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PRELIMINARY COMMUNICATION

# Risk reduction in maize production using weather put option

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## ABSTRACT

The aim of this paper is to provide the basic theoretical assumptions about the weather derivatives and to quantify the risk reducing effect of rainfall put-options by applying a stochastic simulation. For this simulation we analyzed the yield data obtained from the maize producing farm located in the central part of Srem (Serbia). A nearby weather station contributed the meteorological data. To attain this goal, we analyze and compare three cases: Revenue without put-option, revenue with put-option, with basis risk and revenue with put-option, without basis risk. In comparison with having no rainfall put-option, the farmer can hedge 10.000 RSD ha-1 with the put-option, considering the basis risk, and even 20.000 RSD ha-1 when not considering basis risk. Consequently the hedging efficiency of the rainfall put-option is substantial in our example.

**Key words:** basis risk of production, maize, geographical basis risk, revenue, weather put option

## INTRODUCTION

Today, the significance of weather conditioned risks for the agricultural sector is evident; however, its relevance has increased over the last years, since the occurrence of extreme weather phenomena surged constantly in many regions of the world. The European Union has paid particularly high attention to the risk management in its recent agricultural market reforms to avoid successive variations in food prices. The research of crop insurance in Europe has been long actualized, while in Serbia only a small number of papers are devoted to this subject. The fact is that, after a flood, drought or a strong storm it always comes to intensified discussions about crop insurance which can compensate for the loss in production (Breustedt, 2003). Economic attractiveness of different instruments for risk management, such as insurance, depends on the farmers' exposure to different risks (Berg, 2005). So far, loss of yield insurances has been the first choice to deal with weather induced risks. In addition to traditional yield insurance, some authors suggest the need for expansion of the multi-risk crop insurance which is mainly present in the developed countries of Europe and North America (Berg, 2002). Today, even the actual index-based insurance considers the possibility of using weather derivatives in agriculture (Turvey, 2001; Berg et al., 2005; Mußhoff et al., 2005; Marković and Jovanović, 2011a). Indeed, there are some promising practical tests ongoing, in particular in the USA and Canada and scientist point to numerous potential applications (Turvey, 2001; Vedenov and Barnett, 2004). It is significant that the most important aspects of the insurance market in the developed countries can also be applied to the countries in transition.

The aim of this paper is to provide the basic theoretical assumptions about the weather derivatives as a new financial instrument in crop insurance and to quantify the basis risk of a maize production in the central part of Srem (Serbia) with regards to a rainfall put-option and to evaluate the hedging efficiency of this derivative. To attain this goal we analyze and compare three cases: 1. Revenue without put-option; 2. Revenue with put-option, with basis risk; 3. Revenue with put-option, without basis risk.

## MATERIAL AND METHODS

The analysis of the functionality of weather derivatives inherits three steps: The statistical modeling of the observed meteorological factor, the determination of the price of the derivative and the determination of the risk profile of the analyzed farm with and without the application of the derivative (Mußhoff et al., 2007). For the case at hand we analyze a put-option, which is referring to rainfall. We set the cumulating period from April to August, since the correlation between the maize yield and rainfall is at its maximum during this period (Marković and Jovanović, 2011b).

On the basis of empirical metrological data for the years 1999 to 2008, which we obtained from the weather station „Rimski Šančevi, Novi Sad", we estimated the probability distribution for the rainfall index. Further we obtained the maize yield data for the same time period from the mentioned farm in Srem. The yield data allows the development of a production function. This production function displays the correlation between rainfall and the maize yield. To avoid pricing difficulties, which often occur when it comes to evaluate weather derivatives fairly, we decided to price the option according to the "fair premium" approach in the actuarial sense.

## RESULTS AND DISCUSSION

Weather derivatives are a relatively novel tool to deal with the quantity risk of production, which occurred in mid-90's of the last century. They are financial derivatives (like e.g. futures or options) which serve to swap weather risks. They may refer to temperature, rainfall or other meteorological variables. During the construction of weather derivatives it is necessary to determine the following parameters: weather index, the type of derivatives, meteorological station, accumulation period, fair price, strike level, payoff function and payoff limit. A fair price is the expected discounted value of payoff from weather derivatives. The strike level represents the value of index from which the payoff is made, while the amount of payoff is determined with the tick size, which indicates the paid amount per unit index or change of unit index.

Weather derivatives can be traded in stock exchange or over the counter - OTC. On the market of weather derivatives option trading is dominant (Becker and Bracht, 1999). The options belong to the group of forward conditional operations and the customer gains the right, but assumes no obligation to buy or sell a contract to expire on a certain day in the future, and in return, he pays a premium (Berg, 2005). So the buyer of a rainfall option is required to pay the optional premium, but he has the right to a payoff, based on the difference between the weather index and strike level. On the other hand, the seller takes the obligation and receives a premium.

There are call option and put option. Call option gives the holder the right to buy, and put option the right to sell contract and it is frequently used in the crop insurance. From the buyer side payoff of weather put option ($I_p$) arising from differences between the strike level (R) and realized weather index (x), multiplied with tick size (O) (Berg et al., 2005):

$$I_p = O \cdot Max[0, (R - x)] \tag{1}$$

In the event that the weather index is above the strike level, it does not come to the payment. The buyer of weather put option would this way be protected from too low index level. If the premium (P) is taken away from the payoff, it comes to the profit (D), which the buyer from the put option gets (Berg, 2005):

$$D_P^{DP} = O \cdot Max[0, (x - R)] - P \tag{2}$$

Based on the previous, the seller profit from the weather put option is calculated opposite from the buyer's gain, that is, the payoff is taken away from the premium (Berg, 2005):

$$D_P^{KP} = P - O \cdot Max\left[0,(x-R)\right] \tag{3}$$

For option pricing the burn-rate-method is used. Fair price ($P_f$) for the put option can be calculated in the following form (Berg et al., 2005):

$$Pf = \left[(R - E(x|x<R)\ \varpi(x<R)\cdot O\right]\cdot e^{-r\cdot n} \tag{4}$$

In this example, the expression $E(x|x<R)$ represents the expected value assuming that the weather index is below the strike level. The expression $\varpi(x<R)$ is the probability that the weather index is below the strike level, while ($e^{-r\cdot n}$) is the discount factor.

Weather derivatives however, have some striking advantages over traditional insurances. Firstly, the derivative holder does not have to proof the defect nor has he to evaluate its extend. Furthermore the moral hazard problem does not emerge at all. Despite these advantages the market for weather derivatives in the agricultural sector is still fairly small.

The basis risk is a potential impediment for the break-through of weather derivatives since it represents a source of uncertainty for the farmer. The basis risk consists of the basis risk of production and the geographical basis risk. The basis risk of production refers to all individual risk factors which are connected to a specific farm and its entire production process. The geographical basis risk emerges from the divergence of the point of reference (the weather station) of the derivative and the point of production. As the distance of these points increases the geographical risk increases, too. This divergence plays a minor role regarding temperature based derivatives, but it is of vital importance when it comes to rainfall derivatives since the variability of rainfall is much closer connected to the location than temperature is. The entire basis risk remains with the farmer because weather derivatives have no influence on it. Consequently this risk is unhedgeable. Therefore, derivatives can never achieve a perfect correlation between the variation in yield and the weather factor(s), they refer to. This imperfect correlation and consequently the imperfect hedge can discourage farmers from buying derivatives.

Data on rainfall were taken from a reference meteorological station close to the place of production. The weather index based on the monthly amounts from April to August is at the level of 300 mm (strike level), while the tick size is 100 RSD mm-1 (1 EUR = 100 RSD). The payoff is limited to 180 mm, which means that if the rainfall is below this level, it is not going to be paid more, but the payoff remains the same. The weather contract is valid for five months and the payoff is possible if measured rainfall is below the strike level (Figure 1).

Consequently we calculated on the basis of our model for each of the three mentioned cases the distribution of the maize yield. In our model the maize yield depends solitary on the rainfall and the basis risk. The comparison of the distribution with and without the rainfall option gives us finally the hedging efficiency. The developed model incorporates the basis risk of production and the geographical basis risk in its specifications of the index. Both risks combined as the basis risk show a strong influence on the hedging efficiency. The maximum hedging effect occurs at 10 percentile.

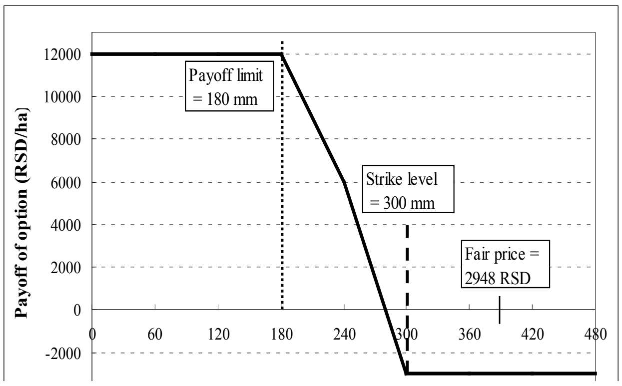


**Figure 1. Fair premium and payoff of put option in maize production**

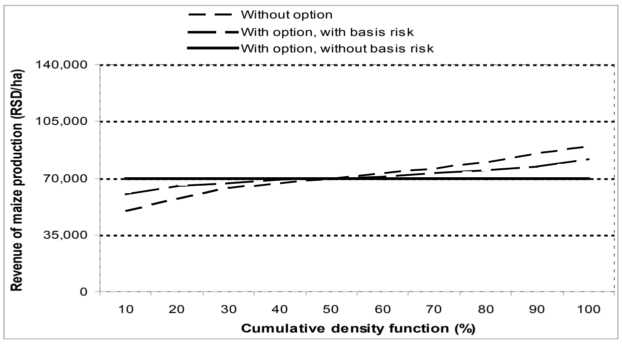


**Figure 2. Revenue distribution of maize production, with and without option**

In comparison with having no rainfall put-option the farmer can hedge 10.000 RSD ha-1 with the put-option, considering the basis risk, and even 20.000 RSD ha-1 when not considering basis risk (Figure 2). Consequently the hedging efficiency of the rainfall put-option is substantial in our example. However, as the basis risk increases the hedging efficiency is decreasing as well. When the farmer has to consider additionally transaction costs then the deployment of rainfall put-options as a risk management tool is clearly questionable.

## CONCLUSION

The presented example of the use of weather derivatives clearly shows that they still indicate the useful tools for weather risk reducing. Special emphasis is placed on reducing the oscillation of economic indicators (for example, revenue), caused by the weather factor. If the place of production is close to the meteorological station (geographical basis risk), and there is a strong correlation between weather index and yield of maize (basis risk of production), the effectiveness of risk reduction is significant (farmer can hedge even 20.000 RSD ha-1 when not considering basis risk). But if they are in remote locations and there is a lower correlation coefficient, the effect of protection is significantly reduced.

Results show that potential sellers of rainfall put-options have to offer a wide range of custom-made options, which allow farmers to pick the most appropriate one for their individual basis risk of production. Furthermore, the sellers are in need of a dense net of weather stations as reference points to minimize the geographical basis risk. These conditions surely scale up the complexity for sellers, but they are inevitable to raise farmer's interest in rainfall put-options in particular and for weather derivatives in general. Nevertheless, it is still unclear in how far weather derivatives will establish in agribusiness in years to come.

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# Smanjenje rizika u proizvodnji kukuruza pomoću vremenske prodajne opcije


## SAŽETAK

Cilj ovoga rada jest ponuditi temeljne teoretske pretpostavke u vezi s vremenskim derivatima i učinkom vremenske prodajne opcije na temelju količine padalina na smanjenja rizika primjenom stohastičke simulacije. Za potrebe simulacije provedena je analiza podataka o prinosu dobivenih s poljoprivrednog dobra na kojem se proizvodi kukuruz, a koje se nalazi u središnjem Srijemu (Srbija). Meteorološka postaja, smještena u neposrednoj blizini, bila je izvor meteoroloških podataka. Kako bi smo ostvarili cilj, analizirali smo i usporedili tri slučaja: prihod bez primjene vremenske prodajne opcije, prihod uz primjenu vremenske prodajne opcije s baznim rizikom, i prihod uz primjenu vremenske prodajne opcije bez baznog rizika. U odnosu na neprimjenjivanje vremenske prodajne opcije, poljoprivredni proizvođač može zaštititi od rizika 10,000 RSD ha$^{-1}$ uz primjenu vremenske prodajne opcije s baznim rizikom, odnosnlo 20,000RSD ha$^{-1}$ bez baznog rizika. Iz toga slijedi da učinkovitost eliminacije rizika primjenom vremenske prodajne opcije na temelju količine padalina ima značajnu ulogu u našem primjeru.


**Ključne riječi:** bazni rizik u proizvodnji, kukuruz, zemljopisni bazni rizik, prihod, vremenska prodajna opcija