HDD index. The CDD index grows in value over the warmer months, reaching its peak in July and August, and in January and December the index is almost null.

From (Graph4) we can see that the maximum value is recorded in August in Bucharest and the lowest in Stockholm also in August. Here we see the formation three groups of cities: Bucharest – which is separated with the highest values; followed by Sofia, Budapest and Vienna, and the lowest values are in the third group formed of London, Amsterdam, Paris and Stockholm. The lowest of the low values are recorded by London and Stockholm. This fluctuation can be also explained through Geography, by the cities situations on the meridians.

Graph 4. Interpretations of the values of Tabel3



Source: Data processed by the author using information available on www.degreeday.net

Derivatives based on CDD’s are usually traded in the U.S., however, they are rarely trade in Europe and Japan.

The relationship between and HDD and CDD

The total amount of HDD’s and CDD’s sites in a given day is shown by the insignificant deviation of the average core temperature: in one day neither HDD nor CDD are zero, or when both are zero then the day temperature is equal with the normal values recorded. Thus, it is apparent that neither HDD nor CDD can have a negative value.

Conclusion

The analysis conducted in this paper, shows that the most common indices used in weather derivatives contracts are the HDDs and CDDs.

In my opinion, this is because weather events can be easily reported as temperature fluctuations in different periods, fluctuations that are accompanied by additional weather phenomena’s. Examples would be the case of the low temperatures, which often are accompanied by winds; moisture that is accompanied by rain and atmospheric pressure increase, or excessive heat that can cause drought.

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