EX-ANTE EVALUATION OF WEATHER-BASED INDEX INSURANCE AND AREA-YIELD INSURANCE FOR REDUCING CROP YIELD RISK

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EX-ANTE EVALUATION OF WEATHER-BASED INDEX INSURANCE AND AREA-YIELD INSURANCE FOR REDUCING CROP YIELD RISK

Raushan Bokusheva, Gunnar Breustedt, Olaf Heidelbach*

Abstract

The study introduces an ex-ante evaluation concept into the analysis of weather-based index insurance effectiveness. We conduct our ex ante analysis by distinguishing between two consecutive periods: the first period is used for determining insurance parameters and optimal number of insurance contracts for an arable farmer; and the subsequent one is considered for the evaluation of the risk reduction due to the insurance contract defined in the first period. The study also employs the common ex-post approach by specifying and evaluating insurance contracts by means of the same period. We compare the empirical results obtained from these alternative evaluation approaches and thus investigate the ability to forecast empirically insurance schemes risk reduction. In addition to weather-based index insurance, we consider two area-yield insurance products and a farm yield insurance. Our empirical results indicate that the common ex-post approach overestimates the risk reduction substantially for most index insurance schemes. Farm yield insurance seems to be robust to the choice of the empirical approach.

Keywords

Crop insurance, ex-ante analysis, Kazakhstan weather-based index insurance,

1 Introduction

Weather-based index insurance schemes represent an innovative crop insurance type. Weather-based index insurance seems to be less vulnerable to information asymmetries than other crop insurance schemes (Skees, Hazell, and Miranda, 1999; Varangis, Skees, and Barnett, 2002; Gine, Townsend, and Vickery, 2006). This feature of weather-based index insurance explains a great interest for its empirical implementation in arid and semi-arid regions where agricultural production is highly sensitive to weather conditions.

An important precondition for introducing a successful weather-based index insurance is high correlation between weather index shortfalls and farm yield shortfalls to reduce farmers’ crop yield risk. Several studies (Skees, Gober, Varangis, Lester, and Kalavakonda (2001); Berg, Schmitz, Starf, and Trenkel, 2006; Odening, Muhhoff, and Xu, 2006) search for appropriate weather indices which can be used as a trigger for weather-based index insurance or derivatives. Other authors investigate the effectiveness of risk management tools based on

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weather indices in terms of risk reduction (Vedenov and Barnett, 2004), Karuaihe, Wang, and Young, 2006; Bokusheva, Breustedt, and Heidelbach, 2007). All mentioned studies are based on the principle of the so-called burn-rate method that is often applied in actuarial practice and assumes that future losses will be distributed as in the past. With regard to weather-based index and area-yield insurance, this presupposes that the historically determined pattern of farm yield dependence on a weather variable or an area-yield will be maintained in the future. This assumption, however, might be crude if the relationship between farm yields and weather variables or between farm and area yields revealed for a past period has changed. In this case, the insurance might be less effective than expected because the estimated relationship between weather and crop yields may differ substantially from the relationship in the years when a farmer actually purchases insurance. In general statistical estimates such as a correlation between farm yields and index insurance payments can be forecasted with only a limited level of precision if the forecasts are based on only few harvesting years. However, so far the literature does not consider the validity of obtained forecasts.

Consequently, ex post analyses may overestimate the effectiveness of weather-based index insurance because they compute a farmer’s decision from ex post information and because they do not consider possible temporary changes in the (estimated) relationship between weather and yields.

In this context, the objective of our study is to introduce an ex-ante evaluation concept into the analysis of weather-based index insurance effectiveness in the sense that insurance payments and optimal number of insurance contracts are determined based on actually available information before purchasing insurance. In addition to our ex-ante approach, we conduct the common ex post analysis to evaluate empirically the robustness of the results obtained by applying these two different approaches. We also compare the effectiveness of weather-based index insurance with two area yield insurance products and a farm yield insurance. The paper proceeds with a review and discussion of the literature on evaluating index crop insurance schemes’ effectiveness. Section 3 presents our data, the insurance products’ specifications, and the methodological framework applied in the study. The section finishes by discussing the empirical results. Conclusions are drawn in the final section.

2 Literate review

We divide the literature review into a presentation of the theoretical framework and into the discussion of the empirical approaches to measure the effectiveness of index crop insurance. Based on this we develop an ex ante approach for measuring the effectiveness of crop insurance schemes which we describe in section 3.

2.1 Theoretical framework

There is considerable literature on assessing the effectiveness of different index crop insurance schemes prior to their market launch. For a crop insurance the indemnity payment \( n \) (per one area unit) is defined as \( n = p \max(x_s - x, 0) \), where \( x \) is an area (farm) yield in the case of area (farm) yield insurance, and a weather index in the case of weather-based index insurance. The indemnity is paid every time when actual values of \( x \) are less than the strike or trigger value \( x_s \) and is defined as their difference \( x_s - x \) times a monetary factor \( p \). If \( x \) is based on another variable than the farm yield we call such an insurance index-based insurance. A

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1 Though Odening, Muhhoff, and Xu (2006) apply in addition to the burn-rate method two simulation approaches, their analysis is based on the assumption that the relationship between the weather variable (which they simulate) and empirical yields will be kept in the future, too.

2 More general, we should say if \( x \) is not perfectly correlated to the variable whose risk should be reduced by the insurance.
farmer is free to choose the number of insurance contracts \( z \) he wants to purchase for index insurance. For farm yield insurance \( z \) is restricted not to exceed one to reduce moral hazard. Under this general setting Miranda (1991), Smith, Chouinard, and Baquet (1994) as well as Mahul and Vermersch (2000) evaluate the effectiveness of area yield insurance in terms of (relative) revenue variance reduction for a farmer.\(^3\) Skees, Gober, Varangis, Lester, and Kalavakonda (2001) look at the reduction of the coefficient of variation for a portfolio of different crops due to weather-based index insurance while VedenoV and Barnett (2004) use two risk measures – the semi-variance of insured revenue and the concept of Value-at-Risk (VaR) – to measure weather derivatives’ effectiveness. In addition, to determine demand for weather-based index risk management tools, VedenoV and Barnett (2004) as well as Karuaihe, Wang, and Young (2006) apply Expected Utility models based on explicit utility functions, including an assumption about the farmer’s level of risk aversion. The theoretical frameworks of the cited empirical studies are consistent in the sense that they either maximize Expected Utility (EU) or minimize a risk measure (RM) for one harvesting year with respect to the number of insurance contracts \( z \).\(^4\) In the following, for simplicity, we refer only to minimizing an RM such as variance or coefficient of variation. The (absolute) effectiveness of an index insurance is measured by the decrease of the RM if the optimal number of contracts \( z^* \) is chosen \( RM(z^*) \) compared to the RM without insurance, i.e. \( z = 0 \), \( RM(0) \). More formally, the difference in an RM \( \Delta RM \) is defined as follows:

\[
\Delta RM = RM(0) - RM(z^*)
\]

(1)

2.2 Problems of empirical evaluation

To define an insurance contract and assess its effectiveness for a farmer historical data on farm yields and of (hypothetical) indemnity payments are needed for an empirical analysis. Most of the above-mentioned studies estimate the optimal number of insurance contracts by

\[
\min_{z} RM_{i|T}^{z} | \Omega_{i|0}^{T}
\]

(2)

where \( \Omega_{i|0}^{T} \) is the information, i.e. yields and indemnities, from the period \( t_0 \) to \( T \). In other words, the RM minimisation is conditioned on all information available after \( T \). Thus, the minimization is done ex post.\(^5\) Further on, it is assumed that the number of contracts is the same in all periods. We call this optimal number of insurance contracts \( z_{i|0,T}^{*} \). However, a farmer must decide about the number of insurance contracts based on different amount of information than the econometrician uses in this case. In reality, the farmer has to decide about purchasing insurance contracts at the beginning of the growing year. In addition, he can purchase different numbers of insurance contracts in different years. Thus, the farmer’s decision problem at the beginning of each year \( k \) to find the optimal number of insurance contracts \( z_{k}^{*} \) is

\[
\min_{z_{k}} E \left[ RM^{k} \right] | \Omega_{0}^{k-1}
\]

(3)

---

\(^3\) A certain and known price as well costs for the agricultural product are assumed in all papers, thus, yield is the only source of risk in our type of analyses.

\(^4\) Both approaches can be equivalent under some restrictions, e.g. minimizing the variance can maximize EU if the insurance contracts are actuarially fair and the random variables follow the so-called location-scale condition (Meyer, 1987).

\(^5\) Due to short farm yield records – in general not exceeding 15 years – econometricians seem to have no alternative to this procedure.
The equation expresses that the farmer wants to minimize his risk, expressed by $RM$, in the year $k = t$ for all $t > T–L$ by purchasing insurance contracts at the beginning of $k$ conditioned on the information he has received from the periods prior to year $k$. Thus, we call $z_k^*$ the ex ante optimal number of insurance contracts for year $k$. We introduce the subscript $k$ to indicate those years for which the analysis is done ex ante. We assume $T>L$ to ensure that the farmer has historical information to determine $z_k^*$.

The solution $z_{t0,T}^*$ derived in the literature may considerably differ from $z_k^*$ because important information about the joint distribution of farm yields and / or indemnities may not be known until $k–1$. Three intuitive examples may examine different cases of this problem. First, in an ex-post analysis the risk reduction cannot be negative because otherwise the number of optimal insurance contracts would be zero. In contrast, in an ex ante framework the number of insurance contracts might be positive, though the risk reduction becomes negative. This might happen because the risk reduction is assessed for the year $k$ whose information was not used for determining the number of contracts $z_k$.

Second, imagine a farm yield insurance with a strike value of 75% of the expected yield, i.e. indemnities are only paid if the actual yield is below 75% of the expected yield. If the shortfall of farm yields until $k–1$ is always below 25% of the expected yield a farmer does not expect to reduce the risk measure for period $k$ by purchasing insurance and, thus, $z_k^* = 0$. However, in an ex post evaluation the econometrician may observe that there is at least one period with a yield shortfall larger than 25% in the periods after $k–1$ and, thus, $z_{t0,T}^* > 0$.

For the third example imagine an area-yield insurance. If there are very specific weather conditions locally on the farm in some of the years until $k–1$, the farmer observes a low correlation between the indemnities of the area yield insurance and his farm yield shortfalls. But taking into account the periods until $T$ the impact of the years with very specific local weather is reduced and the ex post optimal number of insurance contracts may be considerably higher than the number of purchased insurance contracts in the first periods after the periods with very specific weather.

Summing up, the number of insurance contracts and thus, the (expected) risk reduction may differ depending on whether one computes the ex post or the ex ante optimal number of insurance contracts. However, the ex ante framework seems to be more realistic since it represents more appropriately the actual amount of information which a farmer can use to determine number of insurance contracts to purchase at the beginning of a growing year, and the information which an insurer uses to determine insurance contract’s parameters before selling the contract.

This consideration may have led VEDENOV and BARNETT (2004) to develop a methodological framework to analyse so called out-of-sample effectiveness of weather derivatives. They estimate an optimal $z_{t0,T–L}^*$ by solving

$$\min_z \left[ \begin{array}{l}
RM_{t0}^{T–L} \\
\end{array} \right] \Omega_{t0}^{T–L}$$ (4)

According to that, the optimal number of insurance contracts is derived based on the information of a sub-period from $t_0$ to $T–L < T$. In the next step the risk reduction is computed for the remaining period from $T–L+1$ to $T$ assuming that the number of insurance contracts $z_{t0,T–L}^*$ is constant in every single year of the second sub-period:

$$\Delta RM_{T–L+1} = RM_{T–L+1}^T (0) – RM_{T–L+1}^T (z_{t0,T–L}^*)$$ (5)

Although, $z_{t0,T–L}^*$ equals $z_k^*$ if $k = T–L+1$, it may change in consecutive years because an increasing amount of information becomes available in the ex ante approach. This makes the out-of-sample approach less realistic than the ex ante approach described above.
Finally, for now we have assumed that the farm yield data and the data for the indices underlying the insurance schemes are free from any time trend and their relationship stays constant over time. However, testing for a time trend in the data is necessary if a farmer aims at minimizing the risk defined as uncertainty about the expected farm yield and about the expected insurance indemnity, as recent papers do. If there is a time trend the expected yield or insurance index has to be adjusted for that trend. At the same time, detrending has to be consistent with the procedure which determines the optimal number of insurance contracts. It should be consistent in the sense that the same information amount is used for the detrending procedure as for assessing the optimal number of insurance contracts. Then, detrending in the ex post and in the ex ante approach differ because different information amounts $\Omega$ are available according to these approaches. The same applies to the insurance parameters’ specification, such as the strike level or the parameters for computing the weather index. In the ex post approach time trend and insurance parameters are based on the information $\Omega_{t_0}^T$ over the whole period considered in the analysis, i.e. from $t_0$ to $T$ and thus they are assumed to be the same over the whole period. In the ex ante approach the trend and insurance parameters are estimated for every sub-period independently based on the information set $\Omega_{t_0}^{t_k-1}$ and thus may differ between single sub-periods $t_0$ to $k - 1$.

3 Empirical Analysis

3.1 Data

Yield data was collected by means of farm surveys and covers 54 large grain producers in five rayons (administrative units similar to counties) from 1980 to 2002. In 2002, the examined farms’ wheat areas vary from a few hundred to more than 23,000 hectares, and represent 5.8% of the national wheat area. In addition to farm data, the study employs official statistics on national and rayon yields (Regional Statistical Offices, 2003/2004; National Statistical Agency, 2004) as well as data from a weather station in each rayon. The distance to the respective weather station varies for the individual farms within the rayons; this can cause different levels of basis risk for the investigated farms when insurance is based on a weather index.

The expected farm yields for 2002 vary between 0.31 t/ha in north-west Kazakhstan (rayon 4) and 2.37 t/ha in eastern Kazakhstan (rayon 5). In 1998, a year of great drought, the weighted average yield of all sample farms amounted to only 0.38 t/ha, which is 40% of the average observed yield from 1980 to 2002. The average cumulative precipitation during the summer months of June to August lies between 153 mm (standard deviation of 61) and 88 mm (standard deviation of 33). Table A1 in the Appendix presents expected yields, average values of weather variables, and variations of yields as well as weather variables for selected farms.

3.2 Empirical procedures

Our analysis has to two major aims. First, we want to compare the risk reduction due to the ex ante approach and due to the ex post approach. Second, we want to separate the effect of the ex-post detrending and insurance parameters determining from the effect of the ex-post-estimated number of insurance contracts. Therefore, we introduce an additional procedure called mixed approach with an ex ante detrending, ex ante insurance parameters specification, and an ex post optimal number of contracts. In our empirical analysis we distinguish between the ex post and the ex ante approaches by employing two different procedures for each step of analysis: determining the optimal number of insurance contracts and detrending yields. First,
we describe our approaches to derive the optimal number of contracts. Then we present
detrending procedures employed in the ex post and ex ante approaches, respectively.

**Determining the optimal number of insurance contracts**

We start by dividing our sample of 23 years (1980 – 2002) into two sub-samples: the first one from 1980 to 1991 and the second one from 1992 to 2002 and set \( k \in \{1992, 1993, \ldots, 2002\} \). The latter sub-period is used for comparing the risk reduction due to the ex post and the ex ante approach, respectively. The relative variance reduction of the uninsured farm wheat revenue assuming a known and constant wheat price is applied as the risk measure \( RM \).

In the ex post approach, we measure the risk reduction over the period 1992 to 2002, i.e. \( t_0 = 1992 \), and \( T = 2002 \) in (2). Determining the ex post optimal number of insurance contracts follows the standard literature (e.g. Miranda 1991) for the years 1992 to 2002 and we define the insured revenue \( \pi_k \) for a year \( k \)

\[
\pi_k = p y_k - z_{1992,2002}^* n_k - z_{1992,2002}^* E[n] \tag{6}
\]

and find the variance minimising number of insurance contracts \( z_{1992,2002}^* = -\frac{Cov[p y,n]}{Var[n]} \) based on the data from 1992 to 2002. In the ex ante approach, we use the data from years 1980 to \( k - 1 \) to estimate the ex ante optimal number of insurance contracts \( z_k^* \) for year \( k \) following equation (3). \( t_0 \) is set to 1980, \( T = 2002 \), \( L=11 \) (\( T-L=1991 \)), and \( t \in \{1980, \ldots, 2002\} \). We compute the optimal number of insurance contracts \( z_k^* \) separately for each year \( k \) based on the data for the period from 1980 to \( k - 1 \). The ex ante solution \( z_k^* \) is derived following the standard literature (e.g. Miranda 1991), i.e. in the same manner as in the ex post approach but by applying the data from 1980 to \( k - 1 \) only. Accordingly, the insured revenue \( \pi_t \) is defined as follows:

\[
\pi_t = p y_t - z_t^* n_t - z_t^* E[n], \text{ with } t \in \{1980, 1981, \ldots, k-1\}. \tag{7}
\]

The variance minimising number of insurance contracts \( z_k^* = -\frac{Cov[p y,n]}{Var[n]} \) is determined over the whole period 1980 to \( k - 1 \) and, thus, the procedure is applied for each year \( k \), i.e. \( L \) times in total. Then the variance of insured revenue \( \text{var}_{\text{ante}} \) is computed for the whole sub-period considered for the ex-ante evaluation, i.e. from 1992 to 2002 as described in (8):

\[
\text{var}_{\text{ante}}^{2002}_{1992} = (11-1)^{-1} \sum_{k=1992}^{2002} \left( p y_k + z_k^* n_k - 11^{-1} \sum_{k=1992}^{2002} (p y_k - z_k^* n_k) \right)^2 \tag{8}
\]

We assess the relative ex ante risk reduction over the period 1992 to 2002 by

\[
\Delta_{\text{ante}}^{2002}_{1992} = \frac{\text{var}_{\text{ante}}^{2002} - \text{var}_{\text{ante}}^{2002, \text{without} 1992}}{\text{var}_{\text{ante}}^{2002, \text{without} 1992}} \tag{9}
\]

where \( \text{var}_{\text{ante}}^{2002, \text{without} 1992} \) is the revenue variance without insurance over the period from 1992 to 2002 computed analogously to (12) with \( z_k = 0 \).

**Detrending**

The general detrending procedure employed in the study includes the following steps. First, we test the yield data for a time trend by employing second-degree polynomial and linear time trends, alternatively. If estimated trend parameter(s) in the respective regression model is (are) not found to be significantly different from zero according to an F-test, no de-trending is applied. Otherwise, we employ the estimated trend parameter(s) from the respective regression. Then, farms with either autocorrelated yields or negative expected yields are
excluded from the sample. Consequently, after detrending our sample contains 40 farms from 5 rayons.

In the 1995-1998 period farms’ wheat yields declined because of extreme droughts in the individual years. Therefore, to control for this effect in estimating the trend parameters over all years we estimate the time trend parameters taking into account annual weather conditions by employing the meteorological Ped index from (14). Thus, assuming a second-degree polynomial trend we estimate the following regression:

$$s_t = \hat{a}_0 + \hat{a}_1 t + \hat{a}_2 t^2 + \hat{a}_3 \text{Ped}_{t}^{\text{meteo}} + \hat{u}_t$$

(10)

where $s_t$ is the observed yield, $\hat{u}_t$ is the estimated residual, $\hat{a}_j$ with $j \in \{0, 1, 2, 3\}$ are to be estimated, $t \in \{1, 2, \ldots, N\}$, $N$ is number of years included in the detrending, and $\text{Ped}_{t}^{\text{meteo}}$ is the meteorological Ped drought index from (14). The detrended farm and rayon yields are defined as $\hat{a}_0 + \hat{a}_3 \text{Ped}_{t}^{\text{meteo}} + \hat{u}_t$, i.e. the weather effect is kept in the detrended yield because it cannot be foreseen by a farmer.

There are only small differences in the detrending procedure between the ex ante and the ex post detrending. For the ex-post analysis we employed yield time series from 1992 to 2002. Thus, for equation (10) $N$ amounts to 11 and $t \in \{1992, \ldots, 2002\}$. For the ex-ante detrending we estimate the trend parameters for 11 different periods, i.e. we compute (10) eleven times. Thus, equation (10) is estimated for $t \in \{1980, 1981, \ldots, k-1\}$ with $k \in \{1992, 1993, \ldots, 2002\}$ and $N \in \{12, 13, \ldots, 22\}$. The expected yields and detrended yields are calculated for each year $k$ over the 1992-2002 period from the regression based on the data before that year. For example, for 1994 we used the parameters of the regression from the data 1980 to 1993. In doing so, we replicate situations actually observed in the insurance practice, when the length of available time series increases with every succeeding year.

3.3 Insurance schemes

We evaluate two main groups of index insurance products: weather-based index insurance (WBII) and area yield insurance (AYI). In addition, we use farm yield insurance (FYI) as a reference, which is the equivalent to the U.S. standard farm yield insurance. The analysis considers WBII products based on two drought indices developed for Kazakhstan by Selyaninov (1958) and Ped (1975) (quoted in Shamen (1997)). Area yield insurance is defined at the national and rayon level.

In general, we construct our insurance premiums and indemnity payments as described in the theoretical framework. The indemnity is denoted $z*n$ where $z$ is the number of insurance contracts chosen by the farmer and $n$ is defined as $p*\text{Max}[x_i - x, 0]$ where $x$ is the detrended yield or the weather-based index in an individual year and $x_i$ is the strike or trigger value, $p$ represents a monetary factor. The strike value for all index insurance schemes is the expected value. For the farm yield insurance, the trigger value is set to 75% of the expected farm yield, which equals the maximum strike yield in the U.S. farm yield insurance in most U.S. regions. The insurance premium is assumed to be fair, i.e. it amounts to $z*E[n]$.

The index $x$ for weather-based index insurance or derivative products (put options) are usually built either from one or several weather indicators. Skees, Gober, Varangis, Lester, and Kalavakonda (2001) and Turvey (2001) use either cumulative rainfall or temperature, while Vedeno and Barnett (2004) as well as Karuahire, Wang, and Young (2006) analyze the effectiveness of weather derivatives and insurance products based on a linear combination of several weather indicators. To specify an index, i.e. to determine the weights of the various (transformed) weather variables defining an index value, two different

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7 The expected yields follow from $\hat{a}_0$ and the significant parameters $\hat{a}_1$ and/or $\hat{a}_2$ in the linear or quadratic detrending.
approaches are possible. The aforementioned studies regress the crop yield to be insured on weather indicators in different specifications and construct yield-tailored weather indices from these regressions. These indices can be constructed either from farm yields or rayon yields.\(^8\) On the one hand, such indices represent the historical yields as best as possible. On the other hand, due to estimation uncertainty, the yield regressions add uncertainty to predictions that have to be used for calculating future insurance payments. The second manner of constructing a weather-based index is to use exogenous indices found in meteorological studies, which are not adjusted to the yields to be insured, e.g. exogenous meteorological indices. In this case, however, the problem is a presumably higher level of basis risk compared to weather insurance based on yield-tailored indices. In our study, we analyse farm yield tailored and meteorological weather indices.

The farm yield-tailored weather indices are described in equations (11) and (12). The farm yield-tailored Selyaninov index is defined as

\[
S_{\text{t}}^{\text{tailored}} = w_{\text{May}} P_{\text{May}}^t + w_{\text{June}} \frac{P_{\text{June}}^t}{\text{Temp}_{\text{June}}^t} + w_{\text{July}} \frac{P_{\text{July}}^t}{\text{Temp}_{\text{July}}^t} + w_{\text{Aug}} \frac{P_{\text{Aug}}^t}{\text{Temp}_{\text{Aug}}^t} + w_{\text{Sept-April}} P_{\text{Sept-April}}^t \tag{11}
\]

The farm yield-tailored Ped index is computed by

\[
\begin{align*}
\text{Ped}_{\text{t}}^{\text{tailored}} & = w_{\text{June}} \frac{\Delta P_{\text{June}}^t}{\sigma_{\text{June}}} + w_{\text{July}} \frac{\Delta P_{\text{July}}^t}{\sigma_{\text{July}}} + w_{\text{Aug}} \frac{\Delta P_{\text{Aug}}^t}{\sigma_{\text{Aug}}} - w_{\text{Sept-May}} \frac{\Delta P_{\text{Sept-May}}^t}{\sigma_{\text{Sept-May}}} + \frac{\Delta P_{\text{Sept-May}}^t}{\sigma_{\text{Sept-May}}} \\
& \quad - \Delta \text{Temp}_{\text{June-Aug}}^t - \Delta \text{Temp}_{\text{July-Aug}}^t - \Delta \text{Temp}_{\text{Aug-May}}^t - \Delta \text{Temp}_{\text{June-Aug}}^t \\
& \quad - \Delta \text{Temp}_{\text{July-Aug}}^t - \Delta \text{Temp}_{\text{Aug-May}}^t - \Delta \text{Temp}_{\text{June-Aug}}^t - \Delta \text{Temp}_{\text{July-Aug}}^t - \Delta \text{Temp}_{\text{Aug-May}}^t - \Delta \text{Temp}_{\text{June-Aug}}^t \tag{12}
\end{align*}
\]

where \(P\) is the cumulative precipitation in a particular sub-period, \(\text{Temp}\) is the average daily temperature in an indicated sub-period, \(t\) is a year index, \(\sigma\) stands for the long-term standard deviation of a particular weather parameter, \(\Delta\) corresponds to the difference between long-term average and the level of a respective weather parameter in year \(t\), and \(w\) represents a sub-period’s weight, obtained from regressions of farm yields on the right-hand side variables. The regression ensures that the indemnity payments of the weather-based index insurance schemes are scaled similarly to the area and farm yield insurance schemes.

The meteorological Selyaninov and Ped weather indices are described in (13) and (14), respectively, following SELYANINOV (1958) and PED (1975) (quoted in SHAMEN (1997)).

\[
\begin{align*}
S_{\text{t}}^{\text{meteor}} & = \frac{P_{\text{June-Aug}}^t}{\text{Temp}_{\text{June-Aug}}^t} + P_{\text{Sept-May}}^t \tag{13}
\end{align*}
\]

\[
\begin{align*}
\text{Ped}_{\text{t}}^{\text{meteor}} & = \frac{\Delta P_{\text{June-Aug}}^t}{\sigma_{\text{June-Aug}}} + \frac{\Delta P_{\text{Sept-May}}^t}{\sigma_{\text{Sept-May}}} - \frac{\Delta \text{Temp}_{\text{June-Aug}}^t}{\sigma_{\text{Temp}_{\text{June-Aug}}^t}} \tag{14}
\end{align*}
\]

To ensure a similar scale for the latter two indices they were multiplied with a factor which was determined for a respective rayon.

Similarly to the procedure employed for yield detrending, the insurance parameters are specified differently in the ex ante and in the ex post analysis. For the ex-post analysis we estimate respective insurance parameters, e.g. \(w\) in (11) and (12), by employing weather and yield time series from the 1992 to 2002 period. The insurance parameters are estimated for every of the 11 considered sub-periods separately in the ex-ante approach, i.e. 1980 to \(k - 1\).

\(^8\) All previous analyses of weather-based index insurance use regional crop yields. In our study we adjust indices to farm yields. From a practical point of view, additional transaction costs arise for the insurance company, because weather insurance has to be adjusted for each farm. However, for large farms like those in Kazakhstan, these additional costs are small per hectare insured. Problems of moral hazard or adverse selection do not arise due to yield tailoring because actual indemnity payments are only based on the actual weather variables, which cannot be influenced by a farmer. Yield tailoring only means scaling both premiums and indemnity payments equivalently.
3.4 Results

Table 1 presents the relative variance reductions of the analysed insurance schemes under three employed approaches. In the first row the average variance reduction of the common literature approach – the ex post approach (with ex post detrending and ex post estimation of the optimal number of insurance contracts) – ranges from 24 to nearly 44 per cent. The number of farms with a positive variance reduction according to the ex post approach varies between 36 and 40. The last two rows show the results for our ex ante approach. The results differ considerably for some insurance schemes, e.g. the average variance reduction reduces by more than one half for the area yield insurance based on the national yield (second column), the exogenous Ped drought index insurance, and both farm tailored weather insurance contracts (three last columns). For the rayon yield insurance and the exogenous Selyaninov index the average variance reduction decreases by one third and by one fourth, respectively. Only, the average variance reduction due to the farm yield insurance is nearly unchanged between the ex post and the ex ante approach. Moreover, Figure 1 shows that there is not any clear relationship between the levels of the ex post and the ex ante variance reduction for the index insurance with the highest average variance reduction in each approach.

Table 1: Variance reduction from different empirical approaches.

<table>
<thead>
<tr>
<th>40 farms</th>
<th>farm insurance</th>
<th>national yield insurance</th>
<th>rayon yield insurance</th>
<th>Sel meteo</th>
<th>Ped meteo</th>
<th>Sel tailored</th>
<th>Ped tailored</th>
</tr>
</thead>
<tbody>
<tr>
<td>ex post</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>average variance reduction</td>
<td>24.2%</td>
<td>26.7%</td>
<td>43.6%</td>
<td>24.8%</td>
<td>30.3%</td>
<td>26.8%</td>
<td>42.5%</td>
</tr>
<tr>
<td># farms with positive variance reduction</td>
<td>36</td>
<td>38</td>
<td>40</td>
<td>39</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>mixed (ex ante trend, ex ante insurance parameters, ex post number of contracts)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average variance reduction</td>
<td>21.3%</td>
<td>33.8%</td>
<td>41.4%</td>
<td>23.2%</td>
<td>24.2%</td>
<td>24.6%</td>
<td>24.6%</td>
</tr>
<tr>
<td># farms with positive variance reduction</td>
<td>36</td>
<td>39</td>
<td>39</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>ex ante</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>average variance reduction</td>
<td>23.4%</td>
<td>10.3%</td>
<td>31.0%</td>
<td>19.7%</td>
<td>8.1%</td>
<td>8.6%</td>
<td>11.3%</td>
</tr>
<tr>
<td># farms with positive variance reduction</td>
<td>39</td>
<td>32</td>
<td>38</td>
<td>36</td>
<td>25</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td># farms with negative variance reduction</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>15</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>

Insurance purchased in each year for the harvests between 1992 to 2002.

Summing up, (I) overestimation by the ex post approach can be substantial. Consequently, the studies based on the ex post approach which report significant variance reduction through index-based insurance probably overestimate the effectiveness of index-based crop insurance. The variance reduction based on area yields reported by Miranda (1991), Smith,
CHOUINARD, and BAQUET (1994) as well as MAHUL and VERMERSCH (2000) are in the same range as reported for the ex post approach of the insurance schemes analysed in our study. The variance reduction of nearly 50% reported by SKEES, GOBER, VARANGIS, LESTER, and KALAVAKONDA (2001) through weather-based index insurance in Morocco is somewhat higher than the highest ex post variance reduction found in our data.9 (II) The results for the farm yield insurance seem to be more robust to the choice of approaches. This is not surprising in our view since the optimal number of insurance contracts is either zero or one for a farm yield insurance. It is always one for a fair farm yield insurance with a strike level of 75% of the expected farm yield if there is at least one farm yield short fall of more than 25% of the expected yield in the periods used to compute the optimal number of insurance contracts. Since there are 36 out of 40 farms with a positive variance reduction in the ex post approach and there are 39 with a positive variance reduction in the ex ante approach at least 35 farms have a positive variance reduction in both approaches. Thus, there are only five or less farms which have no yield shortfall exceeding 25% of their expected farm yield in the periods 1992 to 2002 and at least one such farm yield shortfall in the period 1980 to 1991 or vice versa.10 Thus, it is not surprising that the recommendations and results from both approaches do not differ substantially.

Figure 1: Variance reduction for rayon insurance in the ex post and in the ex ante approach

![Rayon insurance with strike 100% of expected yield](image)

One farm is not displayed that doubles its revenue variance in the ex ante approach.

To distinguish between two effects: the effect of ex-ante de trending. insurance parameters’ specification, and ex ante contract parameters’ specification we use the mixed approach for which the yield detrending and insurance parameters specification are done ex ante but the number of insurance contracts is determined ex post. Thus, in the mixed approach and in the ex ante approach the data on yields and insurance payments are the same but the optimal

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9 SKEES, GOBER, VARANGIS, LESTER, and KALAVAKONDA (2001) report a reduction of the coefficient of variation of 29%. If the reduction of the standard deviation is 29%, too, the variance decreases by 49.59%. Since the authors assume a fair premium, the mean does not change and the reduction of the coefficient of variation should be equal to the reduction of the standard deviation.

10 However, we have to keep in mind that the detrending is different in both approaches.
number of contracts is determined differently, i.e. ex post and ex ante. The results of the mixed approach are presented in the two middle rows. For the farm yield insurance (first column) again, we cannot state substantial differences in the results of different empirical approaches. The variance reduction through the farm yield insurance from the mixed approach is 21.3% and thus does not differ substantially from the results of the ex post (24.2% reduction) and the ex ante (23.4% reduction) approaches. Obviously, there is not any distinctive over- or underestimating through the ex post determination of the optimal number of the farm yield insurance contracts. Consequently, neither the ex post choice of contracts nor the ex post detrending seem to overestimate substantially the variance reduction of the farm yield insurance. In other words, the ex post approach seems to deliver empirical results which are not less appropriate than results from the ex ante approach for the farm yield insurance. In detail, figure 2 shows that there is a positive correlation between the relative variance reduction in the mixed and in the ex ante approach for the farm yield insurance.

Figure 2: Variance reduction for farm insurance in the mixed and in the ex ante approach

One farm is not displayed that doubles its revenue variance in the ex ante approach.

The results for the index-based insurance schemes are less robust regarding the evaluation approaches applied. In general, the average variance reduction is substantially lower for the ex ante number of insurance contracts than for the ex post number of insurance contracts by applying them to the ex-ante assessed insurance payments and ex ante detrended yields (middle and bottom rows). This conclusion holds for nearly every individual farm (see figure 3). Contrarily, the difference between the ex post number of contracts applied to the ex ante determined insurance payments and detrended yields and the ex post determined insurance payments and yield data is small in general (middle and top rows). Consequently, the ex post approach employed in the literature seems to cause the overestimation of average variance reduction for index insurance schemes primarily due to differences in the estimated number of insurance contracts compared to the ex ante approach.
Figure 3: Variance reduction for rayon insurance in the mixed and in the ex ante approach

One farm is not displayed that increases its revenue variance in the ex ante approach by 67%.
Although, the average variance reduction is similar in the mixed and in the ex post approach for most index insurance schemes figure 4 shows that the relationship between the variance reductions of the rayon insurance under both approaches differs substantially among farms. It seems that the variance reduction of an index-based insurance for an individual farm may depend substantially on the detrending procedure applied.

Figure 4: Variance reduction for rayon insurance in the ex post and in the mixed approach.
4 Concluding Remarks

Previous analyses on weather-based index insurance apply the ex post evaluation framework and thus do not consider possible temporary changes in yield and weather variables’ distributions that may seriously affect insurance effectiveness. In our study we introduce an ex-ante evaluation approach to test effectiveness of weather-based index insurance contracts over time. We conduct our ex ante analysis by distinguishing between two consecutive periods: the first period is used for determining insurance parameters and optimal number of contracts; and the subsequent one is considered for the evaluation of the insurance contract defined in the first period. The study also employs the common ex-post approach by specifying and evaluating the insurance contracts for the same period.

Our estimation results show that the effectiveness of weather-based insurance may change seriously over time. That means forecasting the relationship between weather variables and farm yields seems to be uncertain, at least for short time series of somewhat ten years. Both statistics: the number of farms with positive variance reduction and the average variance reduction are substantially lower according to the ex ante analysis than in the ex post case. Moreover, approximately one third of all considered farms realise a negative variance reduction which means that the weather-based index insurance may increase farmers’ risks.

The considered farm yield insurance demonstrates quite moderate variance reduction, however its results seem to be more robust to the choice of approaches. Though the effectiveness of the area yield insurance based on rayon yields reduces seriously in the ex ante analysis, it provides the highest average variance reduction according to both applied empirical approaches. According to our empirical results overestimation by the ex post evaluation approach can be substantial. Thus, previous studies based on the ex post approach probably overestimate the effectiveness of index-based crop insurance, i.e. weather-based index as well as area-yield insurance. Further on, the ex post approach employed in the literature seems to cause the overestimation of variance reduction primarily due to differences in the estimated number of insurance contracts compared to the ex ante approach rather than different detrending and different determination of insurance parameters in the ex ante and in the ex post approach.

However, if only short time series are available, the feasibility of weather-based index and area-yield insurance may be seriously questioned. Under these circumstances, a farm yield insurance may provide a more reliable crop insurance coverage than a weather-based index insurance from a farmer’s point of view. Thus, it should be evaluated, whether our results regarding the effectiveness of farm yield insurance hold for other strike yields, either. The ex ante approach presented in the paper can be extended by determining the minimal length of time series which is sufficient to estimate reliable ex ante trend and insurance parameters as well as number of insurance contracts. Finally, the ex ante performance of index-based insurance should be evaluated from the insurers’ perspective, too, because the variability of indemnity payments might be underestimated in the ex post approach.
References


Appendix A


<table>
<thead>
<tr>
<th>Rayon number</th>
<th>Farm*</th>
<th>Expected yield (2002) in 0.1t/ha**</th>
<th>Yield STD</th>
<th>Cumulative precipitation in mm</th>
<th>Average daily temperature in °C</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(June-August)</td>
<td>(June-August)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>STD</td>
</tr>
<tr>
<td>1</td>
<td>a)</td>
<td>9.16</td>
<td>3.42</td>
<td>117</td>
<td>49</td>
</tr>
<tr>
<td>1</td>
<td>b)</td>
<td>6.97</td>
<td>4.66</td>
<td>117</td>
<td>49</td>
</tr>
<tr>
<td>2</td>
<td>a)</td>
<td>11.27</td>
<td>2.95</td>
<td>103</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>b)</td>
<td>8.53</td>
<td>4.61</td>
<td>103</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>a)</td>
<td>6.32</td>
<td>3.09</td>
<td>118</td>
<td>49</td>
</tr>
<tr>
<td>3</td>
<td>b)</td>
<td>10.17</td>
<td>4.21</td>
<td>118</td>
<td>49</td>
</tr>
<tr>
<td>4</td>
<td>a)</td>
<td>9.80</td>
<td>4.00</td>
<td>153</td>
<td>61</td>
</tr>
<tr>
<td>4</td>
<td>b)</td>
<td>11.04</td>
<td>5.39</td>
<td>153</td>
<td>61</td>
</tr>
<tr>
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<td>a)</td>
<td>17.44</td>
<td>3.91</td>
<td>134</td>
<td>41</td>
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<tr>
<td>5</td>
<td>b)</td>
<td>16.46</td>
<td>6.17</td>
<td>134</td>
<td>41</td>
</tr>
</tbody>
</table>

*) farm a) is the farm with the lowest, farm b) with the highest standard deviation in the respective rayon,
**) after de-trending by employing ex post approach and by including weather effect.

Source: Own calculations.