Assessing the farm level impacts of yield and revenue insurance: an expected value-variance approach

by

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Contributed paper submitted for the X[th] Congress of the European Association of Agricultural Economists (EAAE)

28-31 August 2002
Zaragoza (Spain)

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Abstract

This paper investigates the farm level impacts of multiple peril yield and revenue insurance in an expected value-variance framework. The analysis is conducted using stochastic simulation jointly with numerical optimisation. Simulation is used to compute the means and variances of revenues as affected by the insurance schemes under consideration. In a second step these results are incorporated in a whole-farm programming approach, which optimises a portfolio that consists of crop production and insurance activities. The results of a case study indicate that from the farmer's point of view there is an incentive to buy multiple peril crop insurance, because it significantly reduces the variability of income. The risk reduction through insurance in turn leads to a specialisation of the production program. The farm level benefit of crop insurance strongly depends on the decision maker's degree of risk aversion. Furthermore, risk free parts of the total income reduce the economic attractiveness of insurance schemes. This applies e.g. to the area payments under the European agricultural policy, which therefore limit the potential demand for crop insurance.

Keywords: crop insurance, risk management, portfolio selection, stochastic programming, expected value-variance analysis

Introduction

Multiple peril crop insurance has become an important issue in the discussion about European common agricultural policy (CAP). The main reason for this is that the prevailing conditions of farming have changed considerably since the CAP reform of 1992. The continuous liberalisation of markets combined with decreasing price support result in an increase of market risks. Besides this, more stringent regulations with respect to the application of agro chemicals cause an increase of yield variability. On the other hand, the currently granted area payments are risk reducing since they are independent from yields and prices. It is certainly debateable whether at all or to what extent this results in an increased variability of net farm income. Latter can be expected with certainty, if area payments will be lowered or linked to environmental constraints, as currently under discussion. It therefore appears worthwhile analysing new or additional risk management instruments. Among these, multiple peril crop insurance concepts, as can be found in the USA as well as in some European countries, have recently gained a considerable amount of interest.

In this paper we therefore address the farm level impacts of multiple peril crop insurance schemes using a modelling approach. The objective of the approach is to evaluate the economic attractiveness of different insurance designs and to assess the relative importance of yield and revenue insurances as farm level instruments of risk management. Risk in the sense of a threat to the survival of the business always refers to the firm as a whole and not to a single production process. Assessing the economic benefit of insurance contracts therefore requires a whole farm approach, which shall be developed in the following sections of this paper. The model is then used in a case study to analyse the effects of different insurance designs.

[*)] This research was partially funded by the Deutsche Forschungsgemeinschaft (DFG) under contract No. BE 1341/4-1

Previous studies

The longest tradition with multiple peril crop insurance can certainly be found in the USA. Consequently, a number of studies that use modelling experiments to address issues regarding crop insurance have been conducted in the US. These studies mostly focus on the analysis of the economic impacts of insurance contracts relative to other risk management instruments, such as cash forward pricing or hedging with futures and options. DHUYVETTER and KASTENS (1997) for example investigate the effects of various combinations of crop insurance policies and futures contracts on the means and variances of revenues. HEIFNER and COBLE go one step further and analyse the influence of different types of insurance contracts (yield and revenue insurances) on optimal hedge ratios (HEIFNER and COBLE, 1997; COBLE and HEIFNER, 1999). By using expected utility as objective function they explicitly consider the decision maker's attitudes to risk. A similar approach is used by WANG et al. to explore the relationship between hedging with futures and options on one hand and different types of crop and revenue insurance contracts on the other hand (WANG et al., 1998; 2000). They expand the scope of the optimisation so that it also determines optimal coverage levels for the insurance contracts. All the above studies refer to single crop farms, so decisions concerning the production program remain unconsidered.

In Europe, MEUWISSEN et al. have studied yield and revenue insurance as risk management instruments by means of stochastic simulation (MEUWISSEN et al., 1999; MEUWISSEN, 2000). The model results illustrate the influence of insurance contracts on the variability (i.e. the coefficient of variation) of net farm income. This approach also refers to single crops leaving the choice of the production program unconsidered. Furthermore, risk attitudes are not explicitly taken into account. In contrast to this SCHLIEPER employs a whole farm approach to optimise a portfolio that consists of a set production activities with and without crop insurance under an expected value-variance framework (SCHLIEPER, 1997).

Arable farms in Europe are typically multi-commodity operations. Hence, crop mix selections are important in the context of risk management, as a diversified production program is risk reducing in itself. A single crop approach would not capture this effect. In the following we therefore develop an approach that combines stochastic simulation with the optimisation of a portfolio that consists of crop production and insurance activities. Hedging with futures and options will not be included in the analysis since these activities have not yet gained much importance in Europe (particularly not in Germany).

Theoretical background

The most general approach for comparing risky choices is by means of expected utility. This requires that all possible outcomes of the risky prospect be translated into utility measures to compute the expected utility. Later on this criterion can be retranslated into a monetary measure, i.e. the certainty equivalent, by taking the inverse of the utility function. The certainty equivalent represents the certain amount of money, which a decision maker with a given utility function would rate as equivalent to the uncertain outcome of the risky prospect (cf. ROBISON and BARRY, 1987, p. 23ff). As the certainty equivalent accurately reflects the decision maker's attitudes to risk, we use this criterion in our modelling approach. Furthermore we derive the certainty equivalent by means of expected value-variance analysis (EV analysis). ROBISON and BARRY (1987) have worked out the conditions under which the EV approach yields results consistent with the more general expected utility models. The reason for choosing the EV approach in the context of this study is that it can be readily employed in stochastic optimisation.

By definition the certainty equivalent CE equals the expected return *E(x)* minus the risk premium π, i.e. $CE=E(x)–\pi$. For the latter PRATT has derived the approximate relationship

$$\pi \approx \frac{1}{2} R(E(x))\, V(x) \qquad (1)$$

where $R(E(x))$ indicates the decision maker's absolute risk aversion measured at the expected value (cf. ROBISON and BARRY, 1987, p. 34). Thus the certainty equivalent can be expressed as

$$CE = E(x) - \frac{1}{2} R(E(x))\, V(x) \qquad (2)$$

The absolute risk aversion function is defined as

$$R(x) = \frac{-u''(x)}{u'(x)} \qquad (3)$$

where $u'(x)$ and $u''(x)$ denote the first and second derivative of the utility function $u(x)$. Determining $R(x)$ therefore requires the definition of the type of the utility function. Two frequently used functional forms are the negative exponential

$$u(x) = 1 - e^{-\lambda x}\ ,\ \lambda > 0$$

and the power function in the form

$$u(x) = \frac{1}{1-\theta} x^{1-\theta}\ , \theta > 1$$

which belong to the same class of utility functions (cf. INGERSOLL, 1987, p. 39). The first one yields $R(x)=\lambda$ and therefore implies constant absolute risk aversion (CARA). It is more likely however that decision makers express decreasing absolute risk aversion with increasing wealth (DARA). This is captured by the power function, for which $R(x)$ takes on the form

$$R(x) = \frac{-u''(x)}{u'(x)} = \frac{\theta}{x} \qquad (4)$$

and therefore reflects DARA. From equation (4) we obtain

$$\frac{-u''(x)\,x}{u'(x)} = \theta$$

Since the term $[-u''(x)x/u'(x)]$ represents a measure of relative risk aversion (cf. HARDAKER et al., 1997, p. 97), the power function characterises the case of constant relative risk aversion (CRRA), the degree of which is determined by the coefficient θ. Substituting (4) into (3) finally yields the certainty equivalent CE as

$$CE = E(x) - \frac{\theta}{2\,E(x)} V(x) \qquad (5)$$

This relation is particularly useful because the risk aversion coefficient θ is independent of the magnitude of x (where x should be expressed in terms of wealth). Thus its numerical specification can be based on other studies (e.g. ANDERSON and DILLON, 1992). Maximising the certainty equivalent according to the definition given in (5) shall therefore serve as objective function in our modelling approach.

Modelling the insurance contracts

The model calculations shall reveal the economic benefits of crop or revenue insurance, respectively, at the level of single farms. A valid indicator for this benefit is the change of the certainty equivalent. As stated above, the certainty equivalent can be expressed in terms of expected value and variance of the financial outcome. The aim of modelling at this point therefore is to quantify these measures. For reasons of simplification we model only the basics of an insurance contract without considering any details. This means that the model mainly captures the indemnity scheme and its consequences with respect to mean and variance of total revenue. In particular, we do not consider such details of the contract, which aim at eliminating moral hazard and adverse selection. Neglecting these aspects can be justified because the objective of the study is to assess the economic potential of such insurances, if the problems of adverse selection and moral hazard can be kept in manageable boundaries.

The following basic assumptions apply to both, revenue and crop insurance:

1. Insurance unit is always the total planted acreage of a crop. The insured may choose a coverage level within certain boundaries. Thus the coverage level is the farmer's central decision variable, where a coverage level of zero means that the crop remains uninsured.
2. Claims arise, whenever the actual yield or revenue, respectively, of an insurance unit falls below the coverage level that triggers the indemnification. The compensation is then determined according to the actual amount of the shortfall.
3. The insurance premium covers at least the expected indemnity (so called fair premium), so the insurance cannot lead to an increase of expected income. This prevents that insurance contracts change their nature in a way that they become income-generating instruments instead of risk management instruments. Only if an economic benefit remains after deducting the fair premium, an insurance market can develop.

With these assumptions the indemnification scheme of yield insurance can be modelled as follows: For the i-th crop the indemnity is computed according to the rule

$$S_i(\delta_i) = \overline{P_i}\; Max[0, (\delta_i \overline{y_i} - y_i)] \qquad (6)$$

In the above equation $\overline{P_i}$ represents the expected market price of the crop and $\overline{y_i}$ is the expected yield, while y_i reflects the yield that is actually realised. The variable δ_i describes the coverage level as portion of the average yield and represents the design variable of the contract. $\delta_i = 0$ means that the crop is uninsured, while $\delta_i = 1$ indicates that the insurance coverage equals the average yield. The face value of the policy equals the maximum indemnity ($\overline{P_i}\delta_i \overline{y_i}$).

The total revenue $L_i(\delta_i)$ is composed of the sales revenue plus the indemnity, where the sales revenue is given by the actual yield y_i times the actual market price P_i:

$$L_i(\delta_i) = P_i y_i + \overline{P_i}\; Max[0, (\delta_i \overline{y_i} - y_i)] \qquad (7)$$

Expected value and variance of these variables are given by

$$E(L_i(\delta_i)) = E\left(P_i y_i + \overline{P_i}\ Max[0, (\delta_i \overline{y_i} - y_i)]\right) \text{ und} \qquad (8)$$
$$V(L_i(\delta_i)) = V\left(P_i y_i + \overline{P_i}\ Max[0, (\delta_i \overline{y_i} - y_i)]\right)$$

where E(·) and V(·) denote the expectation and variance operators, respectively. In this context we assume that the yield y_i follows a normal distribution with mean $\overline{y_i}$ and standard deviation σ_{yi}. Prices, in turn, are assumed to be log-normally distributed with mean $\overline{P_i}$ and standard deviation σ_{Pi}. Furthermore, a (typically negative) correlation between yield and price is considered, if appropriate. The fair premium equals the expected indemnity $E(S_i(\delta_i))$, which can be computed from equation (6).

For the case of revenue insurance the indemnity scheme of equation (6) changes to

$$S_i(\delta_i) = Max[0, (\delta_i \overline{P_i}\ \overline{y_i} - P_i y_i)] \qquad (9)$$

where the term $\delta_i \overline{P_i}\ \overline{y_i}$ now marks the guaranteed revenue that triggers the indemnification. The indemnity amounts to difference between guaranteed and actual revenue. Computing the total revenue $L_i(\delta_i)$ requires analogue changes of equation (7). From this the equations for the expected value and variance of the revenue can be derived as

$$E(L_i(\delta_i)) = E\left(P_i y_i + Max[0, (\delta_i \overline{P_i}\ \overline{y_i} - P_i y_i)]\right) \text{ and} \qquad (10)$$
$$V(L_i(\delta_i)) = V\left(P_i y_i + Max[0, (\delta_i \overline{P_i}\ \overline{y_i} - P_i y_i)]\right)$$

The fair premium again is computed as the expected indemnity using equation (9).

With these assumptions the characterised insurance schemes can be modelled using stochastic simulation (i.e. Monte Carlo simulation, cf. BERG and KUHLMANN, 1993, p. 240ff) in order to determine means and variances of the revenues as functions of the coverage levels of the insurance scheme under consideration. These functions will then be used in the whole farm optimisation approach.

Stochastic optimisation model

Insurance contracts are not the only risk management instruments that farmers have at hand. Besides some forward pricing opportunities the multi-commodity operations that are typical for Europe always have the possibility to influence their risk exposure by the choice of crop mix. Capturing these effects requires a whole farm approach that optimises a portfolio of production activities with or without yield or revenue insurance, respectively. Following we develop a stochastic programming model of that nature.

The objective function of the optimisation model is to maximise the certainty equivalent of end of period wealth according to equation (5):

$$\max CE = E(W) - \frac{\theta}{2\,E(W)} V(W) \qquad (11)$$

In the above equation *E(W)* represents the expected value and *V(W)* the variance of wealth, respectively. The expected value of the end of period wealth results from the initial wealth plus die sum of the expected values of the gross margins $E(GM_i)$ of the production activities multiplied by their respective acreage x_i after deducting fixed cost *FK* and withdrawals for private consumption *C*:

$$E(W) = W_0 + \sum_{i=1}^{n} E(GM_i)\, x_i - (FK + C) \tag{12}$$

with

$$E(GM_i) = E(L_i(\delta_i)) + A_i - K_i - PR_i(\delta_i)$$

$E(L_i(\delta_i))$ represents the expected revenue from crop *i* according to (8) or (10), depending on whether yield or revenue insurance is considered. K_i denotes the variable cost and $PR_i(\delta_i)$ the insurance premium. The variable A_i marks the area payments according to the European CAP.

Since all costs and withdrawals are assumed to be deterministic, the variance of wealth equals the variance of total revenue:

$$V(W) = \sum_{i=1}^{n} V(L_i(\delta_i))\, x_i^2 + 2 \sum_{i=1}^{n} \sum_{j=i+1}^{n} x_i x_j \operatorname{cov}_{ij} \tag{13}$$

In this equation $V(L_i(\delta_i))$ denotes the variance of revenue from crop *i* according to (8) or (10) respectively, while cov_{ij} represents the covariance of revenues between any two crops that reflects the correlation between yields as well as between prices.

The decision variables of this model are the planted acreages x_i of the crops on one hand and the purchased insurance coverage levels δ_i on the other hand. The optimisation is subject to the constraints

$$\sum_{i=1}^{n} a_{ij} x_i \le b_j \quad \text{and} \qquad x_i \ge 0;\ \delta_i \ge 0 \tag{14}$$

These indicate that the total requirements of the production activities must not exceed the respective resources b_j (land, labour, etc.). Furthermore, all decision variables must be non-negative. Last but not least it is taken care in the model that insurance can be purchased only for crops with an acreage greater than zero.

In the above form the model incorporates a non-linear optimisation problem, which can only be resolved using non-linear (numerical) optimisation procedures. In our case Microsoft EXCEL was used along with the included optimisation package SOLVER. The stochastic simulation model was implemented using the EXCEL add in @Risk from Palisade.

Model data

The following model calculations refer to a German arable farm, located in the Rhine area of North-Rhine-Westphalia. The farm size is 150 ha. Table 1 represents the production activities that can be chosen along with the necessary land set aside to obtain the area payments. Price and yield expectations as well as the variable cost figures were derived from field records collected by the extension service.

Table 1: Means and coefficients of variation of crop yields an prices

	yields		prices		
	mean dt/ha	coefficient of variation %	mean €/dt	coefficient of variation %	variable cost €//ha
winter wheat	84	20	11.75	15	527
winter barley	78	21	10.75	15	465
winter rye	79	23	11.00	15	499
malting barley	61	24	13.80	15	445
potatoes	350	29	8.70	30	1432

Sources: SCHLIEPER (1997); RASMUSSEN (1997); MEUWISSEN et al. (1999); Landwirtschafts-kammer Rheinland: Arbeitskreis für Betriebsführung Köln-Aachener Bucht, field records statistics, several years.

The economic effectiveness of crop insurance schemes is heavily influenced by the variability of yields and prices, which therefore are of crucial importance for the analysis. The coefficients of variation in Table 1 are derived from the literature. The figures regarding the variability of yields are based on a comprehensive review by SCHLIEPER (1997). An empirical study conducted by RASMUSSEN (1997) in Denmark led to similar results. The same is true for the figures that MEUWISSEN et al. (1999) have found for different European countries. Latter are depicted in Table 2. This table also contains the coefficients of variation of different product prices derived from statistical data of the years 1986 to 1995. Despite the significant differences across countries one can recognize that the price variability of potatoes is much higher than the respective figure of such commodities, for which European common market regulations apply. In the case of wheat the median of the coefficient of variation is 10.5 %. Since it is unlikely that the relatively short time series capture the whole margin of fluctuations, and based on the hypothesis that further market liberalisation will somewhat increase the variability of prices, the coefficients of variation for all grain prices were set at 15 %, whereas for potatoes this figure was assumed to be twice as high. Furthermore potatoes exhibit a statistically significant negative correlation between price and yield (cf. TRESKOW, 1983), which was considered in the model calculations by applying a coefficient of correlation of –0.5. For all other crops the assumption is that yields and prices are stochastically independent.

Table 2: Coefficients of variation of yields and prices in Europe

	yields			prices		
	from ...	... to	median	from ...	... to	median
potatoes	13.1	31.1	29.1	18	46.1	26.5
wheat	19.4	28.3	22.1	6,5	27.1	10.5
sugar beets	13.3	23.2	19.8	2,8	17.9	6.2

Source: MEUWISSEN et al. (1999) p. 50f

According to equation (13) the optimisation model needs the covariance matrix of crop revenues, which reflects the correlation between yields as well as between prices. Several empirical studies indicate that correlations between crop yields are subject to significant variation across farms and locations (cf. OHLHOFF, 1987; GOETZ, 1991; RASMUSSEN, 1997).

As far as they are significantly different from zero the coefficients of correlation mostly exhibit slightly positive values. It is safe to assume that grain prices are slightly positive correlated as well because of the influence of market regulations. For the model calculations we therefore use the correlations given in Table 3. These suppose positive coefficients of 0.2 between all winter cereal crops, whereas the correlations between spring barley and the winter cereals amount only to 0.1. The revenues of potatoes are assumed to be stochastically independent from those of the cereal crops.

Table 3: Correlation matrix

	Winter wheat	winter barley	winter rye	malting barley	Potatoes
winter wheat	1				
winter barley	0.2	1			
winter rye	0.2	0.2	1		
malting barley	0.1	0.1	0.1	1	
potatoes	0	0	0	0	1

With respect to further model assumptions it shall be mentioned that the share of potatoes is restricted to a maximum of 25 % and that of winter wheat to 40 % of the total acreage via rotational constraints. Fixed cost are considered in the amount of 76 700 €/year and private consumption (including personal taxes) is set to 35 800 €/year. Available financial resources in the amount of 117 600 € serve as indicator for the initial wealth (W_0).

Model results

The first step of model calculations consists in computing the expected indemnities and variances of crop revenues depending on the coverage level. This is done via stochastic simulation. In the second step the simulation results will then be incorporated in the optimisation model.

Expected indemnities and variance of revenues

The above model represents an idealized insurance since we neither consider transaction cost nor basis risk[1]. Under these conditions the revenue insurance is a perfect risk management instrument in the sense that the income variability can be completely eliminated, if the coverage amounts to the maximum possible return. Since yield insurance does not cover price risk, this type of insurance cannot completely eliminate the variance of revenue. Figure 1 illustrates the effects of yield and revenue insurance using wheat as an example. Either type leads to a significant reduction of the variance at coverage levels above 40 %. The variance first declines at increasing, later at decreasing rates. In the case of yield insurance most of the potential reduction is utilised at a coverage level of 120 % of the average yield. Revenue insurance, however, enables a further reduction of the variance, which eventually converges to zero at coverage levels above 200 %. Figure 1 also depicts the response of the expected indemnity to varying coverage levels for both types of insurance. The graphs illustrate that the

[1] Basis risk occurs, if the risk characteristics of individual policy holders (e.g. individual yield distributions) differ from those of the pool.

expected indemnity of revenue insurance is always higher than that of yield insurance, where the curves approach each other at higher coverage levels.

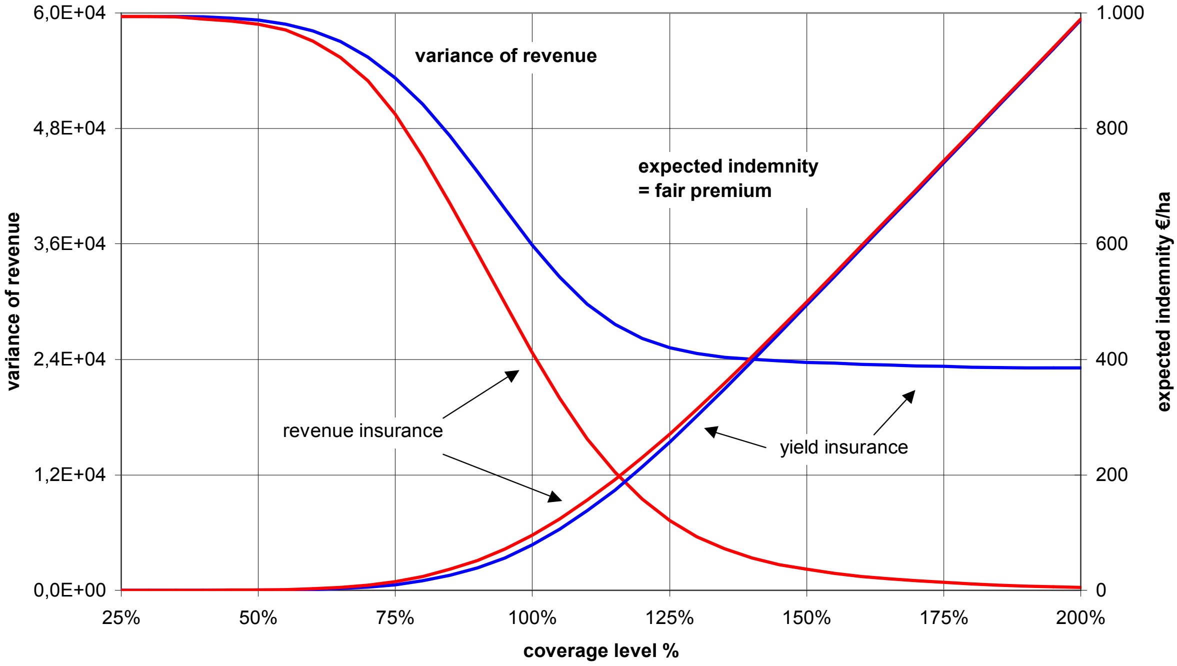

Figure 1: Variance of revenue and expected indemnity as functions of the coverage level, illustrated using wheat as a example

As long as the assumed ideal conditions apply and the insured is only billed for the fair premium, the insurance does not influence the expected value of the revenue, since the insurance premium exactly covers the expected indemnity. In this case it is always favourable to choose a coverage level that minimises the variance. Furthermore revenue insurance is always preferred over yield insurance. Only if the insurance premium exceeds the expected indemnity, the risk reduction through insurance likewise leads to a reduction of expected income.

In reality such ideal conditions never apply. Instead, basis risk as well as uncertain cost figures, which are not considered in the model, reduces the economic benefits of either type of insurance. Furthermore, coverage levels must be restricted to avoid moral hard problems. Latter is particularly true if insurance premiums are subsidized, as normally the case in existing crop insurance programs. Consequently, even revenue insurance cannot completely eliminate risk and therefore other risk management instruments become important. Latter include the choice of the production program, which is considered by the stochastic optimisation approach. The above relations enter this approach via functions, which were estimated using polynomial regression. The estimated functions along with their respective ranges of validity are depicted in Table 4.

Table 4: Estimated functions of the variance of revenues and the expected indemnity

	winter wheat	winter barley	winter rye	malting barley	potatoes
yield insurance					
range of validity					
from δ_{min}	0.4	0.4	0.4	0.4	0.1
to δ_{max}	1.5	1.5	1.5	1.5	1.1
variance of revenue without insurance	5.9619E+04	4.5741E+04	5.5860E+04	5.5889E+04	8.9703E+05
variance with insurance					
a_0 (constant)	1.6990E+05	1.2002E+05	1.2384E+05	1.1450E+05	8.9889E+05
$a_1 \cdot \delta$	-8.1589E+05	-5.5473E+05	-5.1892E+05	-4.5226E+05	-8.8849E+04
$a_2 \cdot \delta^2$	2.2751E+06	1.5641E+06	1.5000E+06	1.3239E+06	6.3938E+05
$a_3 \cdot \delta^3$	-2.9384E+06	-2.0417E+06	-2.0091E+06	-1.7979E+06	-1.6764E+06
$a_4 \cdot \delta^4$	1.7133E+06	1.1981E+06	1.1954E+06	1.0776E+06	7.1686E+05
$a_5 \cdot \delta^5$	-3.6886E+05	-2.5875E+05	-2.5982E+05	-2.3500E+05	1.7512E+05
expected revenue without insurance	986.82	836.59	867.36	840.99	2926.84
expected indemnity					
b_0 (constant)	-3.2104E+02	-2.4654E+02	-2.0871E+02	-1.8268E+02	-1.3866E+00
$b_1 \cdot \delta$	1.8805E+03	1.4536E+03	1.2476E+03	1.0993E+03	3.7018E+01
$b_2 \cdot \delta^2$	-3.8521E+03	-3.0023E+03	-2.6219E+03	-2.3310E+03	-1.3677E+02
$b_3 \cdot \delta^3$	3.1710E+03	2.4941E+03	2.2226E+03	1.9981E+03	4.3690E+01
$b_4 \cdot \delta^4$	-7.9813E+02	-6.2736E+02	-5.5884E+02	-5.0229E+02	4.0683E+02
revenue insurance					
range of validity					
from δ_{min}	0.4	0.4	0.4	0.4	0.3
to δ_{max}	1.5	1.5	1.5	1.5	1.4
variance of revenue without insurance	5.9619E+04	4.5741E+04	5.5860E+04	5.5889E+04	8.9703E+05
variance with insurance					
a_0 (constant)	1.5688E+05	1.0685E+05	1.0681E+05	9.7745E+04	1.3272E+06
$a_1 \cdot \delta$	-7.6439E+05	-4.9202E+05	-4.2891E+05	-3.6081E+05	-4.1126E+06
$a_2 \cdot \delta^2$	2.2435E+06	1.4762E+06	1.3410E+06	1.1531E+06	1.4511E+07
$a_3 \cdot \delta^3$	-3.0063E+06	-2.0153E+06	-1.8987E+06	-1.6656E+06	-2.2928E+07
$a_4 \cdot \delta^4$	1.7818E+06	1.2053E+06	1.1563E+06	1.0241E+06	1.5070E+07
$a_5 \cdot \delta^5$	-3.8533E+05	-2.6189E+05	-2.5342E+05	-2.2540E+05	-3.5179E+06
expected revenue without insurance	986.82	836.59	867.36	840.99	2926.84
expected indemnity					
b_0 (constant)	-2.0661E+02	-1.6034E+02	-1.3943E+02	-1.2394E+02	-2.1198E+02
$b_1 \cdot \delta$	1.2895E+03	1.0093E+03	8.9220E+02	7.9915E+02	1.6735E+03
$b_2 \cdot \delta^2$	-2.8254E+03	-2.2349E+03	-2.0165E+03	-1.8238E+03	-4.5934E+03
$b_3 \cdot \delta^3$	2.4782E+03	1.9823E+03	1.8309E+03	1.6770E+03	4.9641E+03
$b_4 \cdot \delta^4$	-6.3911E+02	-5.1180E+02	-4.7427E+02	-4.3506E+02	-1.3968E+03

Whole farm effects of yield and revenue insurance

The economic potential of risk management instruments depends on the decisions marker's degree of risk aversion. The model calculations are therefore carried out using two different degrees of relative risk aversion. Referring to ANDERSON and DILLON (1992) we use a coefficient of relative risk aversion (θ) of 2.5 as to reflect moderate risk aversion, whereas one of 5.0 represents a strong degree of risk aversion. Within these basic scenarios we examine the situation without insurance and with yield or revenue insurance, respectively. In addition the influence of the area payments according to the European CAP is analysed.

The economic benefits of the different insurance designs are measured in terms of the resulting certainty equivalent changes. The certainty equivalent increase represents the necessary additional amount of certain income in a situation without insurance, that would lead to the same expected utility as the respective insurance design. Thus, this measure likewise reflects the decision maker's willingness to pay (cf. WANG et al. 2000).

The model results are depicted in Table 5. Besides the economic figures the table also contains information with respect to the optimal crop mix and the chosen insurance coverage levels. If moderate risk aversion is assumed, the production program without insurance contains the maximum amounts of potatoes and wheat, as given by the rotational constraints. The remaining acreage is used for malting barley (38.1 ha), winter barley (3.1 ha) and the mandatory land set aside. The resulting expected profit amounts to 58 192 € with a coefficient of variation of 68.5 %.

If yield insurance is offered at the cost of the fair premium, the crop mix changes in a way that malting barley is expanded at the expense of winter barley. All crops are insured at the allowed upper limits of coverage levels (i.e. 100 % of the expected yields). The alteration of the production program results in a slight increase of profit, which is due to the specialisation. The bottom lines of the table contain the certainty equivalent changes caused by the insurance. In the described scenario these figures reflect a willingness to pay that amounts to 4176 € in total or 28 €/ha, respectively.

Revenue insurance at the cost of the fair premium exhibits basically the same effects on crop mix and expected profit as seen from the case of yield insurance. However, the coefficient of variation reduces to 43.3 % because of the additional coverage of price risk. This is also reflected in the CE increase, which is twice as high as for the yield insurance. The revenue insurance would therefore always be the preferred alternative. It must be mentioned however, that problems regarding claims adjustment and adequate rating, which are already present in the case of yield insurance, become even more severe in the case of revenue insurance. Furthermore, since the same market price applies to all producers, price risk is systemic by definition. These effects necessarily result in significant premium surcharges, which then, in turn, reduce the comparative advantage of the revenue insurance.

Table 5: Model results

		moderate risk aversion					strong risk aversion				
		without insurance	yield insurance		revenue insurance		without insurance	yield insurance		revenue insurance	
			fair premium	wedge factor 1.3	fair premium	wedge factor 1.3		fair premium	wedge factor 1.3	fair premium	wedge factor 1.3
winter wheat	ha	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
coverage level	%	-	100	73	100	72	-	100	85	100	91
winter barley	ha	3.1	-	2.3	-	3.2	11.4	3.5	8.7	-	8.2
coverage level	%	-	-	63	-	-	-	100	67	-	63
winter rye	ha	-	-	-	-	-	5.4	-	2.9	-	4.1
coverage level	%	-	-	-	-	-	-	-	62	-	-
malting barley	ha	38.2	41.3	39.0	41.3	38.1	30.4	37.7	29.7	41.3	29.0
coverage level	%	-	100	63	100	61	-	100	71	100	72
potatoes	ha	37.5	37.5	37.5	37.5	37.5	31.0	37.5	37.4	37.5	37.5
coverage level	%	-	100	71	100	90	-	100	83	100	100
land set aside	ha	11.3	11.3	11.3	11.3	11.3	11.9	11.3	11.3	11.3	11.3
expected profit	€	58192	58268	57214	58268	54800	52459	58181	55592	58268	53952
std.-dev. of profit	€	39867	33629	37256	25226	30871	34426	33536	35315	25226	26253
coeff. of variation	%	68.5	57.7	65.1	43.3	56.3	65.6	57.6	63.5	43.3	48.7
certainty equivalent change	€		4176	707	8590	2079		7704	2502	16520	8628
	€/ha		28	5	57	14		51	17	110	58

In order to cover all costs on the part of the insurer, the actual rate must exceed the fair premium. This is considered in the model by applying a loading factor of 1.3, i.e. the actual premium amounts to 130 % of the fair premium. This has consequences with respect to the optimal crop mix and the optimal coverage levels for either insurance design. The effect of the cost increase on the production program can be characterised as a slight diversification, which shifts the production program towards the situation without insurance. At the same time insurance coverage levels fall significantly below 100 %. The highest coverage level is chosen for potatoes, which represent the most risky crop in the whole portfolio. Since insurance cost now exceed the expected indemnity, the risk reduction must be paid by a decrease of expected profit. Nevertheless both types of insurance remain attractive, although the CE increase as well as the decrease of standard deviation is less than in the former case.

This result illustrates the ambivalence of premium subsidies, that are present in virtually all existing crop insurance programs. On one hand such subsidies clearly enhance the economic attractiveness of the insurance contracts. On the other hand they create the incentive to acquire full coverage with all the well-known consequences regarding moral hazard. As soon as complete compensation of potential losses is provided (or the compensation even exceeds the potential market return) there is only little motivation to reduce losses through careful production practice.

The above results strongly depend on the assumptions with regard to the degree of risk aversion. To illustrate this, the described insurance designs have been examined under a stronger degree of risk aversion. The results of these model calculations can be found in the right half of Table 5. They indicate that a higher degree of risk aversion first of all results in a more diversified production program in the reference situation, i.e. without insurance. As a consequence, the expected profit is about 5 700 € less, in turn yielding a lower standard deviation and coefficient of variation. Introducing yield or revenue insurance, respectively, then leads to a more specialised production program. Due to the difference in the initial situation this effect is more intense than at a lower level of risk aversion and therefore also leads to a larger increase of expected profit. These results document that an increasing level of risk aversion likewise increases the attractiveness of insurance contracts, which is also reflected by the respective willingness to pay measures. These are generally higher than before, whereas the differences between the insurance designs remain largely unchanged. A decrease (increase) of the initial wealth position would have a similar effect as the increase (decrease) of the degree of risk aversion, as can be seen from the equations (10) and (11). Thus, the attractiveness of insurance contracts also grows if the financial position of a farm becomes less favourable.

The attractiveness of crop and revenue insurance designs is also influenced by risk free parts of the total income, as e.g. given by the area payments of the European CAP. This can be illustrated by running the model without consideration of area payments and land set aside. Table 6 contains the certainty equivalent changes with and without area payments for the case of moderate risk aversion. The model results show that the area payments significantly reduce the CE increase and therefore the economic attractiveness of the crop insurance designs. Depending on the insurance premium the reduction of the willingness to pay ranges between 24 % and 44 %. Growing risk aversion would even increase this effect. The present agricultural policy therefore significantly hampers the development of a crop insurance market.

Table 6: Influence of area payments on the certainty equivalent change caused by yield and revenue insurances (moderate risk aversion)

		yield insurance		revenue insurance	
		fair premium	loading factor 1,3	fair premium	loading factor 1,3
with area payments	€/ha	28	5	57	14
without area payments	€/ha	37	8	75	25
Difference without ./. with	€/ha	9	3	18	11
area payments	%	24	43	24	44

Concluding comments

Although the model results only refer to one example farm, which is not at all representative, they provide some insights that can safely be generalized. First we can state that there is an economic incentive for farmers to purchase crop insurance. Yield insurance as well as revenue insurance can reduce the variability of income substantially. In this respect revenue insurance is generally more effective, since is covers both yield and price risk. However, latter also embodies additional problems with respect to implementation.

The model results indicate that the insurance solutions remain economically attractive if the rates exceed the fair premium by 30 %. In this case the optimal coverage levels drop below 100 %, leaving a deductible, which is generally useful to avoid moral hazard problems. In turn, this effect leads to the conclusion that a significant portion of the actuarial problems, that virtually all existing multiple peril crop insurances have, are caused by lowering the rates through premium subsidies.

The economic attractiveness of all risk management instruments including insurance contracts depends on the overall risk exposure of the farm and, in addition to that, is influenced by risk free portions of the total net income. Latter refers to the area payments under the current European agricultural policy regime. High payments of that nature reduce the economic attractiveness of crop insurance and vice versa. Thus, the current agricultural policy regime itself limits the potential demand for crop insurance.

The model results are strongly influenced by the assumptions regarding to the decision maker's attitudes to risk. This refers to the general presumption of constant relative risk aversion as well as to the numerical assessment of the risk aversion coefficient. Latter is often set at values around two (e.g. COBLE and HEIFNER, 1999; WANG et al., 1998; 2000) without having any empirical evidence as to whether or not this figure truly reflects farmers' behaviour. Another critical assumption is that of initial wealth, since the model results are very sensitive to variations of this figure as well.

The sensitivity of the model results to changes in risk attitudes on one hand and the little knowledge with respect to the actual risk response of farmers on the other hand indicate that there is a substantial need for methodological as well as empirical research in this area. A reliable evaluation of the possibilities and limitations of crop insurance schemes in Europe also requires further research with respect to the risk exposure of farms relative to the scope of production, farm size, location and ownership conditions. This information provides the necessary data to conduct model experiments on the level of single farms and insurance pools. Farm level models like the one presented in this paper provide insights into the potential demand of crop insurance, while models on the level of insurance pools are to analyse its feasibility from the insurer's point of view.

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