Ertragsrisiko im Ackerbau – Nützen Versicherungen auf Basis des Regionalertrages?

Yield Risk in Crop Farming – May Area-Yield Insurances Help?

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Zusammenfassung

Es wird die mögliche Risikoreduktion von Regionalertragsversicherungen für norddeutsche Ackerbauern mit Fruchtfolge untersucht. In der Literatur werden bisher nur Ergebnisse für Landwirte mit Monokulturen dargestellt. Bei Fruchtfolgelandwirten ist jedoch die komplette Varianz-Kovarianz-Struktur zwischen den Erträgen zu berücksichtigen, um das Ausmaß einer Risikoreduktion durch solche Versicherungen bestimmen zu können. Es beträgt fast 50 % für die untersuchten Betriebe und liegt damit über den Ergebnissen der Literatur für Monokulturbetriebe. Dennoch sollten Versicherungen und Politiker dieses Ergebnis nicht überbewerten, weil Fruchtfolgebetriebe ein vergleichsweise geringes Ertragsrisiko haben und weil durch Diversifikation der Fruchtfolge im Mittel der Betriebe eine höhere Reduktion des Ertragsrisikos erreicht werden kann als durch Versichern und Beibehalten der Monokulturen.

Schlagworte: Diversifikation, Ertragsschwankungen, Ertragsversicherung.

Summary

The potential risk reduction of area yield crop insurances is analysed for multiple crop farmers in northern Germany. Until now, this has been reported only for one-crop farmers in the literature. For multiple crop farmers, the complete variance-covariance structure among yields has to be taken into account in order to evaluate the risk reduction potential of insurances. On average, insurances can reduce the three-

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crops farmers' risk by nearly fifty percent which is higher than previous results in the literature for one-crop farmers. However, insurance companies and policy makers should be aware of overrating this result because multiple crop farmers face only low initial, uninsured risk and because the risk reduction of insuring one-crop-planting on average is lower than the diversification effect of crop rotation.
Keywords: crop insurance, diversification, yield risk.

1. Introduction

Crop insurance is a well known risk management tool in many countries. In particular, it is highly relevant for the agricultural sector in the United States where it is used as an important policy instrument. In Europe, political discussion started some years ago and is still ongoing (MEUWISSEN et al., 2000). First research for the EU Commission was carried out by MEUWISSEN et al. (1999). Among other results, they found that crop yield insurance can provide risk reduction for many farmers in many European regions. Yield insurances provide protection against low physical yields of crops. The insurer pays an indemnity, if the actual yield falls below a strike yield. The payment is the difference between strike and actual yield times a fixed price per crop unit times the coverage level. Since this kind of insurance faces problems in terms of asymmetric information if the yield component is measured on the farm level, insurance schemes based on regional yields were suggested. However, research about this type of crop insurance was not provided by MEUWISSEN et. al. (1999) The EU-commission itself published a working paper on agricultural insurances in 2001 that also mentioned the advantages of area-based crop insurances. They pointed out the crucial condition of sufficient correlation between farm and regional yields. In the academic literature, MIRANDA (1991) analysed the case of soybean producers in Kentucky, MAHUL and VERMERSCH (2000) followed recently with an extensive study for French wheat producers.

The novelty of this paper is an investigation of multiple crop farmers. Growing various crops can be risk reducing as it allows for portfolio diversification. Therefore, the potential for risk reduction by purchasing insurances depends on the situation if a farmer grows one or various crops. In this setting, the models used by MIRANDA(1991) or MAHUL and VERMERSCH (2000) have to be extended to appropriately reflect the more complex variance-covariance structure among yields. Our work adds results about area yield crop insurances and their risk reducing potential for a region (Schleswig-Holstein, Germany) and in addition to wheat for two other crops (barley, rapeseed) for which no previous results are available. Hence, this work provides new insights into the question whether and how crop insurance can increase the welfare of European farmers.

This paper continues with a description of the theoretical model for risk reduction which is then applied to single and multiple-crop farmers. The presentation of data and estimation results follow. Afterwards conclusions for farmers, policy makers, and insurers are drawn. Suggestions for further research finalise the paper.

2. Theoretical Model

The applied model is an extension and synthesis of MIRANDA's and MAHUL and VERMERSCH's models. In our model various insurances are offered to farmers which are each based upon the county yields of different crops. A county yield reflects the average yield of a crop's total acreage in a county. The farmer receives an indemnity payment for an insurance if the yield of the underlying crop in his county falls below a strike yield. The payment is the difference between the strike yield and the county yield times the crop's price which is fixed before purchasing the insurance contract. Purchasing such an insurance is like buying a put option (shown by MAHUL and VERMERSCH, 2000). The farm yields are random and the farmer's profit π is the revenue on the cash market plus indemnity payments minus insurance premium and production costs c. Production costs, total acreage, prices and planted acres for each crop are determined exogenously.[1] The coverage is positive when the corresponding insurance is purchased or zero otherwise.

[1] This model does not analyse the possibility of changing the production shares for crops without facing a higher risk level. Purchasing crop insurances may offer this possibility to obtain a higher certainty equivalent. This issue was recently addressed by BERG (2000) using modeled farms and linear optimising.

$$(1) \quad \pi = \sum_{i=1}^{I} s_i * p_i * y_i + \sum_{j=1}^{J} \phi_j * p_j * i_j - \sum_{j=1}^{J} \phi_j * p_j * \mathrm{E}\left(i_j\right) - c$$

with
π = profit per hectare, I = number of planted crops,
s_i = share of planted area for crop i, $p_{i\,(j)}$ = price for crop i (j),
y_i = farm yield of crop i, J = number of available insurances,
ϕ_j = coverage level of insurance j, E(.) = expectation operator,
$i_j = \max(k - a_j, 0)$ = short fall of area yield,
k = strike yield, a_j = county yield of crop j.

We consider a two-period problem. In the first period all decisions about the coverage levels are made, and in the second all uncertainties about yields are resolved. We assume that the farmer's utility is only influenced by the mean and the variance of profit and that purchasing insurances does not change the mean of profit.[2] Thus, the premium has to be actuarially fair and there are no transaction costs for the farmer incurred by purchasing an insurance. To maximise utility the farmer chooses coverage levels such that the profit's variance var(π) is minimised. It is only affected by the random farm yields and the random indemnity payments. The remaining terms in equation (1) are constant over time. The profit π minus these constants is denoted π^*. We abandon premium payments and costs to obtain (2).

$$(2) \quad \pi^* = \sum_{i=1}^{I} s_i * p_i * y_i + \sum_{j=1}^{J} \phi * p_j * i_j$$

with

$$\pi^* = \pi - \sum_{j=1}^{J} \phi_j * p_j * \mathrm{E}\left(i_j\right) - c$$

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[2] A mean-variance analysis of such an insurance or option model is in general not consistent with expected utility (LAPAN et. al., 1991). From a theoretical point of view, a mean-variance model with three insurance contracts is more consistent with expected utility than the expected utility model used by MAHUL and VERMERSCH (2000) with only one insurance contract in contrast to MIRANDA's (1991) mean-variance analysis.

Consequently, its variance var(π^*) equals var(π). To minimise var(π^*) we use the OLS-procedure which minimises the variance of the disturbance term of a linear combination of variables. π^* is a linear combination of the cash revenues and the indemnity payments that are a function of the coverage levels. We can choose the variance-minimising coverage levels like determining regressors in the OLS. Consequently, the variance of profit π would be minimised if (3) holds.

$$(3) \quad \sum_{i=1}^{I} s_i * p_i * y_i = \hat{\beta}_0 - \sum_{j=1}^{J} \hat{\beta}_j * p_j * i_j + \hat{u}$$

with

û = profit such that var(π) is minimised (disturbance term in the OLS),

$\hat{\beta}_{J(0)}$ = least squares estimators.

The variance of the disturbance û is the minimum of the profit's variance. Thus $\hat{\beta}_J$ is the optimal coverage level for insurance j and the covariance between û and i_J amounts to zero. This corresponds to the common assumption of regressability between a cash product and a hedging tool (for common hedging theory see JOHNSON, 1959/60; BENNINGA, et al, 1984for crop-yield risk MIRANDA, 1991 and MAHUL, VERMERSCH, 2000).

So, we obtain the optimal coverage levels by regressing the cash revenue on the indemnity payments. The expected value of the county yield is assumed as strike yield and the cash prices equal the crop prices for the indemnity payment fixed before purchasing the insurance. The variance reduction is measured in relation to the variance of an uninsured farmer.

3. Data

The farm data are obtained from the German Farm Accountancy Data Network. All farms are located in the state of Schleswig-Holstein in northern Germany between the North and the Baltic Sea. All farms are included that produced wheat, barley and rapeseed in each year as from 1986 to 1995 (=22 farms). The variances of the different crop yields and the covariances among different crop yields of a farm and among these crop yields and the area yields are observed. The means of the farm yields are 77 quintals per hectare for wheat and 70.2 for barley and 33.8 for rapeseed, respectively. Yields were linear detrended and means are 1995 equivalent.

The price relations are set for barley / wheat at 0.9 and for rapeseed / wheat at 2.0. Then, the initial revenue variances with a wheat price of 100 €/t but without insurances are 7200 €²/ha², 8300 €²/ha², 13900 €²/ha² on average among farms for wheat, barley and rapeseed production, respectively. Planting all three crops, each on one third of the arable land ($s_1 = s_2 = s_3 = 1/3$ in (3)) amounts to an average variance of 4300 €²/ha². Even in comparison to the crop with the lowest variance, wheat, the variances are reduced by 25 % due to the diversification effect.

Regional yields are obtained from the Statistical Bureau of Schleswig-Holstein for the period of 1970-2000. They were linear and quadratic detrended to account for the long time period. The average county yields are taken as strike yields. In the estimation the trend residuals from 1986-1995 are used. Insurance premia were measured as expected indemnity payments in percentage of total insurer liability. They refer to area yield. We can get the farm-specific premia by multiplying the premium with the individual coverage level of the corresponding crop. The premia for county insurances of wheat vary around 2%, the premia for barley are in a range between 2.1 % and 3.6 %. The premia for rapeseed are highest in a range from 2.5 % to 4.6 %. The variation among counties is smaller than the variability between crops. The fair premia for wheat confirm MAHUL and VERMERSCH's (2000) results for regional insurance.[3] MIRANDA`s, (1991) fair premium of 1.6 % is not comparable because of the empirical design of his work.

4. Variance reduction through insurance

We evaluate the variance reduction for different settings. Firstly, planting only one crop (wheat, barley, or rapeseed) and insuring it with the

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[3] They present farm-specific premia but they can be recalculated to be comparable with our work.

corresponding area yield (1 crop, 1 insurance – model; I=J=1 in (3)).[4] Farms are assumed to grow only one crop and to purchase only the corresponding area yield insurance. We estimate three 1,1-models for each farm. Planting and insuring wheat solely, then barley solely and rapeseed solely. In a second specification farmers can purchase three insurances while planting only one crop (I=1, J=3). We estimate three 1,3-models for each farm. In the last settings each farmer plants all three crops, each on one third of his arable land ($s_1 = s_2 = s_3 = 1/3$), and is offered the three corresponding insurances (I=J=3; 3,3-model) or only one insurance, respectively (I=3, J=1; 3,1-models). For each farm one 3,3-model and three 3,1 models are estimated. Equation (3) is estimated with the expected county yields as strike yields to obtain the optimal coverage levels. Thus, independence among (co-)variances and acreage shares of the crops is implicitly assumed. Only positive coverage levels are allowed.

The estimation results on average for the one-crop settings are shown in Table 1. The variance can be reduced on average by one third for rapeseed and one fourth for barley, respectively. The average variance reduction for wheat planting and solely insuring is less than 20 %. All means are similar to the medians. By definition of equation (3), the availability of three insurances can only increase the variance reduction compared with only one insurance. The increase amounts to somewhat 10 %-points comparing the average variance reductions. The results of the diversified farms can be found in Table 2. The average variance reduction is highest with 45 % when three insurances can be purchased. There are only small differences in the variance reduction between the one-crop-only farming and the diversified cropping when only one insurance is available.

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[4] The variance reduction for insuring one-crop-only production with an area-yield of a different crop is considerably low. Results are available upon request from the author.

Table 1: Variance reduction in % for one-crop-only farming (1,1- and 1,3 models)

	variance reduction in %		
specification	**1 crop, corresponding insurance**		
planted crop, purchased insurance	wheat	barley	rapeseed
average	18	25	32
variance	360	408	581
specification	**1 crop, 3 insurances**		
planted crop	wheat	barley	rapeseed
average	28	35	40
variance	500	486	579

Table 2. variance reduction in % for diversified cropping (3,1- and 3,3-models)

	variance reduction in %			
specification	**3 crops, 1 insurance**			**3,3 model**
purchased insurance	wheat	barley	rapeseed	all
average	15	22	33	45
variance	125	373	478	587

Table 3 shows farm-individual data. The potential of risk reduction varies in a wide range among individual farms. The optimal coverage levels among farms also differ in a wide range. They represent the amount of insurance contracts a farmer should purchase per hectare arable land if the insurance contracts refer to one hectare regional yield. The average optimal coverage level including the non-insured farmers is 1.3 and 1.2 for a farmer who only grows and insures rapeseed or barley and 0.9 for producing and insuring wheat solely (1,1-models). The coverage levels in the 3,3-model are less because they refer to the total arable land. The total coverage level (0.47+0.26+0.57=1.3) does not change considerably. Five of the 22 farms purchase only two insurances, four only one and two cannot realise any variance reduction in the multiple-crop-multiple-insurance setting. The highest absolute reduction can be achieved by insuring the production of rapeseed. The average variance of insuring single-crop farming is always higher than the uninsured initial variance of the diversified farmer.

Table 3. Optimal positive coverage levels, variance reducion

	optimal coverage level						**Variance reduction at optimal coverage (%)**			
	wheat		**barley**		**rapeseed**					
	3,3-	1,1-	3,3-	1,1-	3,3-	1,1-	1,1-model			3,3-model
farms	model		model		model		wheat	barley	rapeseed	3 crops
53-1	0,2	0,9	0,2	1,0	0,3	0,6	25	22	8	16
53-2	0,1	0,9	0,3	1,2	0,9	1,4	28	21	46	67
53-3	0,0	0,0	0,1	0,4	0,7	1,8	0	17	66	66
53-4	0,5	1,4	0,2	0,8	0,4	1,1	39	20	15	30
53-5	0,2	1,0	0,2	0,9	0,3	0,6	42	23	14	41
53-6	1,2	0,5	0,5	2,9	0,6	2,6	4	50	77	54
53-7	0,0	0,7	0,3	0,8	0,5	0,4	5	13	9	33
55-1	0,0	0,0	0,0	0,8	0,6	1,3	0	7	42	38
57-1	0,0	0,6	0,0	0,5	1,0	2,7	4	7	64	72
57-2	0,1	1,2	0,0	0,5	0,9	1,8	31	3	30	44
57-3	0,0	0,0	0,0	0,0	0,5	0,9	0	0	21	22
57-4	0,0	1,0	0,0	0,3	0,0	0,0	10	1	0	0
58-1	2,3	2,0	0,3	2,0	0,4	2,0	39	52	23	82
59-1	0,0	0,0	0,3	0,0	1,7	3,2	0	0	41	49
59-2	1,1	3,9	0,0	1,6	0,1	0,8	69	69	5	19
59-3	0,8	0,1	1,4	1,9	0,8	0,3	<1	32	1	83
60-1	0,7	0,3	0,6	1,6	0,3	1,0	2	18	32	37
60-2	1,5	1,2	0,3	2,6	0,9	2,4	7	46	44	58
60-3	0,6	1,3	0,6	1,2	0,2	1,4	19	16	54	54
61-1	1,0	0,8	0,5	1,3	0,5	1,8	10	43	60	70
62-1	0,0	1,4	0,0	1,1	0,9	1,4	29	26	58	62
62-2	0,0	1,2	0,0	2,6	0,0	0,0	36	59	0	0
mean	0,47	0,93	0,26	1,18	0,57	1,34	19	25	32	45
variance	0,39	0,73	0,10	0,69	0,16	0,80	361	408	581	590

Farms are presented in the first column. The first two figures show the county of the farm and the figure behind "-" counts the farms of the same county.

5. Conclusions

We find that a farmer using crop rotation with three crops can substantially reduce his revenue variance in relation to his initial variance by purchasing insurances. The variance reduction of specialised production and insuring with the corresponding area-yield insurance contract is highest for rapeseed with 32 % on average. It amounts to 25 % for barley and 19 % for wheat, respectively. The relative risk reduction for three-crop farmers reaches 45 % on average and is higher than the results in the literature for specialised production of wheat or soybeans. Furthermore, the reduction in this case is considerably higher than the relative risk reduction for single crops, thus reflecting the special situation of the three-crop farms. The estimated risk reduction for specialised rapeseed production does not reach the average variance reduction of 39 % found by MIRANDA (1991) for soybeans, keeping in mind that in his study, the risk reduction is probably overestimated because the average yield of the used data panel serves as a proxy for the regional yield. MAHUL and VERMERSCH (2000) do not present average variance reductions among farms. They present 20 out of their 124 farms but these seem not to be randomly chosen if one looks to their numbering. If these farms are representative their risk reduction for wheat is twice as high as in our findings. But it is similar to our findings for rapeseed.

Looking to the absolute changes of revenue variance, the highest reduction can be achieved by insuring the production of rapeseed. Hence, in terms of risk reduction diversification is on average a better strategy for the investigated farmers since the variance of one-crop-only farming cannot be lowered to the level of diversified production due to purchasing area-yield insurances. However, a general recommendation to the farmers has to take into account the profits of the different crops and their interdependencies and the farmers' risk preferences. The high potential for risk reduction in rapeseed production indicates that the highest potential insurance demand might exist for rapeseed insurance. Furthermore, insurance can reduce diversified farmers' yield variance by one half. But it is debatable, if we can conclude that they are interested in crop insurance since their initial, uninsured risk is low.Insurance companies and policy makers should be aware of overestimating the willingness to pay of multiple crop farmers for area yield insurances. Consequently, it is not sufficient to estimate only the single correlation between farm and area yield of the same crop as it had been done in the literature so far to evaluate the demand potential of area-yield insurances.

The effects of different crop insurance contracts on the systemic risk for the insurer and the question of the optimal aggregation level of area-yields, e.g. state-based or nation-wide yields versus county yields are probably issues for fruitful further research.

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