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Evaluation of an index-based risk management contract for agricultural activities

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Abstract

This paper proposes and evaluates area index-based financial contracts for specific farm activities. These financial contracts allow not only for removing moral hazard and adverse selection as index insurances do, but also for adding more flexibility and, hence, better risk protection. The evaluation of these financial contracts uses FADN farm data of Belgium from 1990 to 2007. Area indexes based on yield and yield-in-value perform well in stabilising revenues from some farm activities, but badly from some others. The variation in the estimated actuarially fair premiums across agricultural area shows the importance of designing those financial contracts according to homogenous agricultural area.

Keywords: agricultural risk management, index insurance, financial contract, Belgium

JEL classification: D81, Q12, Q18.

1. INTRODUCTION

Agricultural insurances are generally plagued by problems of moral hazard and adverse selection due to asymmetric information between the insurer and the insured (Miranda, 1991). Different measures exist to mitigate these problems but are often costly to implement and control. This paper proposes and evaluates a new risk management tool that can overcome these two problems.

This tool is an area index-based financial contract, but different from the typical index insurance, that is designed to stabilise revenues from specific farm activities. This contract triggers a payment to farmers when an area index that is purposely selected to be highly correlated to revenues from one of their main farm activities passes below a given threshold independent of their having a loss or not. Farmers individually choose the amount of payment to be received for a particular trigger level and the provider of the payments sets the price of each individual contract on the basis of the chosen trigger level and the amount that is at stake. Possible evident area indexes include area yields and yields-in-value, i.e., yields times the output price.

This proposed index-based financial contract differs from index insurances because the individual payments correspond to fixed amounts that are agreed on *ex-ante* before the realisation of the particular event that could trigger these payments. Unlike an area index insurance, these payments are independent to the *ex-post* decrease in the area yield or yield-in-value from some predetermined critical yield or yield-in-value level. As for index insurances, they do not necessarily correspond to a compensation of the actual losses of the farmers but are eventually highly correlated to the occurrence of such losses.

Over a typical agricultural insurance this index-based financial contract has the double advantages of removing the moral hazard problem and counteracting possible adverse selection as does a typical index insurance (Bielza Diaz-Caneja, 2008). Moral hazard is removed because farmers have no incentive to alter their efforts to prevent risk since they cannot individually influence the trigger that is exogenously determined as well as the payment amount that is locked *ex-ante* in the contract. Possible adverse selection does not jeopardize the index financial product since pricing is made according to the expected individual locked-in payment. Like index insurances, the index-based financial contract offers superior risk protection compared to agricultural insurances since deductibles or co-payments are not needed to lessen the moral hazard problem. It can even offer greater risk protection when compared to index insurances since farmers can chose *ex-ante* payments according to their own risk aversion and exposure. As such it is a better targeted index-based risk management tool than the typical index insurance. Like index insurances, it has lower administrative costs than agricultural insurances since it does not require inspection and individual farm data.

Like for the index insurance, the main disadvantage of this index-based financial contract is its likelihood to produce a basis risk, i.e., the risk associated to the differences existing between the area index on which the contract is based and the actual risks experienced by the farmer (Bielza Diaz-Caneja, 2008). Since this contract mainly covers the systematic part of the risks, opportunity exists for private or mutual insurance companies to cover the residual idiosyncratic risks that are diversifiable and, hence, insurable. Because price risk tends to be more systematic that yield risk, less basis risk is expected for a contract that is based on a yield-in-value index than a yield index. A second disadvantage is the need of sufficient historical data for obtaining the probability distribution of the index and recent data for calculating the current index at a level of a homogenous area. The last disadvantage is the need of an adequate reinsurance system for addressing risk of insolvency of the contract provider. In sum, the index-based financial contract that we propose adds flexibility to the advantages of a typical index insurance since it can be better tailored to the individual need of the contract buyers and, hence, higher level of risk coverage.

In this paper we focus on assessing this financial contract for three major farm activities in Belgium that are potatoes, wheat and milk and two indexes that are area yield and yield-in-value. We emphasize that the assessment of these area index-based financial contracts does not aim at estimating the full operational cost of them, neither pricing for them. In addition to the actuarially fair premiums, the full operational cost would need to include the administration and the operating expenses of providing the index financial product that can be relatively high in the designing phase of financial products and the cost of risk capital that can also be relatively high for covering extreme events. Estimates that we generate are however a preliminary step in that direction, in particular to calculate the Value at Risk to determine the risk margin of the financial product.

The next section outlines the method for assessing these different index-based financial contracts and introduces the data. The third section provides and discusses the results. The last section draws some conclusions and recommendations.

2. METHOD AND DATA

We want to design index-based financial contracts that can stabilise the revenue of the main activities of the farm. Therefore, we focus our attention on the stabilisation of the yields-in-value of the main activities of the farm.

The method for designing and assessing such index-based financial contracts is composed of four steps. First, we identify appropriate area indexes that are highly correlated to the loss in yields-in-value of the main activities of the farm among the sample farms at disposal. Second, we construct the most appropriate area indexes that we want to use. Third, we evaluate the performance of these area indexes against past farm data. Fourth, we calculate the actuarially fair premiums of these index-based financial contracts.

We use the Farm Accounting Data Network (FADN) data of Belgium from 1990 to 2007 to select the area indexes and assess the financial contracts for three major farm activities that are potatoes, wheat and milk.

2.1. Method

Identification of appropriate area indexes

To identify appropriate area indexes that are strongly correlated to the loss in yields-in-value of the main activities of the farm among the sample farms at disposal, we first isolate the variability in yields-in-value across years and farms for each activity estimating the following expression:

$$\text{Ln}\,(P \cdot Y)_{mit} = \alpha_{mi} + \beta_m \cdot t + \varepsilon_{mit} \qquad (1)$$

where: indexes *m*, *i* and *t* indicate the farm activity, the farm and the calendar year respectively,

the variable *P* represents the output price of the activity,

the variable *Y* represents the yield of the farm activity,

the parameter α_{mi} represents the farm-specific fixed effect,

the parameter β_m represents the time-specific fixed effect,

the error term ε_{mit} represents the residual.

Note that all parameters and error term are expressed in terms of variation rate. This expression (1) is estimated weighting farm observations according to their frequency in their original population to improve efficiency (Greene, 2011).

Then, we isolate the negative error terms from this estimation and estimate their correlation with a series of potential variables that can be used to construct the area index. The negative error terms represent the loss in yields-in-value but expressed in terms of variation rate. Variables showing the highest correlation with the loss in yields-in-value are used to construct area indexes.

Construction of area indexes

We first isolate the residual variation rates μ_{mit} of these variables from their farm- and time-specific fixed effects using the same expression (1). We then calculate the average of the residuals μ_{mit} per year and homogenous area using the following expression:

$$E(\mu_i)_{mtr} = \sum_{i\in r} (w_{it}\, \mu_{mit}) / \sum_{i\in r} w_{it} \qquad (2)$$

where: the index *r* indicates an homogenous area,

the variable w_{it} represents the frequency weight of the sample farm in its original population.

These average variation rates per year and area constitute our series of area indexes but expressed in variation rate. When these yearly area averages are below some trigger levels as shown in Table 1, then payment is activated.

Table 1: Trigger levels

Trigger	Level
1	$E(\mu_i)_{mtr} \leq -0.10$
2	$E(\mu_i)_{mtr} \leq -0.15$
3	$E(\mu_i)_{mtr} \leq -0.20$
4	$E(\mu_i)_{mtr} \leq -0.30$

Performance of area indexes

The performance of these area indexes are evaluated on the annual series of farm data at disposal. For each trigger level, we calculate the averages and the standard deviations of the individual residual variation rates in years when the trigger is not activated and years when the trigger is activated. We test whether the differences between these two averages are statistically significant for each trigger level.

The actuarially fair premiums

In the final step, we report the probability of the activation of the trigger per trigger level and area. This allows us to calculate and compare the actuarially fair premiums of these index-based financial contracts across trigger levels and area indexes. These actuarially fair premiums can serve to price the area index-based financial contracts.

2.2. Data

From the FADN for Belgium, we use two farm samples. The first sample includes the crop farms of the FADN, namely the types of farms 1110, 1120, 1130, 1210, 1220, 1243 and 1244 from 1990 to 1993 and the types of farms 1310, 1320, 1330, 1410, 1420 and 1443 from 1994 to 2007. The second sample includes the dairy farms of the FADN, namely the types of farms 4110, 4120 and 4310 from 1990 to 2007.

To assess the area index-based financial contracts for the potato activity, the crop sample is reduced to crop farms which grow potatoes at least for two years. It includes 1 042 observations for the period 1990 - 2007, implying an average of 58 observations per year. This sample is further reduced to 570 observations for the period 1999 - 2007 because since 1999 the variability in potato prices drops from a coefficient of variation of 40% between 1990 and 1998 to a coefficient of variation of 28% between 1999 and 2007.

To assess the area index-based financial contract for the wheat activity, the crop sample is reduced to crop farms which also grow wheat at least for two years. It includes 1 685 observations for the period 1990 - 2007, implying an average of 93 observations per year.

To assess the area index-based financial contract for the milk activity, the dairy sample is reduced to dairy farms which produce milk at least for two years. It includes 6 456 observations for the period 1990 - 2007, implying an average of 358 observations per year.

Output prices are constructed in terms of their Törnqvist index.

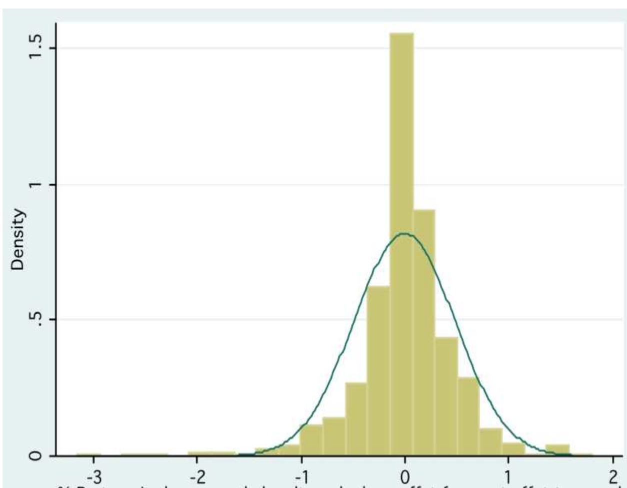
3. RESULTS AND DISCUSSION

We show and discuss the results following the method outlined above for the potato, wheat and milk activities to facilitate comparisons across farm activities.

3.1. Identification of appropriate area indexes for the potato, wheat and milk activities

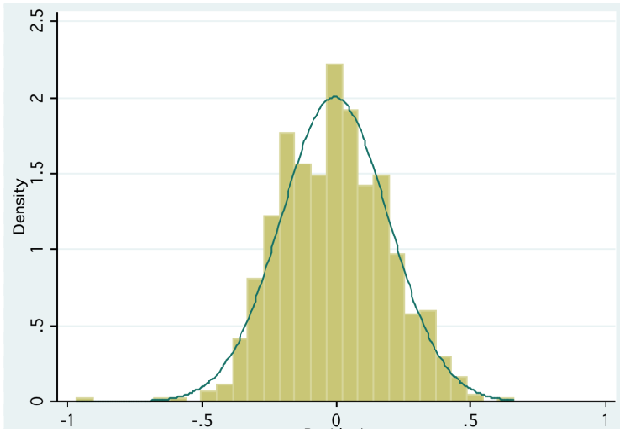
Estimation of expression (1) for the yields-in-value of potato activity between 1999 and 2007 and wheat and milk activities between 1990 and 2007 gives the histograms and normal distributions of the residuals ε_{mit} that are reported in Figures 1 to 3 respectively. The yields-in-value distribution is not normal for the potato and milk activities but close to normal for the wheat activity. The non-normality of the yields-in-value distribution reflects the existence of extreme events for those two activities. These extreme events are more frequent than it should under a normal distribution. It is therefore critical to find an area index that is closely correlated to those catastrophic events.

Figure 1. Histogram and normal distribution of the residuals for the yields-in-value of potato, Belgium, 1999-2007



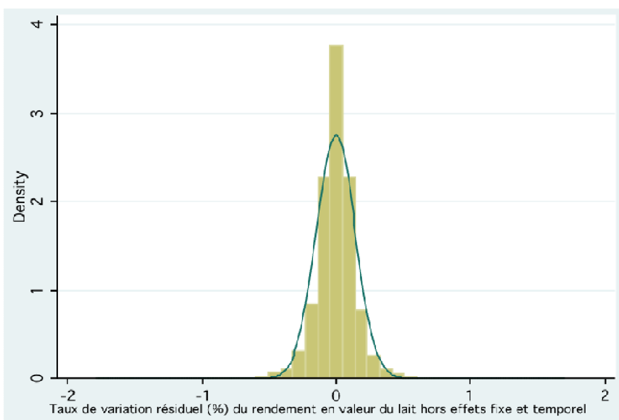
Source: FADN

Figure 2. Histogram and normal distribution of the residuals for the yields-in-value of wheat, Belgium, 1990-2007



Source: FADN

Figure 3. Histogram and normal distribution of the residuals for the yields-in-value of wheat, Belgium, 1990-2007



Source: FADN

The correlations between the negative error terms generated by these estimations and potential variables to construct the area index are estimated and reported in Table 2 for the potato, wheat and milk activities. As expected, the yield-in-value variable obtains the highest correlation with the negative error terms, followed by the yield variable for the three activities. Correlation is also high with the price variable for the potato and wheat activities. This last correlation confirms the interest in using future markets to stabilise yields-in-value of the potato and wheat activities. The farm gross revenue and the output production obtain the lowest correlation with the negative error terms for the potato and milk activities and even a negative correlation for the wheat activity. We, therefore, concentrate on constructing the area indexes on the basis of the yield-in-value and yield variables for the three farm activities.

Table 2: Correlations between the negative error terms of the yield-in-value and potential variables for the farm activities, Belgium

Potential variable	Potato activity (1999-2007)	Wheat activity (1990-2007)	Milk activity (1990-2007)
Farm gross revenue	0.088	-0.017	0.09
Output production	0.113	-0.049	0.18
Price index	0.238	0.297	0.02
Yield	0.238	0.208	0.38
Yield-in-value	0.298	0.461	0.37

Source: FADN

3.2. Construction of the area indexes

Since estimations of expression (1) for the yield-in-value variables of the three farm activities are already available to obtain the residual variation rates μ_{mit} of the yield-in-value variables, the estimation of the same expression is performed for the yield variables of the three farm activities to obtain the residual variation rates μ_{mit} of the yield variable. Expression (2) is then used to obtain two annual series of area indexes per activity and area, one for the yield-in-value variable and the second for the yield variable.

3.3. Performance of the area indexes

Because of lack of space, we only report the performance of the area yield-in-value index.[1] Tables 3 to 5 report the averages and the standard deviations of the residual variation rates μ_{mit} of the yield-in-value variables in years when the trigger is not activated (0) and years when the trigger is activated (1) for the three farm activities respectively. Differences between these two averages are statistically significant. For the potato activity, they are larger for the area yield-in-value index than for the area yield index, indicating that the area yield-in-value index is a better discriminating index that the area yield index. For the wheat and milk activities, performance of the area yield index is poor because their variability is much lower than the individual yields.

1. The performance of the area yield index is available upon request.

In Table 3 for the potato activity, we see that the average drop in the individual variation rates of the residual is 32% upon activation of trigger 1 but the average rise in the individual variation rates of the residual is 9% upon non-activation of trigger 1. The difference between the two averages increases from trigger 1 to trigger 4. In Table 4 for the wheat activity, we see the same phenomenon except for trigger 4 because no crop farm experiences such large negative variation rate of the residual. In Table 5 for the milk activity, we see the same phenomenon but limited to trigger 1. For the other triggers, no dairy farms experience variation rate of the residual that is greater than 10%.

Table 3: Averages and standard deviations of the residual variation rates of the yield-in-value variable for the potato activity per trigger level, Belgium, 1999-2007

Trigger	Residual variation rate		Observation number (%)
	Average	Standard deviation	
Trigger 1: 10% drop in area yield-in-value			
0	.086	.417	456 (80.0%)
1	-.322	.670	114 (20.0%)
Trigger 2: 15% drop in area yield-in-value			
0	.083	.418	459 (80.5%)
1	-.330	.680	111 (19.5%)
Trigger 3: 20% drop in area yield-in-value			
0	.045	.460	510 (89.5%)
1	-.406	.717	60 (10.5%)
Trigger 4: (30% drop in area yield-in-value			
0	.022	.484	543 (95.3%)
1	-.511	.764	27 (4.7%)
Total	~0	.509	570 (100.0%)

Source: FADN

Table 4: Averages and standard deviations of the residual variation rates of the yield-in-value variable for the wheat activity per trigger level, Belgium, 1990-2007

Trigger	Residual variation rate		Observation number (%)
	Average	Standard deviation	
Trigger 1: 10% drop in area yield-in-value			
0	.063	.176	1215 (72.5%)
1	-.169	.133	459 (27.5%)
Trigger 2: 15% drop in area yield-in-value			
0	.026	.186	1477 (88.2%)
1	-.206	.127	197 (11.8%)
Trigger 3: 20% drop in area yield-in-value			
0	.007	.193	1615 (96.5%)
1	-.231	.091	59 (3.5%)
Trigger 4: 30% drop in area yield-in-value			
0	-.001	.195	1674 (100.0%)
1	-	-	-
Total	-.001	.195	1674 (100.0%)

Source: FADN

Table 5: Averages and standard deviations of the residual variation rates of the yield-in-value variable for the milk activity per trigger level, Belgium, 1990-2007

Trigger 1: 10% drop in area yield-in-value	Residual variation rate		Observation number (%)
	Average	Standard deviation	
0	.004	.141	6128 (93.6%)
1	-.097	.176	328 (6.4%)
Total	-.001	.145	6546 (100.0%)

Source: FADN

3.4. The actuarially fair premiums

In the final step, we report the probability of the activation of the trigger per trigger level and area. This allows us to calculate and compare the actuarially fair premiums of these index-based financial contracts across trigger levels and area indexes. These probabilities are weighted according to the corresponding farm frequency weight.

In Table 6 for the area yield-in-value index applied to the potato activity, we see that the actuarially fair premiums for a payment of 100 euro widely vary across area from 10.5 euro in Hainaut to 44.1 euro in Limburg for the first trigger. These premiums tend to decline from triggers 1 to 4 as expected. For the area yield index for the potato activity, estimates not shown here indicate that premiums are quite different than with the area yield-in-value index for the same activity.

In Table 7 for the area yield-in-value index applied to the wheat activity, we see that the actuarially fair premiums for a payment of 100 euro also vary widely across area from 7.9 euro in West Flanders to 40.6 euro in East Flanders for the first trigger. These premiums also tend to decline from triggers 1 to 3 as expected. For the area yield index for the wheat activity, estimates not shown here indicate that premiums are quite different than with the area yield-in-value index for the same activity.

Finally, in Table 8 for the area yield-in-value index applied to the milk activity, we see that the actuarially fair premiums for a payment of 100 euro vary across area from 2.3 euro in Luxembourg to 11.1 euro in Hainaut for the first trigger.

Depending on the area index, actuarially fair premiums vary. They also vary across area under the same trigger indicating the importance of establishing financial contracts per homogenous area for improving risk coverage.

Table 6: Weighted probability (%) of activation for the area yield-in-value index for the potato activity per area, Belgium, 1999-2007

Province	Trigger 1 (10% drop in area yield-in-value)	Trigger 2 (15% drop in area yield-in-value)	Trigger 3 (20% drop in area yield-in-value)	Trigger 4 (30% drop in area yield-in-value)
Limburg	44.07	35.94	10.66	-
East Flanders	41.68	41.68	41.68	29.45
Flemish Brabant	13.37	13.37	-	-
West Flanders	17.99	17.99	-	-
Walloon Brabant	24.67	24.67	24.67	-
Hainaut	10.47	10.47	-	-
Liège	-	-	-	-
Namur	-	-	-	-
Belgium	21.24	20.35	9.80	4.10

Table 7: Weighted probability (%) of the activation of the triggers for the area yield-in-value index for the wheat activity per area, Belgium, 1990-2007

Province	Trigger 1 (10% drop in area yield-in-value)	Trigger 2 (15% drop in area yield-in-value)	Trigger 3 (20% drop in area yield-in-value)
Antwerp	30.68	-	-
Limburg	19.68	6.57	5.76
East Flanders	40.63	12.04	-
Flemish Brabant	27.47	5.47	-
West Flanders	7.86	7.86	-
Walloon Brabant	24.61	11.58	-
Hainaut	33.30	17.26	17.83
Liège	23.95	19.32	33.77
Luxembourg	39.06	39.06	-
Namur	28.97	4.75	-
Belgium	26.21	10.73	3.32

Table 8: Weighted probability (%) of activation of the triggers for the area yield-in-value index for the milk activity per area, Belgium, 1990-2007

Province	Trigger 1 (10% drop in area yield-in-value)
Antwerp	4.89
Limburg	-
East Flanders	-
Flemish Brabant	-
West Flanders	-
Walloon Brabant	4.39
Hainaut	11.14
Liège	3.58
Luxembourg	2.30
Namur	2.74
Belgium	3.31

4. CONCLUDING REMARKS

Among the three area index-based financial contracts that are evaluated, only the financial contract for stabilising revenues from the potato activity is actually pertinent. Between the two considered area indexes, the area index based on yields-in-value allows for a better stabilisation of the potato revenues.

Despite its performance, the area yield-in-value index-based financial contract is most likely inappropriate for stabilising revenues from the wheat activity. Because the performance of the financial contract based on the area yield as the index is disappointing for stabilising revenues from the wheat activity, we suspect it is the price variability embedded in the yield-in-value variability that actually makes the yield-in-value index relevant. The higher correlation of yields-in-value with wheat prices than with wheat yields confirms it (see Table 2). To stabilise revenues from the wheat activity, it is therefore more relevant to rely on future markets to protect against systematic price risks, on one hand, and revenue insurances to protect against the idiosyncratic yield-in-value risks resulting from yield variability among crop farms, on the other hand.

In the perspective of a rise in the variability of milk price as a result of the deregulation in the dairy sub-sector, hedging on future markets, contracting milk supply and adding higher value are probably better alternatives than insurance tools.

We would like to conclude with four remarks. First, it is critical to define the area index at a level of homogenous areas to guarantee a strong correlation between the selected area index and the farm revenues. It is also critical to adjust premiums with respect to the systematic part of the risk of loss. Second, the basis risk can still remain an important concern for farmers. Agricultural or revenue insurances can then cover the idiosyncratic part of the risks. Third, compared to these more traditional insurances, the implementation of an area index-based financial contract is simplified but updating timely the area index is still a challenge. Fourth, the sustainability of these financial products rests on the performance of reinsurance mechanisms to address in particular situations of catastrophic risks.

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