

RISK MANAGEMENT IN PLANT PRODUCTION WITH WEATHER DERIVATIVES

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SUMMARY: It has been long known that weather conditions are the main factor of uncertainty in plant production. For this reason, an integrated system of risk management in plant production is necessary today in order to somewhat compensate for the loss caused by weather risks. In the past, farmers have bought insurance for protection against fluctuations in crop yields caused by weather risks. Relatively new tools for risk management in plant production are weather derivatives. Although weather derivatives show many advantages over traditional insurance the market for these products is still relatively limited. Therefore, it is necessary to quantify the effect of risk reduction that can be achieved by using weather derivatives on the example of selected farm in Germany. If the field of production is close to the meteorological station, and if a high correlation between weather indices and yield is assumed, then the effect of risk reduction is significant (up to 40 %).

Key words: risk management, crop insurance, weather derivatives, hedging effectiveness.

INTRODUCTION

In the recent years various weather disasters have caused serious damage to agricultural areas. Crop insurance is the most frequently used instrument for risk management in plant production.

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 always after a flood, drought or a strong storm there are intensive 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). 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

Original scientific paper / Originalni naučni rad

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using weather derivatives in agriculture (Turvey, 2001; Berg et al., 2005; Mußhoff et al., 2005). 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 cropweather put option.

MATERIAL AND METHODS

The basic source of data is the documentation of average yields and selling prices of winter barley from the selected farm in Oberfranken (Germany), as well as the information on monthly amounts of rainfall from the nearby meteorological stations for the period from 1999 to 2008.

The successful application of weather derivatives depends on the strength of rainfall influences on the yield of winter barley (Vedenov and Barnett, 2004). During the construction of weather put option the key issue is to determine fair premium, which the buyer is willing to pay for the transfer of risk. To determine the premium, the burn-rate-method is used, where the fair premium is the expected discounted value of payoff from weather derivatives (Berg et al., 2005). Following the same methodology the other parameters necessary for the construction of weather derivatives (weather index, payoff function, payoff limit) are determined.

Using quantitative methods for risk estimation, it is determined whether the weather risk reduction (hedging) is more successful with or without weather derivatives. This paper applies the methods of stochastic simulation and value-at-risk. The concept of stochastic simulation compares the distribution function (cumulative density function) of the winter barley revenue with and without weather derivatives (Brandes et al., 1992). On the other hand, the standard deviation as a measure of dispersion in statistics and percentile in the revenue distribution is being considered, and based on that, the possibility of down side risk reducing with and without weather derivatives is determined (Berg et al., 2005). All necessary calculations are performed using computer software (@ Risk), which was especially developed for the risk management.

RESULTS AND DISCUSSION

Weather derivatives are new financial instruments for transfer of risk, which occurred in mid 90s of the last century. They are the financial instruments that do not consider the base value such as the price of traded goods or any other financial category, but instead they take into account weather variables, such as rainfall (Berg, 2005).

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. 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):

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

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)

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

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

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

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):

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

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 $\omega(x < R)$ is the probability that the weather index is below the strike level, while ($e^{-r \cdot n}$) is the discount factor.

In the example of the winter barley production the hedging effectiveness of weather derivatives is estimated. The basic data are taken from an individual farm in Oberfranken (Germany). This agricultural farm has an area of 75 ha, and 22 ha are under barley. The average yield in the selected time amounted to 8 t/ha (standard deviation 1 t/ha). The average price was 100 €/t, and the revenue 800 €/ha (standard deviation 100 €/ha).

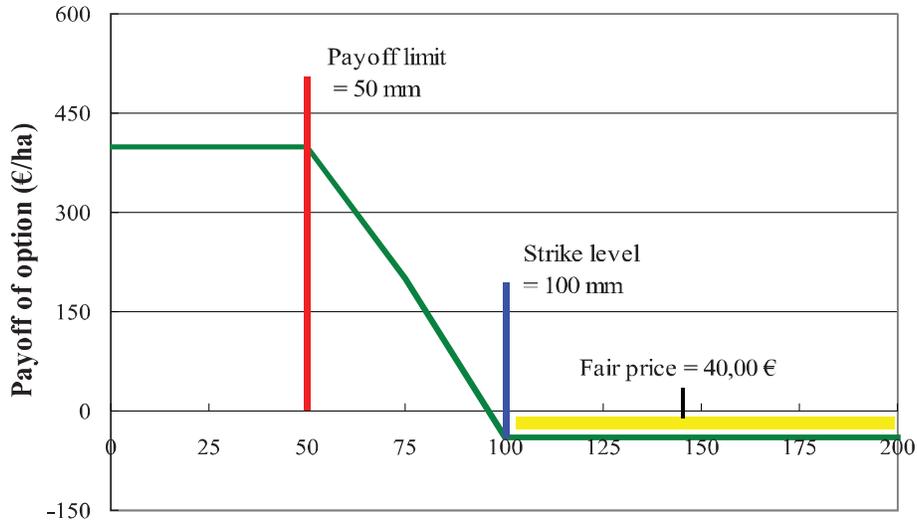


Chart 1: Fair premium and payoff of put option in winter barley production
 Grafikon 1: Fer premija i isplata iz prodajne opcije u proizvodnji ozimog ječma

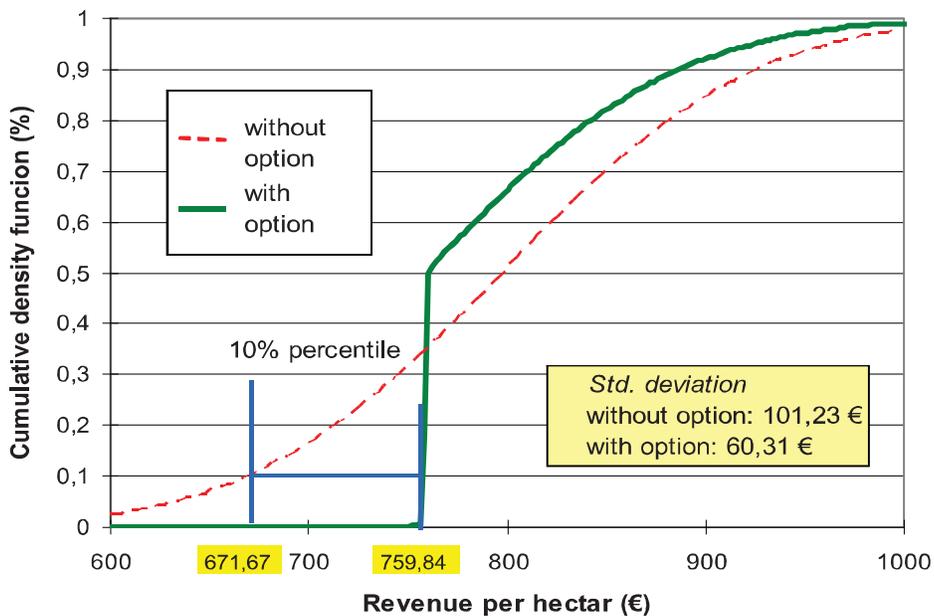


Chart 2: Revenue distribution of winter barley with and without option
 Grafikon 2: Raspodela vrednosti proizvodnje ozimog ječma, sa i bez opcije

The analysis was conducted on the farm and it was determined that the amount of rainfall during the period April-May had a decisive influence on the height of winter barley yield. In order to prevent yield variability farmer decides to buy rainfall put option on OTC market. The data on rainfall were taken from a reference meteorological station close to the place of production. The weather index based on the monthly amounts of rainfall in April and May is at the level of 100 mm, which is the strike level, while the tick size is 8 €/mm. The payoff is limited to 50 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 two months and the payoff is possible if meas-

ured rainfall is below the strike level (Chart 1). If in the formula (5) the discount factor ($e^{-r \cdot n}$) includes the interest rate of 5% and as the weather period the two months (April-May) are taken, you get the option price of 40 € (Chart 1).

In order to determine the revenue with and without weather derivatives the method of stochastic simulation is used. In case without weather put option the total revenue is equal to the market revenue, while in case with option, the farmer adopts profit from the option according to the formula (1). Rainfall and yield are stochastic size and since there is a strong positive correlation between them, the revenue below 800 €/ha is compensated from the payoff of the put option. When the fair premium of 40 €/ha is paid, it can be noted that the revenue under 760 €/ha is completely “cut off” and the lower revenue cannot happen (Chart 2). The standard deviation is reduced from 101.23 €/ha (without option) to 60.31 €/ha (with option). This way the down side risk is significantly reduced (40.42 %).

If the percentile is taken as the measure of risk reduction, then the lower part of the distribution, where the lowest revenue is, is taken into account. In the case without option in the 10% years, the expected revenue is under 671.67 €/ha, while in the case with option it is increased to 759.64 €/ha. In case of option revenue of 759.84 €/ha instead in 5% it will be lower in almost 35% of years (Chart 2). In this way with put option the down side risk is being reduced.

CONCLUSION

The presented example of using 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, and there is a strong correlation between weather index and yield of winter barley, the effectiveness of risk reduction is significant (up to 40%). But if they are in remote locations and there is a lower correlation coefficient, that significantly reduces the effect of protection. In practice, it is reasonable that a fair premium is increased with transaction costs and risk premium, which also reduces the positive effect of these instruments. However, preliminary calculations show significant potential of weather derivatives in reduction of production risks, and therefore they can be a supplement to the existing instruments for risk management in plant production.

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UPRAVLJANJE RIZIKOM U BILJNOJ PROIZVODNJI PRIMENOM VREMENSKIH DERIVATA

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Izvod

Odavno je poznato da vremenske prilike predstavljaju glavni faktor nesigurnosti u biljnoj proizvodnji. Iz tog razloga jedan integrisani sistem upravljanja rizikom danas predstavlja neminovnost, kako bi se donekle kompenzovale posledice vremenskih neprilika. U prošlosti su poljoprivrednici kupovinom osiguranja pokušali da se zaštite od kolebanja prinosa useva i plodova uslovljenih vremenskim rizicima. Relativno nov instrument za upravljanje rizikom u biljnoj proizvodnji predstavljaju vremenski derivati. Iako vremenski derivati pokazuju brojne prednosti u odnosu na klasično osiguranje, tržište ovih proizvoda još uvek je relativno malo. Zbog toga je potrebno na primeru ozimog ječma na izabranom individualnom gazdinstvu u Nemačkoj kvantifikovati efekat smanjenja rizika koji se postiže upotrebom vremenskih derivata. Ukoliko je mesto proizvodnje u neposrednoj blizini meteorološke stanice i ako je pretpostavljena visoka korelacija između količine padavina i prinosa ozimog ječma onda je značajna efikasnost smanjenja rizika (do 40 %).

Ključne reči: upravljanje rizikom, osiguranje useva i plodova, vremenski derivati, efikasnost smanjivanja rizika.

Received / *Primljen*: 12.07.2010.

Accepted / *Prihvaćen*: 26.12.2010.