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The relevance of basis risk in the weather derivatives market

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Abstract

The relevance of basis risk of financial instruments for hedging business risks differs largely. In the case of weather derivatives it can be shown that particularly location basis risk can reach critical level for the hedging company in some cases. However, basis risk is rarely considered in weather derivatives market today. Often the hedger's counterpart is arguing with high correlation coefficient between offered index station and hedged location. But it can be shown that for the hedger the distribution of residuals is in most cases more important than the correlation coefficient. Product and time basis risk can be important in some cases too. It is concluded that consideration of basis risk in weather derivatives market enlarges acceptance of these instruments. In this respect, proper assessment of the basis risk for a weather hedge is important for all players in this market.

1 Introduction

In business, apart of other risks, there may arise weather related price and volume risks. As stated elsewhere [8], weather derivatives are particularly suited to hedge weather related volume risks. As when hedging with other derivative instruments, the question of basis risk arises. In Hull's famous textbook [6], basis risk is defined as the difference between spot price and future price. For some commodities - as electricity - the so called location basis risk is in most cases important too. Electricity is difficult to store and to transport from one location to the other. Location basis risk arises then if price of hedged location and location of reference of the derivative are different. Moreover, basis risk can be

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an important point in derivative disasters, as in the case of 'Metallgesellschaft', where basis risk was the true stumbling block for this company. In weather derivative markets the notion of basis risk must be defined even in a broader sense, as weather itself is not tradable. Basis risk in weather markets may be defined as the difference between the actual loss and the actual payout of the weather derivative. Astonishingly enough, basis risk is not always considered in weather derivative markets and rarely mentioned in more than a footnote in literature. One exception for a more extensive consideration of this aspect represent the papers of Varangis & al. [11] and of Hess & al. [5] where the authors go into the question of the value of weather derivatives for developing countries and point out the importance of basis risk for weather derivatives taken to hedge crops. Another source about basis risk in weather markets are the master theses of Garcia & Sturzenegger [3] and of Gort [4]. The latter mentions that location basis risk may represent an important handicap for the further development of weather derivatives. In this paper the following questions are treated:

- What types of basis risk can arise in weather markets?
- Is there a dependence of the relevance of basis risk from meteorological index?
- Is a rather high correlation coefficient between index at location to be hedged and location of reference a warranty for the absence of location basis risk?
- What is the importance of basis risk in weather derivatives markets?

2 Types of basis risk in weather markets

It is stated here that companies bearing a weather related exposition wanting to hedge with a weather derivative must consider the following types of basis risk:

- Location basis risk
- Time or calender basis risk
- Product basis risk

2.1 Location basis risk

Location basis risk can be defined as a mismatch between value of weather derivative at location referring to and presumed value if based on ideal location to hedge weather related risk. Particularly exchange traded weather futures are based on a few key locations per continent. As weather related business risks rarely arise just in these spots, a location basis risk may occur when using such instruments for hedging. However, the possibility to refer an OTC-traded weather derivatives to a non official meteorological station is very restricted as well. This means that there is a location basis risk involved when hedging with weather derivatives in most cases.

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2.2 Time basis risk

Time basis risk is known from other derivative markets. Metallgesellschaft used a backwardation situation to profit from price differences between long and short running futures. This company realised in the end an immense loss because of the inherent time basis risk when the market turned into contango (cf. e.g. [1]). In analogy to commodity markets, a time basis risk can be defined for weather markets as the mismatch between period of exposure and period of reference of the weather derivative. Such a risk for rainfall occurrence and crop exposures in Morocco is mentioned by Hess & al. [5]

2.3 Product basis risk

In analogy to the commodity markets, for weather derivatives can be defined a product basis risk as well. In practice it may be difficult to find a counterpart willing to offer the index or the combination of indexes best suited for the exposure to be hedged. Taking then an other index can result in a larger gap between actual exposure and payout [10]. Moreover, in most cases, there is a residual volume risk not related to weather. This risk can also be defined as part of product risk if hedging with weather derivatives.

3 Basis risk and meteorological index

Importance of basis risk may depend heavily on meteorological index, as shown in figure 1.

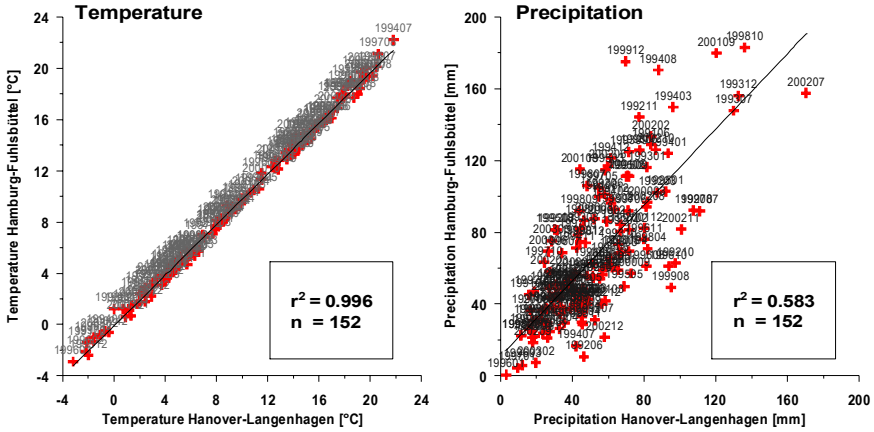

Figure 1. Comparison of the correlation for the indexes mean monthly temperature and monthly precipitation sum for Hamburg vs. Hanover for January 1991 to August 2003. The two stations are located in a air distance of about 150 kilometres. Numbers at data points denote year and month. Data: DWD [2].

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In Figure 1 correlations of mean monthly temperature and monthly precipitation of Hamburg vs. Hanover are compared. These two stations are situated a mere 150 kilometres air distance away. Whereas the temperature indexes are well correlated and show no outliers, coefficient of determination of precipitation indexes is clearly lower. Moreover, there are some strong outliers as e.g. in December 1999 where precipitation sum of Hanover is not far from long-term mean, but in Hamburg it is about double the mean. This means that precipitation based indexes can bear some severe location basis risk problems, even if station of reference is not far away from exposure.

4 Location Basis Risk for temperature based indexes

In weather derivative markets temperature based indexes - like mean monthly temperature or heating degree days - can be designated in analogy to financial derivatives as 'plain vanilla' products. This means that derivatives based on these indexes make up a considerable part of weather market. As it is shown in figure 2, even in continental Europe product basis risk is rather small when relating gas demand to mean daily temperature. From this can be inferred that heating degree days are equally suited to hedge volume risks in central Europe. Very similar curves for Northern America can be found e.g. in [7].

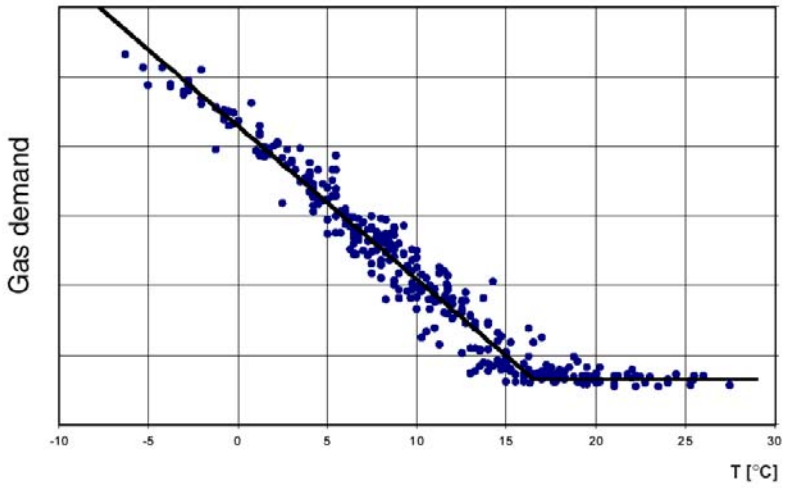

Figure 2. Dependence of gas demand from mean daily temperature for a Swiss supply region (taken from [9]).

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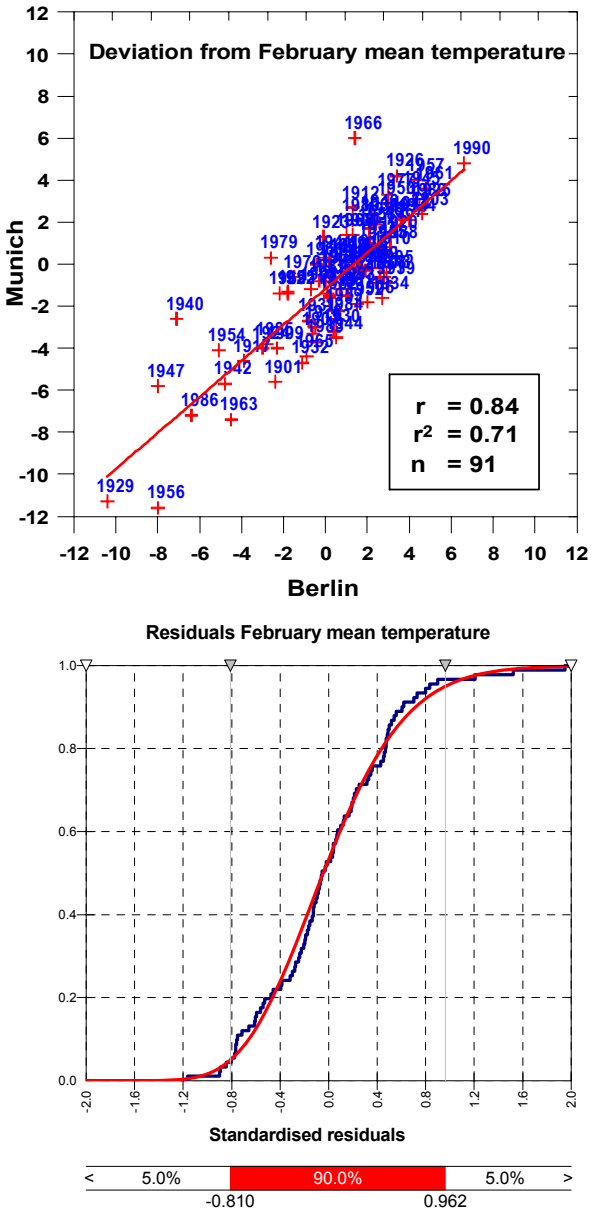

Figure 3. Deviation of monthly air temperature from long-term mean and distribution of standardised residuals Berlin vs. Munich. Assumed that a business risk should be covered in Munich and is hedged with a weather derivative referring to Berlin, location basis risk is rather high, despite a correlation coefficient of 0.84. Data: DWD [2].

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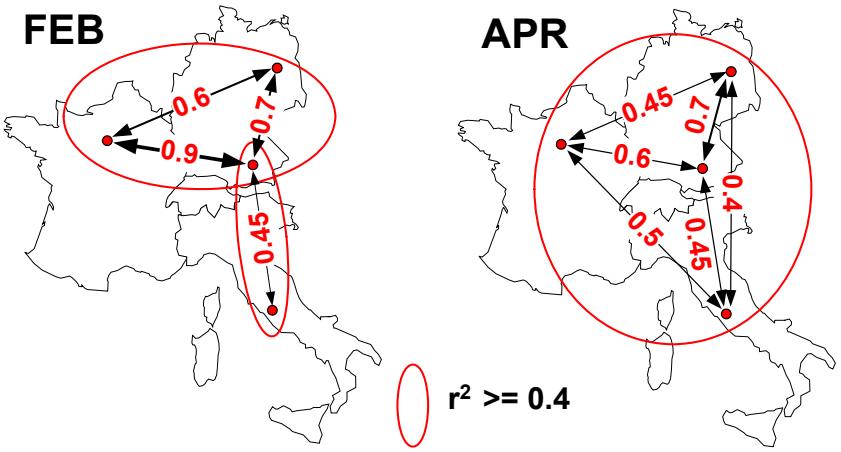

Figure 4. Coefficients of determination (r^2) of mean monthly air temperature for February and April between the big European metropolis Paris, Munich, Rome and Berlin for the years 1949 – 1988 (n= 40). Data: Wetterzentrale [11].

4.1 Spatial correlation of temperature based indexes

As it is shown in figures 3 and 4, the correlation coefficients between mean monthly values of air temperature of European metropolis - even if hundreds of kilometres apart - are rather high. However, as shown in figure 4, the goodness of fit changes from month to month.

4.2 Distribution of residuals and basis risk

It is often stated that location basis risk for temperature based indexes is usually rather small, even when using a station a few hundred kilometres away for hedging. As a 'proof', rather high correlation coefficients are given. However, despite the rather high correlation coefficient between the mean February temperature of Berlin and Munich, location basis risk can reach considerable values for single years (cf. figure 3). The distribution of the residuals of the correlation indicates, that there is a 10% risk that estimation value from Berlin is about 0.8 standard deviations too small or 1.0 standard deviations too high.

5 Importance of basis risk in weather derivative markets

Basis risk is still rarely considered in literature. More often the statement is found that there is no natural hedge. Natural hedge means taking advantage from geographical diversification of weather related exposition within Europe or even a smaller geographical unit as stated in [3]. Figure 4 shows that this is certainly true when speaking from temperature related indexes. However this does not mean that there is no location basis risk for temperature related indexes within Europe. For single years location basis risk can reach significant values which

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can be relevant for hedging effectiveness of a temperature related business risk. For indexes referring to precipitation the spatial representativity is even smaller, as shown in figure 1. As exchange traded instruments are referred to a small selection of cities dispersed over the whole continent, basis risk may reach or exceed critical level for single location hedge. Rarely discussed is however the possibility of alternative risk transfer to reinsurance treaties for insurance companies. Varangis & al. [11] mention this possibility for retrocession of agro-insurances in developing countries. But in Europe as well it may be interesting to hedge a multitude of single expositions of entire seasons and regions by exchange traded weather futures.

6 Conclusion and summary

Up to now, often basis risk in weather derivatives is neglected. However, in this paper it is pretended that consideration of basis risk in weather derivatives market enlarges acceptance of weather derivatives. In this respect, proper assessment of the basis risk for a weather hedge is important for all players in this market. In exchange traded instruments basis risk can reach critical level even for temperature based instruments serving as hedge for a very local business risk. On the other side, exchange based instrument could serve as an alternative to reinsurance treaties.

The following statements summarise the findings of this paper:

- Correlation coefficients for temperature based indexes between European cities like Berlin, Paris, Rome or Munich are rather high.
- High correlation coefficients of mean monthly temperatures between European metropolis mean that even in a large geographical space there is no natural hedge for temperature related business risks. Hence, it can be stated that weather derivatives are very valuable to hedge these risks.
- However, high correlation coefficients between exposed and hedged location do not necessarily mean that the location basis risk is negligible.
- Location basis risk may be acceptable for temperature based indexes, but is often problematic if based on other indexes as e.g. rainfall amount.
- Even if location basis risk of exchange traded instruments is usually rather high, weather futures can be an effective tool for retrocession of weather based insurance exposures.
- Spread payout vs. loss may deter hedgers from using weather derivatives another time.
- An open information policy about basis risk of weather derivatives is therefore important for further success of these instruments.

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