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Evaluating the potential of whole-farm insurance over crop-specific insurance policies

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Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

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Abstract

Since 1996, different formats of whole-farm insurance (WFI) have been launched in North America and Spain. Their rationale is to pool all farm's insurable risks into a single policy that provides cheaper coverage against the farm's revenue losses. We evaluate the gains of moving from a situation of full insurance coverage delivered by crop-specific policies to WFI. Based on the records of individual farmers gathered by the Spanish Agricultural Insurance Agency (ENESA), we select two representative farms in Valencia that have consistently purchased insurance during 1993-2004 for three crops (apricots, plums and wine grapes). WFI is designed to deliver exactly the same expected revenue than does the combined effects of three crop-specific multiple-peril insurance policies, covering from the same risks. We carry out Monte-Carlo simulations to compare crop-specific insurance with WFI, looking at premium differences, farms' revenues, and farmers' utilities (DARA-CRRA). From ENESA's database we evaluate the parameters of the yield distribution functions, the eligible losses distribution functions and their correlation. Results show that WFI is slightly superior to crop-specific insurance. Premia are 20% cheaper, and certainty equivalents slightly larger. Yet, the left tail of the revenue distribution is only weakly reduced by either insurance strategy, due to crop risks that are not covered by either policy. The main conclusion is that, if crop-specific insurance is sufficiently mature, farmers would benefit from WFI and Governments would enhance the efficiency of their insurance subsidies.

JEL: Q14, G, Q18

Keywords: agricultural insurance, whole-farm insurance, simulation, crop risks, Spanish agriculture

Introduction

Whole-farm insurance policies are meant to provide overall coverage to all farms' crops. Since most crop risks do not perfectly covariate, whole-farm insurance (WFI, hereafter) provides a more efficient coverage than insuring each crop or animal with a specific policy. This is because WFI provides coverage for the whole farm's revenue or margin, which are good proxies of farmers' profitability. Its rationale is based on simple diversification and portfolio management. Following Hennessy et al. (1997), if a farm grows two crops, A and B, a policy insurance based on the farm's total revenue will be cheaper than the sum of the premia of crops A and B for the same expected revenue; the savings being regardless of, but proportional to the correlation between contemporaneous crops' revenues. In principle, the lower is the correlation, the greater the premium rebate that WFI results over specific crop insurance.

WFI has been developed and applied following two different formats. First, farm revenue insurance (FRI) provides coverage against farm's margin losses. In the examples we shall briefly review, farmers can purchase insurance against reduced or negative margins, evaluated accordingly with certain cost and revenue accountant rules. With the second format, farmers can purchase multi-crop insurance (MCI) policies (or portfolio insurance for other authors) by which the combined revenue results of the eligible crops are insured against losses below a certain level.

The main disadvantage of FRI stems from measuring the farm's revenue or margin in a manner that avoids moral hazard and is acceptable for insurers. As a result, WFI is more often developed along the MCI format, but there are also examples of FRI that will be reviewed below. MCI can provide coverage for yields losses or crop failures, but can also include revenue protection. If all farm's crops are included in the MCI revenue, its effects would be equivalent to FRI's.

Using Monte-Carlo simulations, Hennessy et al (1997) show that MCI provides a similar, albeit cheaper revenue protection than insuring corn and soybeans with separate premia for the case of an Iowa representative farm. Babcock and Hayes (1999) show that a corn and soybeans producer could purchase relatively cheaper insurance for the same crops if the policy includes coverage against revenue losses in hogs' production. Hart et al. (2003) developed several whole-farm crop revenue insurance programs to include livestock. Their whole-farm insurance product covered crop revenues from corn and soybeans and livestock revenues from pig production. They found that at coverage levels of 95 percent or lower, the fair insurance premiums for this product on an Iowa pig farm are much lower than the fair premia for the corn alone on the same farm.

From an actuarial point of view, the premium reduction that is achieved by WFI is based on pooling the risks of the crops included in the policy. For the insuree, this means that the distribution of pay-offs will be more concentrated around the mean, reducing the probabilities of both tails. As the negative outcome of one crop may be fully compensated by the positive one of another crop, WFI may not yield any indemnity in cases where specific-crop premia might do so. Yet, if government subsidizes the premia, the efficiency of support, in terms of increase of certainty equivalent per dollar spent in subsidies, may be significantly larger with WFI than with crop-specific premia.

To evaluate the benefits of WFI for a farmer that grows and purchases insurance for more than one crop, one has to assume that he/she would maintain the same acreage allocations, because WFI premia and outcomes depend on them. In addition, as the distribution of benefits exhibit a reduction of mean-preserving spread, WFI would only appeal to risk-averse farmers. Further, since total liability is reduced with WFI with respect to specific-crop insurance for the same coverage, re-insurance may be less costly.

The objective of this paper is to evaluate WFI policies for farmers that have shown consistent and sustained crop-specific insurance strategies. Using the farm-level records of the Spanish Insurance Agency (ENESA) for twelve years, we evaluate the premia of WFI for farmers that have purchased more than one crop-specific multiple-peril policy. The comparisons of total paid premia and farmers' revenue and utility, with WFI and with various insurance policies, are based on Monte-Carlo simulations, using probability density functions evaluated from ENESA records. WFI is designed to deliver exactly the same expected revenue than does the combined effects of three crop-specific multiple-peril insurance policies, covering from the same risks. In contrast with previous works, we account for the possibility of damages not covered by the insurance policy by considering three stochastic effects: crops' yields, the magnitude of the indemnities and the probability of experience crop losses or failures due to non-insurable risks. The parameters of these distributions are estimated from actual data pertained to the selected farmers and to their *comarca*'s (as counties are called in Spain).

Previous experiences with Whole-farm Insurance

Since 1996, various models of revenue insurance have been developed in USA. CRC (*Crop Revenue Coverage*) and IC (*Income Protection*) were initiated in 1996, RA (*Revenue Assurance*) became available in 1997 and GRIP (*Group Risk Income Protection*) was marketed in 1999 for the first time. Until 1999, the only revenue insurance available for the whole-farm was a variant of *Revenue Assurance* (*RA*) (Babcock & Hayes 1999). For this, actuarially fair premia were evaluated using a similar procedure as that developed by Hennessy et al. (1997), giving it a format of portfolio insurance providing a coverage against revenue losses[1]. In 2000 a new revenue WFI policy, *Adjusted Gross Revenue* (*AGR*), offered farmers a coverage against losses below the average revenues of the previous five years, including crops, livestock and fish-farm productions. It was initially offered experimentally in Northeast States, but presently is eligible for farmers of West Coast and Idaho (USDA, 2005a). Since 2004, *AGR-Lite* is offered in 11 Northeast States, and provides WFI based on farms profits. It includes all revenues originating from the same crops eligible with AGR, plus livestock and horticultural crops. It was especially designed for medium-size and small farms, since total liabilities can not exceed $250,000 (USDA, 2005b).

In Canada, CAIS (*Canadian Agriculture Income Stabilization*) was initiated in 2003, integrating all available programs and income stabilization instruments. CAIS, the heir of the old NISA (*Net Income Stabilization Account*), is not an insurance-type mechanism, and fits better with the notion of self-insurance funds, to which both Provincial and Federal governments match the growers' contributions (Government of British Columbia, 2005a). Growers can make withdrawals from their individual accounts when their farms' margins fall below the reference margin. In contrast with insurance-type mechanisms, making withdrawals is optional to the farmers, which may provide a smoother flow of revenue and better adapted to farmers' needs (Turvey, et al. 1997). Since 2001, hog farms and horticultural farms from the Province of British Columbia can purchase *NMI* (*Whole Farm Negative Margin Insurance Pilot Program*). This program guarantees subscribers complete recovery of their production costs, in case of low product prices, crop losses or unexpected increase of input costs. (Government of British Columbia, 2005b).

In Spain, there are various WFI, all of them developed under the format of MCI insurance. There is one group of WFI policies which include all field crops, differentiating

[1] This RA variant is commercially offered by American Farm Bureau Insurance Services, Inc., in six midwestern US States.

dry-land crops and irrigated crops. Yield and multiple peril insurance are offered within this group. Another group of WFI policies is targeted to fruit producers, so that all fruit species, excluding citrus, are included in the same the policy. Citrus specific multi-crop and vegetables specific multi-crop policies provide coverage against multiple perils including hailstorm, freeze, flood, persistent rain, strong winds and fire. The Spanish Insurance system has expanded from crop-specific policies, grouping them in MCI policies of increasing complexity and coverage variations. This work deals with some of them, looking in more detail at a various combinations of crops for which there are not WFI policies offered yet.

The modeling framework

The modeling framework includes the evaluation of specific-crop premia and the WFI premia for a number of representative growers who exhibit consistent and stable insuring strategies based on various crop-specific insurance (CSI) policies.

Let's suppose that a farmer grows *I* crops, each crop *i* with a yield probability distribution function of $f_i(x_i)$. For each crop, an actuarially fair premium $\Pr_i$ is estimated by:

$$\Pr_i = \underset{i}{E}\left[\tilde{I}_i\right]$$

$$\tilde{I}_i = \begin{cases} p_i \times [\bar{X}(1-(\tilde{\lambda}_i(1-\tilde{l}_i)+(1-\tilde{\lambda}_i))] & if \quad \tilde{x}_i < \bar{X} \\ 0 & if \quad \tilde{x}_i \geq \bar{X} \end{cases}$$

where I_i is the indemnity of crop *i*; $\tilde{x}_i$ is the stochastic yield; p_i is the crop price at which crop losses are paid, assumed non-stochastic; $\tilde{\lambda}_i$ is the probability of getting an indemnity when yields are below the insured level, and $\tilde{l}_i$ is the stochastic loss eligible for indemnity (which does not strictly correspond with the total loss). Essentially, what variable $\tilde{\lambda}_i$ does is to capture the event of experiencing low yields for a reason that does (λ_i =1) or does not (λ_i =0) lead to an indemnity, as defined by the insurance policy.

For the WFI policy, fair premium should result from:

$$\Pr = E\left[\tilde{I}\right]$$

$$\tilde{I} = \begin{cases} \min\left[\sum_i s_i I_i, (R - \sum_i s_i p_i \tilde{x}_i)\right] & if \ \sum_i s_i p_i \tilde{x}_i < R \\ 0 & if \ \sum_i s_i p_i \tilde{x}_i \geq R \end{cases}$$

where *R*, which is farm-specific, is the insured revenue. It is equal to the expected revenue that the farm would obtain should all crops be insured with crop-specific policies. In the above formulation, note that Pr is idiosyncratic to the farmer because the cropping patterns, s_i, are needed to compute it. Furthermore, since the crops' yields functions are in principle not independent, the numerical computation of Pr and $\Pr_i$ needs also the correlations among random variables $\tilde{l}_i$ and $\tilde{x}_i$.

The savings in terms of insurance costs for the same expected revenue can be measured by: $\Delta \Pr = \Pr - \sum_i s_i \Pr_i$.

In addition, we can evaluate the utility gains with ΔEU = EU($\tilde{\pi}_{WFI}$)-EU($\tilde{\pi}_{CSI}$), where $\tilde{\pi}$ account for the farm profits with the different insurance possibilities, U(π) is DARA – CRRA utility function, such as $U(\pi)=\pi^{1-r}/(1-r)$, with r being the coefficient of relative risk aversion. Similarly, we can compute the difference of Certainty Equivalents ΔCE = CE($\tilde{\pi}_{WFI}$)-CE($\tilde{\pi}_{CSI}$).

Note that, by the very definition of WFI, the difference of expected profits $\Delta\pi^e = \pi^e_{WFI} - \pi^e_{CSI} = 0$, because:

$$\pi^e_{WFI} = \underset{x_1,\ldots x_I}{E}\left[\max[\sum_i^I s_i \times p_i \times \tilde{x}_i, R] - \sum_i^I C_i\right] - \Pr = R$$

$$\pi^e_{CSI} = \sum_i^I [s_i \times p_i \times \underset{x_i}{E}\left\{\max[\tilde{x}_i, \overline{X}(\tilde{\lambda}_i(1-\tilde{l}_i) + (1-\tilde{\lambda}_i)] - C_i\right\} - \Pr_i] = R$$

Where C_i is crop *i*'s cost, and *E()* is the mathematical expectation operator. Both results are equal to the implicit insured revenue (R) because we consider actuarially fair premia.

Assumptions and data

With the above stylized model, we designed a three-crop Whole-farm insurance which combines insurance for a) Irrigated apricot; b) Irrigated plums; c) Non-irrigated wine grapes. The simulation and numerical study is carried out for two representative farmers of the Comarca Val d'Albaida (Valencia, Eastern Spain). They have been selected from ENESA's records amongst those farmers that have purchased the three crop-specific insurance policies corresponding to the crops mentioned above. Those insurance policies provide coverage against hailstorms, torrential flood-rain, persistent rain, strong winds, frost, and, for wine grapes, the risk of premature physiological ripeness. Our WFI policy is designed to provide coverage from the same risks as the current single-crop insurance policies described above. This means that they are not yield insurance but multiple-peril insurance.

The data base originates from ENESA's individual farmers records for the seasons 1993 to 2004. Our two representative farmers were selected based on the criterion of having purchased insurance for the three considered crops during 10 out of the twelve considered seasons. Yet, premia (Pr_i and Pr) have been evaluated taking into account all farmers within the Comarca Val d'Albaida who purchased the three insurance policies at least one of the twelve seasons, and at least one policy in ten out of the twelve seasons. This allowed us to pool together a much larger data set from which some of the parameters of the distribution functions could be estimated.

From the records available, it was found that yields (x_i) and losses or indemnities (l_i) follow beta distribution functions, whereas the loss eligibility parameter (λ_i) yields 0 or 1 from a binomial distribution function, whose frequency is obtained from the data. For each of the two selected farmers, we took their individual average yields, but both the maximum and the coefficient of variation of the crop yields, as well as the correlations were taken from the larger data set containing all *comarca*'s farmers. Losses, l_i, are expressed in relative terms over the liabilities of crop *i*, and its distribution function is also estimated from the larger farmers selection, as well as the frequency of the binomial function of losses, which is estimated from the frequency of indemnities over total observations. In addition, the correlations of yields and losses among the crops are estimated from the same dataset.

The insured acreage, s_i, is taken from the two farmers' in season 2000. Crop price, p_i, is the 5-year average of the prices used by ENESA to compute the indemnities during the seasons 2000 through 2004. Lastly, we have taken the same coverage level offered in season 2004 which amounts to 100% of expected yield (in prior seasons it has been 80% for some of the crops). Lastly, the DARA-CRRA function assumes a relative risk aversion level of r=1.2, although we shall report sensitivity analyses that assume greater risk aversion preferences.

We show on table 1 the main parameters of the yield distribution functions, and of the losses (indemnities relative to liabilities). The frequency of the losses for the binomial distribution, which is not shown on the table, was found to be 0.20, 0.23 and 0.9 for apricots, plums and wine grapes respectively. This frequency was doubled to account for its use only on the left half of the distribution (values below the mean). On the bottom part of table 1 we show the correlation matrix.

The premia, Pr and Pr_i, together with the above mentioned measures of benefits were obtained from Monte-Carlo simulations, using the Latin Hypercube sampling of @Risk (Palisade Decision Tools).

Table 1. Distribution functions' parameters and correlation matrix (yields are in kg/ha; losses are expressed in relative terms to total liability)

	Yields Apricot	Yields Plums	Yields Wine grapes	Losses Apricot	Losses Plums	Losses Wine grapes
CV	0.30	0.39	0.16	0.70	0.72	0.60
Mean	Farm 1: 15603 kg/ha Farm 2: 6564 kg/ha	7224 8226	12305.92 13419.89	0.24	0.21	0.37
Max / min	28086 / 0	14808 / 0	18750 / 0	1 / 0	1 / 0	1 /0
Correlation matrix of $\tilde{l}_i$ and $\tilde{x}_i$						
Yields - Apricot	1					
Yields - Plums	0.173	1				
Yields - Grapes	0.550	0.289	1			
Losses - Apricot	-0.073	0.087	-0.148	1		
Losses - Plums	0.017	0.095	0.028	0.471	1	
Losses - Grapes	0.140	-0.054	0.030	1	0.060	1

Results

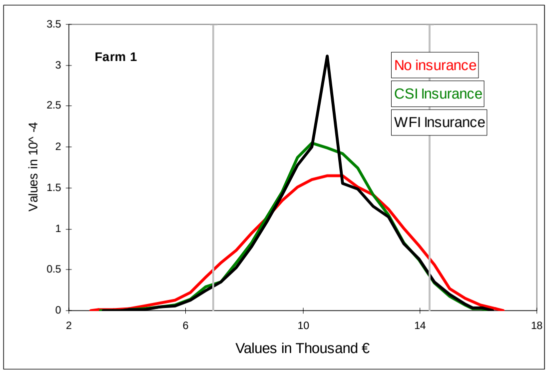
Table 2 reports the average results of the Crop-Specific Insurance (CSI) and the Whole-Farm Insurance (WFI) cases. For both farms, WFI ensures slightly better average results than CSI. With about the same expected revenue, the Certainty Equivalent grows from CSI to WFI. The WFI premia, as expected, would be significantly reduced with respect to the CSI case, the reductions being 19% for farm 1 and 15.5 % for farm 2.

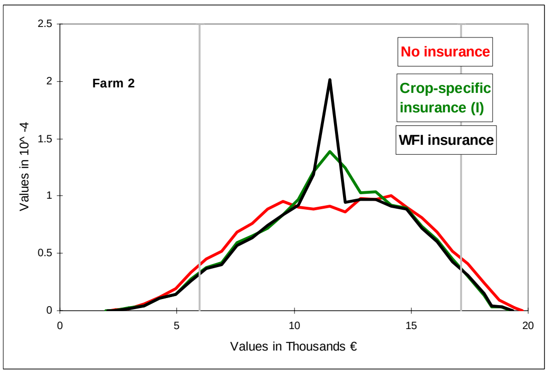
Table 2. Comparison of the Crop-specific insurance and Whole-farm insurance results

farm 1	Apricot	Plums	Wine grapes	Crop-specific insurance (CSI)	Whole-farm insurance (WFI)	Differences (WFI-CSI)
Surface (ha)	0.77	0.88	1.44	3.09	3.09	
Pure premium (%)	5.00%	4.48%	3.15%	4.04%	3.32%	-0.72%
Liability (€)	3948.08	2174.52	4841.74	10964.35	10964.35	0.00
Pure premium (€)	193	96	154	443	358	-85.00
Expected revenue (€)				10762.00	10762.76	0.76
Certainty Equivalent (€)				10536.00	10546.10	10.10
farm 2	**Apricot**	**Plums**	**Wine grapes**	**Crop-specific insurance (CSI)**	**Whole-farm insurance (WFI)**	**Differences (WFI-CSI)**
Surface (ha)	0.75	2.82	0.63	4.2	4.2	
Pure premium (%)	4.92%	4.40%	3.04%	4.19%	3.55%	-0.64%
Liability (€)	1617.68	7935.23	2310.01	11862.92	11862.92	0.00
Pure premium (€)	81	345	71	497	420	-77.00
Expected revenue (€)				11691.77	11691.02	-0.75
Certainty Equivalent (€)				11110.37	11127.02	16.65

Figures 1a and 1b graph the density functions of both farms' revenues for the three- case analyses (No insurance in red; WFI in black and CSI in green).

Figures 1a and 1b. Density functions for benefits of farmers 1 and 2

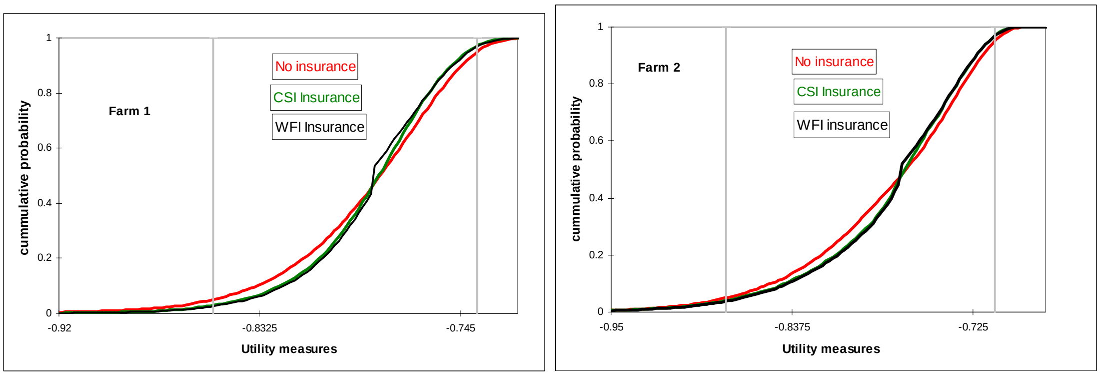




In both cases, insurance reduces the spread of the results with respect to the no-insurance case. Yet, the differences between the CSI and WFI cases are only significant for results near the average, as WFI concentrates more probability around the mean than CSI. This is because of the risks' compensation effect that WFI has embedded on its actuarial evaluation. In this sense, moving from CSI to WFI represents a reduction of a mean-preserving spread, as defined by Rothschild and Stiglitz (1970), but does not contribute to reduce the probability of the left tail. The reason for this is that there are some risks for which our insurance does not provide coverage, which is modeled by means of the stochastic variable $\tilde{\lambda}_i$. As WFI exactly reproduces the same loss adjustment and crop-specific risks than does CSI, the left probability tail is not effectively reduced by WFI.

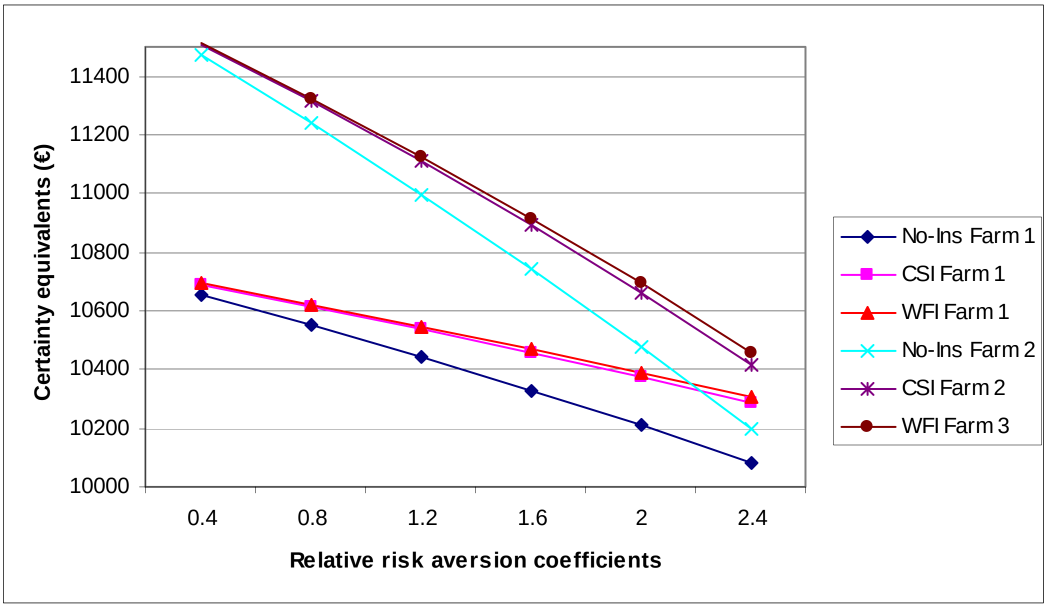
Slight stochastic dominance of WFI over CSI is shown on the utility measures graphed in Figures 2a and 2b. The differences of WFI and CSI are marked right beyond the Utility values where the cumulative distributions of both insurances' graphs cross the no-insurance case. The kink in the WFI curves corresponds to the spike of the density functions shown on Figures 1a and 1b.

Figures 2a and 2b. Utility cumulative distribution functions for farms 1 and 2



In a final set of results, we have simulated the effects of various risk aversion levels on the certainty equivalents of the 3-case results. Figure 3 shows that certainty equivalents are quite similar for low to medium risk aversion rates.

Figure 3. Certainty equivalents for both farms and 6 levels of relative risk aversion coefficients



Concluding Remarks

Whole-farm insurance (WFI) can provide welfare-increasing outcomes with respect to crop-specific insurance (CSI), for the same coverage-guarantees and expected revenue levels. This is because WFI concentrates more probability mass around the mean than does CSI. Yet, the differences among WFI and CSI can be small if: a) the left-tails are unaffected by moving from CSI to WFI, because only insurable risks are covered; b) the correlation among all crops' yields and losses are small or positive; and c) for low levels of risk aversion. In fact, WFI provides a gain if and only if farmers exhibit a certain level of risk aversion.

We show that fair premium could be reduced by 15 to 20% with WFI with respect to the situation of a set of crop-specific insurance policies. As governments typically subsidize premia based on a proportion of their value, subsidies could be reduced significantly without impairing the risk reduction potential granted to the farmers.

There is a potential advantage of WFI over CSI that we have not addressed in this paper. It is fair to assume that farmers only claim indemnities when they expect that the loss adjuster would approve it. As a result, it is very likely that WFI's administrative costs may be lower than with CSI, because farmers would not be interested in reporting losses in one crop when they expect that favorable results from others make up for the losses of the failed one. Should this be the case, lesser loss adjustment costs would also be another advantage of WFI over CSI.

Among some of the disadvantages of WFI is the need to compute individual premia for each farmer and to recompute them every year that cropping pattern changes. Yet, with good information technology systems, this need not represent a major obstacle.

Extensions of this work will be made once a survey to 1000+ Spanish farmers, with questions that address the potential demand for WFI, is analyzed.

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