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REDUCTION IN REVENUE VOLATILITY IN MAIZE PRODUCTION APPLYING THE INDIRECT-INDEX INSURANCE[1]

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Summary

This paper is aimed at providing the basic theoretical postulates of indirect-index insurance and by its application at quantifying the effect of the reduction in risk using a stochastic simulation. The paper uses data on maize yield gathered from family farm in the central part of Srem, and weather data were acquired from the nearest referential meteorological station. For the purpose of achieving a stated aim, two situations were analysed: maize production value by using the indirect-index insurance and by using no indirect-index insurance. In the case of applying this type of insurance, a farmer can decrease the risk by 8,816 RSD/ha (r=1.0), 4,116 RSD/ha if the correlation coefficient is 0.8, that is 2,598 RSD/ha (r=0.6). Therefore, it is possible to conclude that there is a significant effect of the reduction in risk by applying indirect-index insurance.

Key words: *indirect index insurance, maize, revenue, volatility, family farms.*

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Introduction

The weather factor significantly influences the economic trends, thus even 70% of world economy is influenced by the fluctuation in weather (Jain, Foster, 2000), that is 5% of gross domestic products in the Western Europe are affected by the fluctuations in weather

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(Meyer, 2001). The projections of climate changes, particularly expressed through the danger of drought, indicate a great problem which will arise in the future (Beniston, Diaz, 2004). On the basis of this, it is necessary to use different instruments for risk management (Bielza et al., 2007). At the moment, 40% of insurance price (premium) in Serbia is subsidized. But OECD governments are increasingly interested in emphasizing investments rather than subsidies (Ivanović et al., 2012), which will influence future level of subsidies.

Most insurance systems (single risk insurance, combined risk insurance, multi-risk crop insurance, all-risk crop insurance, revenue insurance, income insurance, whole farm insurance) are related to the results on the individual farms and caused damages are estimated in the field, and the total losses are calculated at the farm level. On the other hand, index insurance is based on the data related to a certain region or administrative unit. This group comprises area yield based insurance, area-revenue insurance and indirect-index insurance. These insurance systems exist in the developed countries of North America (USA and Canada), and in recent years, the projects aimed at their implementation are initiated in some European countries.

Since this type of crop insurance is not found in Serbia, the aim of this study is, on the one hand, to completely explain the role and significance of index insurance as a new financial instrument in crop insurance, and on the other hand, to point to the possibility of the application of indirect-index insurance in our agriculture. It will be achieved on the basis of the simulation, in the example of maize, as a production line which has a significant share in the sowing structure and income of most farms.

Material and method

The basic data are acquired from a family farm in the municipality of Ruma, on the territory of Srem. The farm has an area of 75 ha, of which 22 ha is sown with maize (share in sowing structure is 30%). The average maize yield, in the period 1999-2008 was 8 t/ha, whereas the standard deviation of yield was 1 t/ha. The average price came to 10,000 RSD/t. This implies that the expected revenue is at level of 80,000 RSD/ha, whereas its standard deviation is 10,000 RSD/ha. Near the farm there is a meteorological station, where the data on average monthly temperatures and average monthly rainfall are available.

If the calculated revenue is increased by the potential influx from indirect-index insurance and decreased by insurance price (premium), it leads to the revenue by using indirect-index insurance (Schmitz, 2007). At this point, a logical question can be raised: is the hedging efficiency more successful with or without the use of this mode of insurance? The answer to this question is obtained using the quantitative methods for risk assessment. This paper applies the method of stochastic domination and analyses the expected values and variances. The concept of stochastic domination compares the functions of distribution (cumulative probability) of maize production values with the use of indirect-index insurance and without it. In the case that the distribution functions do not intersect, then it is a case of first-order, and in the case that they intersect it is second-order stochastic dominance (Brandes, Odening, 1992). Similarly, the standard deviation was considered as a dispersion measure in statistics, as well as percentiles in the distribution of revenue and on the basis of them the possibility of reducing the risk of loss was determined (Berg et al., 2005).

Results and discussion

The index crop insurance is based on the data related to a certain administrative unit or region. Thus, for example, *area yield based insurance*, where the difference between predetermined average yield for that region and really achieved average yield is considered, is developed as an alternative to traditional multi-risk crop insurance. The intent is to provide the possibility of a long-term insurance against different risks in plant production, as well as to reduce the degree of state`s shares, which is substantially evident in the case of individual insurances (Ebneth, 2003). In the case of this concept of insurance, on the basis of regional yield, the calculation of insurance premium is carried out, as well as quantitative and qualitative determination of damage and as a result of this, the amount of compensation is determined. It is therefore necessary to establish such geographic regions, which are mutually homogeneous as regards climatic conditions. The insured case is only when the realised average yield in the region is lower than the expected average yield. This means that all farmers of that region pay the equal insurance premium, calculated on the basis of parameters of distribution of historical regional yield (Ebneth, 2003). In the event of the insured case, the farmers are compensated on a flat rate basis, depending on the amount of achieved average yield in that region. This hence implies that the compensation of damage is provided independently of really inflicted damages on certain farms.

The decisive advantage (*Table 1*) of this insurance system is reflected in a drastic reduction in moral hazard, since the certain policy holders do not have any impact on the achieved average regional yield, or on the amount of compensation (Chambers, Quiggin, 2001).

Table 1. Advantages and disadvantages of area yield based insurance

Advantages	Disadvantages
• No negative selection • No moral hazard • Lower premium of risk • Protection from related risks • Reduced transaction costs • Lower franchise • Higher level of cover	• No protection from independent risks • Poor acceptance by farmers • Banks do not acknowledge it as a credit insurance • Later damage compensation • Risk of loss that cannot be compensated

Source: authors' analysis

However, this type of insurance is not applied sufficiently in practice. The main reason for its rejection by farmers is impossibility of individual insurance against the fluctuation of yield, because in this way farmers may have a loss, which will not be compensated (Ebneth, 2003). Thus it follows that the greatest benefit is provided to those farmers, whose yields are closely correlated with the average regional yields. Observing other advantages and disadvantages of this insurance model it can be said that as for farmers the insurance based on average yield of the region can provide better comprehensive protection from the risk compared with the individual yield insurance (Miranda, 1991; Schlieper, 1997; Bertelsmeier, 2000).

The *area-revenue insurance* is based on the product of average yield and price for a certain region. If that amount is lower than predetermined average revenue for this region all insured farmers from this region will receive the compensation.

In this paper is used *indirect-index insurance* which does not refer to the average yield or revenue of a certain region, but to the appropriate meteorological parameters. For these reasons this type of crop insurance is also called parametric insurance. In this case, the compensation is provided if a certain limit value (e.g. rainfall or average temperature) is exceeded or is not achieved.

It is well known that the amount of rainfall largely determines the future yield of most arable crops. The analysis carried out by Marković and Jovanović (2011a) determined that the amount of rainfall in the period from April to August has a high impact on the quantity of maize yield. Similar problem concerning wheat production was analysed by Marković and Jovanović (2011b).

For this research data on rainfall were obtained from the referential meteorological station Rimski šančevi in Novi Sad. Weather index, based on monthly amounts of rainfall in the period April-August, has a normal distribution, whose average is 300 mm, and standard deviation is 12.5 mm. The value for calculating the inflow from indirect-index insurance represents the average amount of rainfall (critical point), whereas the price of 1 mm of rainfall amounts to 800 RSD. A weather contract shall be valid for five months and the influx is possible if a measured precipitation is below the average amount of rainfall.

The inflow from indirect-index insurance (N_I) is calculated as follows:

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

In the given formula (O) represents the price of weather index, (R) indicates a critical point, whereas ($\tilde{x}$) marks a weather index.

Fair premium[5] of indirect-index insurance corresponds to discounted expected value of inflow *E(* N_I *)*. It is calculated as a price product of weather index (*O*) and the expected values of negative deviations from a weather index ($\tilde{x}$) and a critical point (*R*). The factor (e^{-rn}) discounts the inflow in the period (*n*) with an interest rate (*r*):

$$P_f = e^{-r\cdot n} E(N_I) = e^{-r\cdot n} \cdot O \cdot E(Max[0,(R - \tilde{x})]) \tag{2}$$

The expected value of the maximum function $E(Max[0,(R - \tilde{x})]$ can be interpreted as a measured average of all payment, which (do not) occur when the critical level is exceeded, that is, not achieved (Schmitz, 2007):

[5] A fair premium represents the lowest price of indirect-index insurance which is paid by buyers. In practice, this value is added transaction costs and risk premium, but in this case they will be excluded (Marković, 2010).

$$E(Max[0,(R-\tilde{x})]) = H(R)\cdot\left(R-E(x|x\le R)\right)+(1-H(R))\cdot 0 \tag{3}$$

As regards the preceding formula (*H*) is the probability that ($\tilde{x}$) is lower than (*R*), whereas on the other hand $(1-H(R))$ expresses the probability that (*R*) is lower than ($\tilde{x}$). Based on the formula $F(x)=\int_a^b f(x)dx$ [6] the probability (*H*) corresponds to the area below the density function *h(x)* to the critical level (*R*).

$$H(R)=\int_{-\infty}^{R} h(x)dx \tag{4}$$

Since (*R*) is known (300 mm), the expected value of ($\tilde{x}$) must be determined assuming that it is lower than (*R*), and it is symbolised by the expression $E(x|x\le R)$ and corresponds to the expected distribution value of random variable ($\tilde{x}$) above the level (*R*).

If a normal distribution is taken for ($\tilde{x}$), the probability that that value is lower than (*R*) can be shown (Hartung, 2005):

$$H(R)=\Phi(z) \quad \text{where} \quad z=\frac{R-E(x)}{\sigma} \quad \text{is,} \tag{5}$$

The expected value of a normal distribution above the level (*R*):

$$E(x|x\le R)=E(x)+\sigma\cdot\frac{-\phi(z)}{\Phi(z)} \tag{6}$$

In the above formulas, (*z*) is a standardised random variable, $\Phi(z)$ is a standard normal distribution, and $\phi(z)$ represents its density function[7].

Using the data on the expected value and standard deviation of weather index the probability of 0.5 for *H(300)* is obtained, and value of 290 mm for $E(x|x\le R)$. If that value is included in the formula (3), the result of 5 mm is obtained, representing the average negative deviations of a weather index from a critical point. If that deviation value is replaced in the formula (2) or multiplied by the price of weather index (800 RSD/mm), a fair premium amounting to 4,000 RSD/ha is obtained. The procedure is extremely simplified by excluding a discount factor.

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[6] A starting point in investigating the dominance is a cumulative probability distribution of different alternatives. This distribution function is a certain integral of the assumed density function. In the given example, for the alternative (*F)* as a target value the expected revenue (*x*) with minimum (*a*) and maximum limit (*b*) and the density function *f(x)* is taken (Marković, 2010).

[7] The standardised random variable is obtained by subtracting the expected value *E(x)* from arbitrary random variable - limit level (*R)* and then by dividing this difference by standard deviation σ (Mladenović, Petrović, 2007).

Earlier it was emphasised that a successful application of indirect-index insurance in large part depends on the correlation between the achieved yield and the weather index. Hereafter it is shown what influence on a total revenue per hectare ($\tilde{V}_P$) different correlation levels have between these two parameters, particularly on:

- The variant without the use of indirect-index insurance, where the revenue is yield product ($\tilde{y}$) and product price (c_y);

$$\tilde{V}_P = \tilde{y} \cdot c_y \qquad (7)$$

- The variant with the use of indirect-index insurance, where starting from the formula (7), the achieved market revenue is increased by the inflow from the indirect-index insurance (N_I), which on the basis of the previous calculations can be represented as a product of price of a weather index and deviation of the expected index value from the critical point ($O \cdot Max[0,(E(x)-\tilde{x})]$), lessened by an fair premium ((P_f):

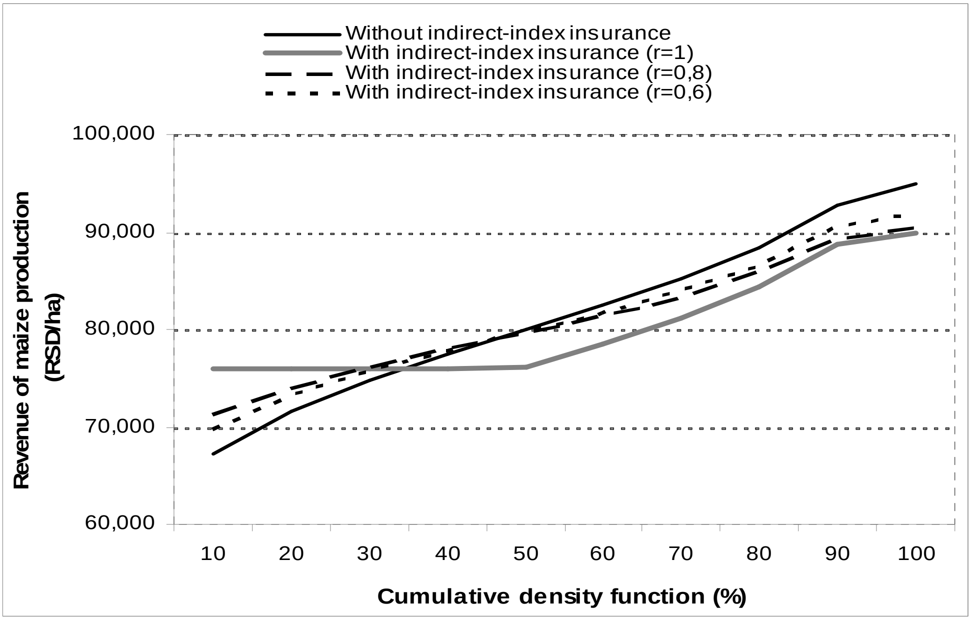
$$\tilde{V}_P = \tilde{y} \cdot c_y + O \cdot Max[0,(E(x)-\tilde{x})] - P_f \qquad (8)$$

The stochastic values ($\tilde{y}$ = 8 t/ha) and ($\tilde{x}$ = 295) have a normal distribution and mutually positive correlation. Based on this, by applying the formula (8), the stochastic simulation model can be formed, whose results are shown in the form of cumulative function with indirect-index insurance and without it (Graph 1)[8]. Since when calculating the revenue with indirect-index insurance a fair premium, which corresponds to average collection from the option, is subtracted, both distributions (with and without insurance) have the same expected value.

In the case of correlation of +1.0 the market revenue below 80,000 RSD/ha is compensated by the inflow from indirect-index insurance. When the fair premium of 4,000 RSD/ha is paid, it can be noted that the revenue below 76.000 RSD/ha is completely „cut-off", and lower expected production value cannot occur. If the percentiles are regarded as a measure of risk reduction, the revenue in percentiles of 10% without insurance amounts to 67,182 RSD/ha, and in the case with insurance it rises up to 75,984 RSD/ha (*Graph 1*).

[8] The simulation was carried out by means of a computer software Excel AddIn@Risk. This programme allows taking into account different correlations between the yield and weather index (Marković, 2010).

Graph 1. Revenue distribution of maize production, with and without indirect index-insurance



Source: authors' calculations

On the other hand, decreasing the correlation coefficient between the weather index and yield leads to the decrease in a positive effect, which is achieved from this insurance. Thus, for example in the case of correlation of +0.8 the possibility of occurring of lower revenue can be excluded. In the case of insurance this probability is lower, but it can happen that the yield is lower, so the full compensation will not be received. In the case of the percentiles of 10% the revenue with insurance (71,283 RSD/ha) will be higher by 6.12% than the variant without the application of indirect-index insurance (*Graph 1*).

If the correlation is even weaker (+0.6), the positive effect of this type of insurance increasingly decreases and the distribution curves (without and with insurance) almost overlap. The revenue in the case of percentiles of 10% without insurance amounts to 67,167 RSD/ha, and in the case with insurance it rises up to 69,765 RSD/ha (*Graph 1*). When the correlation coefficients are lower, the benefits from the application of indirect-index insurance are insignificant for risk prevention.

Conclusion

A presented example of using indirect-index insurance clearly shows that nowadays it represents a useful instrument for reducing weather risks. A special emphasis is put on reducing the oscillations of economic indicators of success (e.g. revenues), affected by a weather factor. If there is a strong correlation between weather index and maize yield (r=1.0), then the effect of reducing the risk is significant (8,816 RSD/ha). However, if the correlation coefficients are lower (r=0.8 or r=0.6), then the effect of prevention decreases (4,116 RSD/ha or 2,598 RSD/ha). 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.

Based on the previous provisions, it follows that suppliers of indirect-index insurance should allow denser network of meteorological reference stations, they should offer a mixed-weather-index (for example, by combining the rainfall and average temperature) or weather index with data from several meteorological stations, as well as a wider range of different types of index insurance. This refers primarily to the weather contracts design, with special emphasis on determination of critical point and the price of weather index, and it is also important to select the appropriate weather index and to study the correlation between yield and weather index.

These conditions surely scale up the complexity for sellers, but they are inevitable to raise farmer's interest for indirect-index insurance in general. At the moment it is still unclear in how far this financial instrument will establish in agribusiness in the years to come. Nevertheless, the previous calculations show a significant potential of indirect-index insurance in reducing the production risks, therefore it can be a supplement to the existing instruments for risk management in plant production.

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SMANJENJE VOLATILNOSTI PRIHODA U PROIZVODNJI KUKURUZA PRIMENOM INDIREKTNOG INDEKSNOG OSIGURANJA

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Rezime

Cilj rada je da pruži osnovne teorijske postavke indirektnog indeksnog osiguranja i da se njegovom primenom kvantifikuje efekat smanjenja rizika koristeći stohastičku simulaciju. U radu su korišćeni podaci o prinosu kukuruza sa porodičnog poljoprivrednog gazdinstva u centralnom delu Srema, a sa najbliže referentne meteorološke stanice uzeti su vremenski podaci. Da bi se ostvario zadati cilj analizirane su dve situacije: vrednost proizvodnje kukuruza sa upotrebom indirektnog indeksnog osiguranja i bez njega. U slučaju primene ovog tipa osiguranja poljoprivrednik može smanjiti rizik za 8.816 RSD/ha (r=1,0), 4.116 RSD/ha ako je koeficijent korelacije 0,8 odnosno 2.598 RSD/ha (r=0,6). Stoga se može zaključiti da postoji značajan efekat smanjenja rizika primenom indirektnog indeksnog osiguranja.

Ključne reči: *indirektno indeksno osiguranje, kukuruz, prihod, volatilnost, porodična gazdinstva*

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