Unclassified **AGR/CA/APM(2002)16/FINAL**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

18-Dec-2003

English - Or. English

DIRECTORATE FOR FOOD, AGRICULTURE AND FISHERIES
COMMITTEE FOR AGRICULTURE

AGR/CA/APM(2002)16/FINAL
Unclassified

Working Party on Agricultural Policies and Markets

THE IMPACT OF CROP INSURANCE SUBSIDIES ON LAND ALLOCATION AND PRODUCTION IN SPAIN

English - Or. English

JT00156111

NOTE BY THE SECRETARIAT

This paper is the fifth of a series of five papers on the measurement of decoupling under Activity 6 of the Programme of Work 2001-2002 of the Committee for Agriculture. It has been written by Alberto Garrido, Associate Professor, María Bielza, Research Assistant, and José M. Sumpsi, Professor, of the Departamento de Economía y Ciencias Sociales Agrarias, of the Universidad Politecnica de Madrid, Spain. It follows the conceptual framework defined in [COM/AGR/APM/TD/WP(2000)14/FINAL] declassified at the 26-28 September 2000 session of the APM. It presents the study of the impacts of crop insurance subsidies on land allocation and production in Spain.

This paper has already been discussed in the Working Party on Agricultural Policies and Markets (APM) of the Committee for Agriculture at its 32nd Session hold on 21 to 23 May 2002 and at the Technical Meeting on Decoupling that took place in Paris on the 21 May 2002. A revised version of the paper was discussed in the APM meeting at its 34th Session hold on 31 March to 2 April 2003, where it was decided that some further changes were required. The current version includes technical improvements and additional caveats and explanations that were suggested in those meetings.

TABLE OF CONTENTS

THE IMPACT OF CROP INSURANCE SUBSIDIES ON LAND ALLOCATION AND PRODUCTION IN SPAIN[1]

Executive summary

Spanish cereal growers generally contract agricultural insurance policies. Two insurance alternatives were available up to 1999-2000; the first covered crop destruction caused by fire, hailstorm and other extreme events. The second, called yield insurance, covered yield losses due to unfavourable crop conditions, such as drought or excessive heat, in addition to losses covered by the first scheme. As of the 1999-2000 season, growers can contract a new yield policy that expands the coverage offered by the first yield policy, with the difference that the premia are calculated on an individual basis.

This study, which will cover only the first two insurance schemes, seeks to evaluate the impact of crop insurance policies on decisions made by Spanish cereal farmers. Specifically, it will aim to establish whether farmers respond to insurance subsidies by either augmenting yields (changing non-land inputs use) or by changing crop patterns, or both. It also aims to provide an evaluation of farmers' relative risk aversion coefficients.

Data was obtained from the Spanish National Agency of Agricultural Insurance (ENESA). Nine seasons, beginning with 1991-92, and a cross-section of 19 377 individual farmers serve as the reference base. The results, however, are potentially distorted by some data limitations, the most serious one being that the database includes observed cereal acreage only when an insurance policy was contracted. Missing value was thus replaced by the acreage for the most recent season for which ENESA has records.

Despite the limitations, the data set offered several empirical possibilities. First, relative risk aversion coefficients were evaluated using basic theoretical results and comparing the willingness of agents to pay for insurance to the actual premium paid. Using a simple mathematical procedure based on a random selection of farmers it was possible to demonstrate that their risk preferences confirm the assumption of Decreasing Absolute Risk Aversion and Constant Relative Risk Aversion, with CRRA coefficients (rr) ranging between of 0 and 4 (although 70% were between 0 and 1). Alternative econometric models were also estimated, with specifications aimed at explaining changes in insurance strategies, yields, and cereal supply.

Results show that once farmers have begun to contract insurance policies, they continue to contract the same policies over time. The incentives influencing farmers' decisions to buy insurance, however, differ from those that seem to guide their decisions about switching from low- to high-coverage policies. It was also found that individuals subject to large production risks tended to insure more than those operating in less risky conditions.

1. This study was prepared by Alberto Garrido, Associate Professor, María Bielza, Research Assistant, and José M. Sumpsi, Professor, of the Departamento de Economía y Ciencias Sociales Agrarias, of the Universidad Politecnica de Madrid, Spain.

The results of the yields equations, interpreted jointly with those obtained from the supply equations, show that farmers tend to obtain lower yields when they contract insurance, but may increase cereal acreage. The effect of the expected cereals and other crop prices, as well as the expected price variance and direct per hectare payments, confirm *a priori* economic theories. In other words price effects on yields and supply are larger than the effects of the remaining variables. It is thus clear that policies affecting cereal prices do act as important incentives influencing farmers' decisions.

The cereal supply equations show that insurance subsidies tend to increase cereal supply. However, subsidies for yield insurance have less impact on production than do subsidies for insurance against fire and hailstorm. In elasticity terms, the effects on production of subsidies to both types of insurance policies are smaller than the effects of price or other direct support policies.

Absolute and relative effects of price support, area payments and insurance subsidies have been evaluated using the corresponding supply elasticities estimated from the production models. The benchmark for the estimation of the relative effects of the different instruments is a 1% increase in market prices. The same absolute increase in support is then applied in the form of an increase in area payments or an increase in the insurance subsidy. The results show that price effects and insurance subsidies are somewhat similar, but that the effects of area payments are much greater. However, it should be noted that the amount of additional subsidy that would have to be given on insurance (in order for the increase to be equivalent to the increase in market price support) is 54% for increase yield insurance. In the case of fire and hailstorm insurance the extra subsidy to be distributed is so large that the farmer would actually purchase the insurance for free, and even receive a financial bonus for doing so.

The main policy conclusion of this study is that yield insurance subsidies do not seem to have a large effect on cereal production. Nonetheless, the results presented could be improved through the use of a greater number of observations and perhaps partitioning the sample by some other criteria. Secondly, more sophisticated econometric techniques could possibly answer additional policy-relevant questions than were investigated here. Nevertheless, the lack of data for those farmers who refuse to buy insurance is a serious limitation for which there is no easy solution.

1. Background

Spanish winter cereal production is subject to extreme climatic variability and, in some areas, to restrictions imposed by seem-arid conditions. For instance, three of the most common crop rotations in dry-land farming are: (1) winter cereal — fallow; (2) winter cereal — fallow — oil crop; (3) winter cereal — fallow — legume crop. These rotations imply that between 33% and 50% of the land is followed each year.

Since 1990, winter cereal producers can contract four types of insurance policies with agricultural insurance companies. These policies are outlined in Table 1, beginning with lowest level of coverage.

Table 1. Insurance lines

Insurance lines	Scope of loss evaluations	Coverage and deductibles	Premia calculation basis	Contracting date	Premia adjustments	Premium subsidies
Fire and hailstorm	Plot basis	100% of the loss (as evaluated by the loss adjuster) No deductible	Based on historical yields	1st March	None	From 8% to 27%
Yield insurance (includes fire and hailstorm risks)	Plot basis	65% of the difference between historical yields and actual yields	Based on the difference between historical yields and the actual yields	1st September	- based on structural factors - based on individual history	From 22% to 41%
Complement for fire and hailstorm on incremental yield	Plot basis	100% of the loss of the incremental yield	Based on the expected incremental declared by the farmer	1st March	None	
Yield whole farm insurance (since year 2000-not included in this study)	Whole farm basis (fire and hailstorm plot basis)	65% of the difference between historical yields and actual yield	Based on the difference between historical yields and the actual yields	1st September	- based on structural factors - based on individual history	From 22% to 45%

Source: Entidad Estatal de Seguros Agrarios (web page and various Annual Reports).

The two main insurance policies are those covering losses from fire and hailstorm, and the yield plot-basis insurance. Both types of insurance cover damage for the most common types of non-irrigated winter cereals: wheat, barley, rye, oats, etc. The fire and hailstorm insurance also covers exceptional damage caused by torrential rains, persistent rains, hurricanes, winds and floods. Yield insurance guarantees 65% of the yield for all risks which cannot be controlled by the farmer and guarantees 100% of the losses caused by hailstorm and fire, and droughts.

ENESA has collected data on all cereal growers who have contracted an insurance policy for at least one season since 1990. Although ENESA also has records for farmers who have contracted crop insurance for legume and oil crops, these were not used in the study.

Insurance premia are actuarially based, with a mark-up of about 30.5% to cover administrative and loss adjustment costs. Under the yield insurance option, ENESA introduced bonus-malus adjustments, thus increasing its actuarial soundness. Premia are based on records of the farmer's historical yields, or on the area yield if the farmer has not kept an uninterrupted series of records. Where the latter is the case, ENESA has completed the missing years by adjusting the area yield with a factor based on the correlation between area yield and the farmer's yield from previous seasons.

Farmers are free to contract any type of premium irrespective of the options chosen in any previous year. Tables 2 and 3 provide a summary of the historical data related to both insurance lines.

Table 2. Fire and hailstorm insurance for winter cereals

Year	Insured farms	Insured surface (ha)	Production (T)	Insured capital (1 000 €)	Premia	
					Value (1 000 €)	Subsidies
1990	96 322	1 874 837	5 735 167	897 544	20 154	21%
1991	97 505	2 020 833	6 160 854	941 800	18 965	20%
1992	128 797	1 489 088	4 220 234	657 543	12 477	20%
1993	78 150	1 507 966	4 465 193	526 892	12 539	20%
1994	77 872	1 488 205	4 711 040	595 989	13 172	20%
1995	63 596	1 359 261	3 798 157	435 777	9 803	17%
1996	87 618	1 832 580	6 330 129	764 596	17 638	18%
1997	79 969	1 903 176	5 404 861	652 181	14 208	15%
1998	89 335	2 098 175	6 892 392	831 042	20 979	14%
1999	81 137	1 873 053	5 924 298	714 680	17 816	14%
2000	93 577	2 256 327	7 606 269	872 013	21 645	14%

Source: ENESA 2002.

Table 3. Winter cereals yield insurance

Year	Insured farms	Insured surface (ha)	Production (T)	Insured capital (1 000 €)	Premia	
					Value (1 000 €)	Value (Subsidies
1990	65 719	1 630 800	4 035 431	601 831	63 539	38%
1991	132 861	1 754 512	4 282 940	647 191	74 499	38%
1992	69 658	2 081 930	4 916 239	576 144	70 755	36%
1993	68 482	2 138 445	5 269 080	664 874	90 757	36%
1994	61 266	2 063 014	4 935 647	563 610	74 311	36%
1995	80 474	2 588 512	6 193 525	744 465	87 772	31%
1996	65 039	2 358 784	5 436 914	653 500	75 446	31%
1997	58 160	2 185 350	5 274 669	634 027	67 002	28%
1998	65 784	2 390 482	5 829 266	700 637	69 837	27%
1999	65,529	2 360 482	5 909 767	674 816	66 326	26%
2000	51 656	1 810 019	4 512 784	461 079	45 278	26%

Source: See Table 1.

Tables 3 and 4 show that farmers who contract winter cereal yield insurance tend to have lower yields than those under the fire and hailstorm insurance (hereafter F&H). In addition, yield insurance premia are subsidised at rates between 26% and 38%, whereas the F&H policies are subsidised between 14% and 20%. As shown, insurance subsidies have decreased during the study period. Premia for F&H represent, on average, 2.5% of the insured capital, while the total premia for yield insurance represents 11% of the insured capital. Combining both types of policies, the overall participation rate ranges from a 57% in 1995 to 75% in 2000, measured as the percentage of insured acreage over declared acreage to claim CAP per hectare subsidies. Geographically, participation rates range from 90-95% in the traditional cereal production provinces (Burgos, Soria, Valladolid in the region of Castille-Leon; and Seville and Cadiz in the region of Andalusia) to 35% in the provinces with little cereals' acreage (ENESA, 2003).

As regards problems of moral hazard and adverse selection, the Spanish agricultural insurance system exhibits remarkable actuarial soundness, as evidenced by the comparison between the agricultural insurance loss ratios in Spain, Canada and the US (Table 4).

Table 4. Loss ratios in the agricultural insurance sector in Canada, US and Spain

Year	Canada Premia (% of insured capital)	US Premia (% of insured capital)	Canada (Loss ratio)[1]	US (Loss ratio)[1]	Spain (Loss ratio)[2]	Canada (Loss ratio)[2]	US (Loss ratio)[2]
1990	12.2	6.52	0.67	1.16	1.25	0.79	1.24
1991	10.35	6.57	0.59	1.3	1.23	0.74	1.74
1992	11.08	6.69	1.51	1.22	1.62	1.65	1.66
1993	11.7	6.66	0.92	2.19	0.89	1.07	2.66
1994	11.6	6.98	0.59	0.63	0.87	0.75	1.02
1995	11.77	6.5	0.6	1.02	1.33	0.75	1.33
1996	10.68	6.84	0.46	0.81	0.42	0.6	1.11
1997	10.59	6.97	0.53	0.56	0.87	0.68	0.85
1998	10.73	6.72	0.48	0.89	0.60	0.63	1.17
1999	9.84	7.47	0.5	1.05	1.24	0.66	1.29
2000	9.53	7.37	1.16	0.97	0.54	1.32	102

Notes: 1. Indemnities/Premia.
2. (Indemnities + Administrative cots /Premia)

Source: Canada and US Risk Management Agency (US Department of Agriculture). For Spain: Burgaz Moreno (2002).

2. Objectives

The main objectives of this study are, as mentioned above, to evaluate the impact of crop insurance policies on Spanish cereal farmers' decisions. Specifically, it aims to establish whether farmers respond to insurance subsidies by either altering yields (changing non-land inputs use), changing cropping patterns or both. In addition, the analyses aim to provide empirical answers to questions with respect to winter cereal growers. Specifically, these are:

- To measure the relative risk aversion of growers.
- Estimate the complementarity/substitutability relationship between insurance and land and/or other inputs, and a characterisation of the demand for insurance.
- Estimate the effect of insurance subsidies on production and the relative importance of the non-price effects compared to the price effects on production.
- Establish the relative importance of price and non-price effects of insurance subsidies as compared to area payments and market price support.

3. Estimating farmers' relative risk aversion

3.1. Theoretical background

Several authors have found evidence of agents exhibiting Decreasing Absolute Risk Aversion (DARA) preferences (Arrow, 1965 Binswanger, 1981, Saha *et al*., 1994 and Chavas and Holt, 1990). While Saha *et al*. (1994) found empirical evidence for Increasing Relative Risk Aversion (IRRA) preferences, many others have assumed Constant Relative Risk Aversion (CRRA) and tried to estimate the CRRA coefficient (referred to as 'rr'). The empirical literature suggests that rr values would be in the range of 2 to 4 (Nicholson, 1997). Myers (1989) has estimated that relative risk aversion for a representative farmer in the US is between 1 and 3. This is consistent with other studies, which propose a range between 0 and 4, where *rr=0* implies risk neutral preferences (Antle, 1987; Arrow, 1971; Binswanger, 1980; Hamal and Anderson, 1982; Little and Mirrlees, 1974).

Based on the assumption that the utility function is DARA and CRRA, we posit an exponential functional form for the DARA-CRRA utility function (Nicholson, 1997):

$$\text{If } rr=1 \qquad u(x)=\ln(x)$$

$$\text{If } rr \neq 1 \text{ and } rr>0 \qquad u(x)=x^{(1-rr)}/(1-rr),$$

where rr is the relative risk aversion coefficient to be estimated.

In order to estimate rr from observed behaviour (farmer's income, insurance coverage and maximum premia paid), the following reasoning is used:

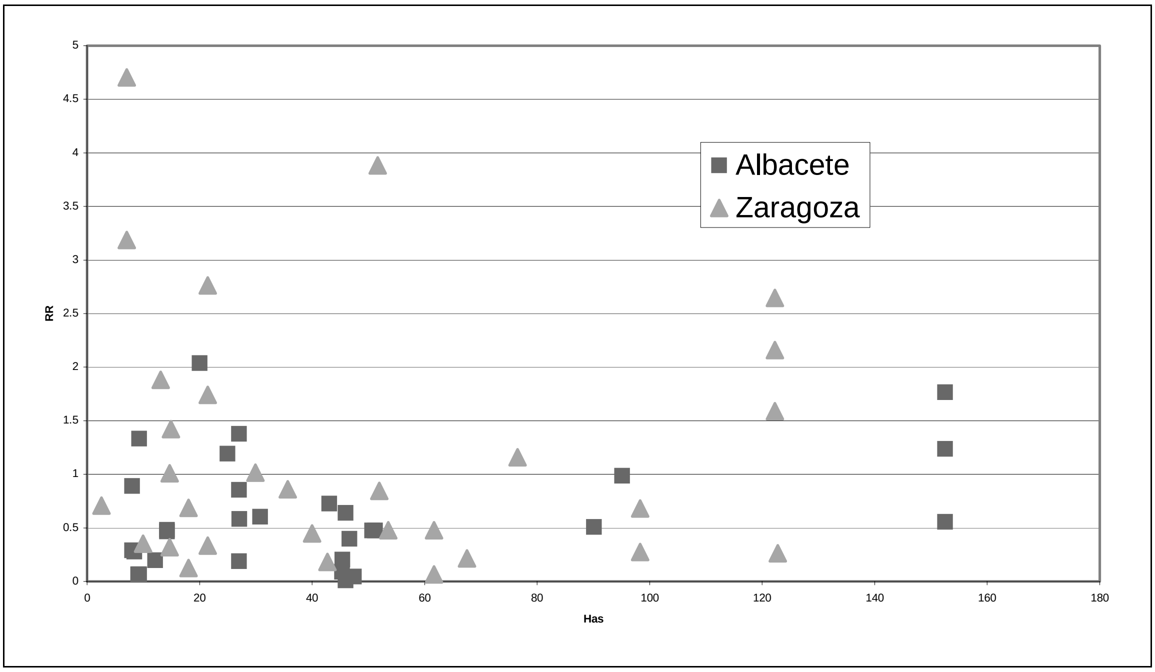
- The Certainty Equivalent, $CE1= u^{-1}[E(u(w_i))]$, can be estimated for the no insurance situation. The CE is the inverse of the expected utility of the possible levels of wealth/income (w_i). From this CE1, we estimate an actuarially fair premium, denoted by p^*, based on the individual risks faced by the agent.
- In the case where an agent buys insurance, the modified expression of his Certainty Equivalent is $CE2= u^{-1}[E(u(w_i-Pp_i+Ind_i))]$, where w_i is the same as in the no-insurance case, plus the indemnities minus the premiums paid.
- Lastly, because of the concave nature of the utility function, the difference between both Certainty Equivalents is equal to the maximum an agent would be willing to pay above the actuarially fair premium in order to be insured. This difference is also a measure of the utility gain that results from buying insurance and provides the means to characterise the agent's preferences towards risk. The sole unknown of the equation, $\max(Pp_i-P^*)=CE2-CE1$, is the relative risk aversion, rr.

3.2. Data and methodology

The above theoretical setting is applied to the data collected by ENESA from those farmers who have taken out cereal insurance for at least three years between 1990 and 1998. From the original data set, we have selected those who have bought yield insurance just once during the nine-year period, the assumption being that the premium paid by them approaches the maximum farmers would be willing to pay. Data from two Spanish provinces, Albacete and Zaragoza, have been selected for this application. A complementary data set is that of the "comarca"[2] yield insurance premiums for these provinces and the premiums subsidies of the nine years.

In order to compute the w_i, we take the observed prices and farmers' acreage for the season covered by an insurance policy. Random yields are assumed to follow a beta distribution function, the parameters of which were calculated from the actual observed yields. Two thousand random yields were then generated following the beta distribution and the expected income was calculated with and without insurance and the actuarially fair premium. Inserting these in the equation, $\max(Pp_i\text{-}P^*)=CE2\text{-}CE1$, yields a unique value of 'rr' for each farmer.

Figure I. Relative risk aversion coefficients



3.3. *Results and discussion*

Relative risk aversion coefficients are plotted in Figure 1 with reference to farm size: about 70% of farmers have a level of rr below 1[3]. The size of the farm does not seem to explain the differences in rr across farms. Although the risk aversion hypothesis is confirmed, this should be considered as a preliminary finding given that selected farms are far from representative and the procedure applied to a number of farms yielded indeterminate solutions for the premium difference equations. This may be an indication that, for many farmers, the premiums paid are well below that which they are willing to pay, while also suggesting that subsidy premiums may be partly redundant or unnecessary. Indeed, it would be useful to pursue the evaluation of farmers' insurance behaviour in order to characterise their risk

2. Comarca is a geographical demarcation smaller than the province. Many agricultural statistical sources refer to the comarca level.

3 Although the statistical significance of the results is poor, authors chose to keep them in the text for its methodological value. We believe that this method is valid when micro-unit data are available and can inspire further work to investigate risk aversion farmers' attitudes based on their observed insurance strategies.

preferences because this would allow for a direct estimation of the utility function parameter for individual farmers.

4. Literature review on farmers' response to agricultural policies

The seminal work of Chavas and Holt (1990) has given rise to a body of literature that focuses on the analysis of farmer risk aversion and their acreage and production decisions under price and yield uncertainty. These authors suggest that risk and wealth variables are influential factors guiding farmers' acreage decisions. A policy relevant conclusion is that farm programmes that truncate the distribution function of prices will affect both the expected revenue and the expected revenue variance. Under the standard assumptions of farmers' risk aversion preferences, this conclusion implies that policy analyses must take into account risk reducing effects and wealth effects.

The literature attempting to characterise farmers' responses to various policy' incentives has yielded conflicting results. This is due, in part, to the difficulty of empirically separating the effects of policy programmes on key decisions made by the farmer. In particular, the presence of insurance policies providing different coverage levels for a number of production or market risks adds further complexity to establishing the complementary or substitution relation among agricultural policies.

Focusing on the effects of insurance, Goodwin (2001) concluded that farmers may not be strongly risk averse and thus will have limited willingness to pay for private insurance coverage. This result is not consistent with findings from other authors, such as Makki and Somwaru (2001), who showed that revenue insurance products have attracted many corn belt farmers, initially under traditional crop insurance, and that the level of premium subsidy is a significant factor affecting farmers' decisions. Another issue of discrepancy is related to the incentives from revenue insurance to expand cultivated areas, which otherwise would have been devoted to other uses. While Keeton *et al.* (2000) concluded that risk management programmes led to an expansion of 20 million hectares of cultivated land in the United States, Young and Vandeveer (2000) suggested that these programmes had very modest aggregate responses. The fact that Keaton *et al.* include disaster assistance payments and several other programs in addition to crop insurance may explain these differences. Nonetheless, whether or not the response is significant largely determines the extent to which changes in prices, trade patterns and other sectors will be relevant.

The literature has also given rise to conflicting views about the effects of crop insurance on farmers' production decisions, in particular the use of chemicals. While Horowitz and Lichtenberg (1993) showed that farmers' expected yields may rise when they buy crop insurance, Smith and Goodwin (1996) and Babcock and Hennessy (1996) concluded otherwise. Such disparate conclusions gives rise to opposing views as to what extent subsidising insurance premia is decoupled from production.

Wu (1999) expands this literature and jointly analyses chemical use and cropping patterns. He concludes that the effect of crop insurance is greater at the extensive margin (acreage decisions) than in the total use of chemicals. Wu and Adams (2001) focus on revenue insurance and confirm that a farmers' acreage is sensitive to the various levels of revenue insurance.

To date, there have been no attempts to model farmers' acreage responses, input level decisions and insurance strategies, assuming market and yield risks as well as their standard risk preferences. The lack of available testable hypotheses obliges empirical analysts to develop models guided by intuition and previous experience. This limitation can in part be mitigated by the use of time-series and longitudinal data, from which acreage, yields and insurance strategies are available. These can be supplemented by other policy variables. The results reported here are subject to the above limitations, but enriched because they are derived from a large database including observations of 87 000 Spanish winter cereal growers over nine seasons.

5. A simple theory of insurance demand

A well-established theory of farm production with both yield and price risks indicates that farmers are responsive to perceived levels of risks and to policies that reduce these risks. Clearly, agricultural insurance can potentially affect farmers' decisions in at least two ways: through distortions of the variability of crop revenues caused by different insurance products offered for various crops or groups of crops, and through a wealth effect which can result in farmers undertaking riskier cropping patterns and input level decisions.

A standard formulation of a farmer's utility can be expressed as a certainty-equivalent (Coyle, 1999):

$$U = \overline{W} - \alpha(\overline{W}, \sigma^2_w)\, \sigma^2_w/2$$

where ($\overline{W}$, σ^2_w) represent the mean and the variance of final wealth, and α is the absolute risk aversion coefficient which may or may not depend on ($\overline{W}$, σ^2_w). Following Coyle, the producer's maximisation problem is given by:

$$V(\overline{\mathbf{p}}, \mathbf{w}, \Omega_p, \overline{\varepsilon}, \sigma^2_\varepsilon, M) =$$

$$\max_{\mathbf{x}, y > \mathbf{0}} \{W_0 + \overline{R}(x, \overline{\mathbf{p}}, \overline{\varepsilon}, \sigma^2_\varepsilon, M) - y\, I^P\, \mathbf{w}\,\mathbf{x} - \alpha(.)\,(1-\lambda y)\sigma^2_R(\mathbf{p}, \mathbf{w}, \Omega_p, \overline{\varepsilon}, \sigma^2_\varepsilon, M)\}$$

Where $\alpha(.) = \alpha(W_0 + \overline{R}(x, \overline{\mathbf{p}}, \overline{\varepsilon}, \sigma^2_\varepsilon, M) - \mathbf{w}\,\mathbf{x}, \sigma^2_R(\mathbf{p}, \mathbf{w}, \Omega_p, \overline{\varepsilon}, \sigma^2_\varepsilon, M))$; **x** is the vector of input levels; $\overline{\mathbf{p}}$ is the vector of average prices; **w** the vector average input; $\overline{\varepsilon}$ and σ^2_ε are the mean and average of a weather index (spring precipitation, for instance); *M* some other relevant moments; *y* is discreet choice variable that takes a value of 1 if a farmer contracts insurance; I^P is the insurance premium; and λ, $0<\lambda<1$, is the variance reduction factor delivered by contracting insurance.

Coyle's approach is adequate to make farms' behavior hypotheses in a context of multi-input and multi-output production units. For the purpose of our paper, and taking into account its data limitations, it suffices a formulating simpler problem in which the choice variable is *h* and denotes the selected coverage level of an insurance policy, can be analysed according to Coyle's approach. Let *Y* represent the random yield and *H* the insured yield. If yields are insured at level *H*, *Y* is a truncated random variable:

$$y = \begin{cases} \text{H if Y<H} \\ Y \text{ if } Y \geq H \end{cases}$$

Define $h = (H - \bar{Y})/\sigma_Y$ as the choice variable representing the desired coverage level for the crop insurance policy.[4] Expected net revenue is given by $\pi^e(h) = p\ y - \varphi\ (h)$, where $\varphi\ (h)$ is a function that yields the actuarially fair premium for each level of coverage, *h*, with $\varphi'(h)$ and no *a priori* hypothesis about the sign of $\varphi''(h)$; *p* is the net output price. Define standard, mean-variance preferences as follows:

$$U(\pi^e(h),\ \sigma_\pi^2(h)) = \pi^e(h) - 0.5\ \alpha\ \sigma_\pi^2(h)$$

Maximising the utility yields $h = h^*(p, \alpha, \sigma_Y)$, which is the selected coverage level if $\varphi''(h) = 0$. The following comparative static results are obtained (see Appendix 1):

$$\frac{\partial h^*}{\partial p} > 0; \frac{\partial h^*}{\partial \alpha} > 0; \frac{\partial h^*}{\partial \sigma_Y} > 0$$

This implies that farmers would buy insurance with larger coverage with increasing output price, yield variability and increasing risk-aversion. It should be noted that in this simple model, we focus on just one crop and make the unrealistic assumption that yields are unaffected by the agent's production strategies. A more complex setting is unlikely to yield clearer results unless the model imposed bolder assumptions.

6. Data sources and description

6.1. Data sources

The data are derived from three sources:

a. ENESA database: Farm level data were obtained from this database, which contains information from 130 746 farms that look at insurance for at least three years within the 1990 to 1998 period.

b. Data was collected from various publications issued by the Statistics Division of the Spanish Ministry of Agriculture, Fisheries and Food. These include:

   - CAP Annual crop aids per tonne
   - Yields at the comarca level which have been used to calculate the aid per hectare for CAP crops.
   - Annual average market prices for different crops, mainly wheat, barley, sunflower seeds and beans.
   - Land prices at the provincial level

c. Monthly precipitation/rainfall data from the National Meteorological Institute for every province. Accumulated rainfall from October to December is assigned to the following crop year.

From the original data, the following provinces from five regions, or *Comunidades Autónomas,* were selected (in 1997, they represented 81.7% of Spain's crop production): Castilla-León (34.2%), Castilla-La Mancha (15%), Aragón (14.5%), Andalucía (11.6%) and Extremadura (6.3%).

4. This approach is equivalent to the one Chavas and Holt (1990) developed for price support policies. The steps omitted in the present document can be found in their paper.

As ENESA's database was too large to handle for a standard PC, a random selection of farm units was made. Of the 97 000 farms remaining after the geographical filtering, we produced two groups comprised of approximately one-tenth of the farms, that is 9 695 and 9 682 farms for each group (which corresponds to 87 255 and 87 138 year-farm observations). The procedure for the random selection was based on the assignation of a number to every farm, and selecting those farms whose number finished by "2" (2, 12, 22, etc.) for the first group and by "7" for the second group. The databases thus generated are named A and B. All monetary data have been converted into year 2000 constant Euros. Surfaces are in hectares and yields in tonnes per hectare.

Before describing each variable, it is important to clarify a few points about the nature of some of the key variables included in the database.

- Cereal acreage: The database has records of each farmer's cereals acreage for nine seasons, independently of whether or not he bought insurance. If the farmer did buy insurance, the recorded observation provides an accurate measure of his cereal acreage. If he did not buy insurance in a given year, the database inserts the acreage most recently insured.
- Cereal yields. The database includes two types of cereal yields for each farmer and season:
  - Obtained yields: For farmers who bought insurance in a given season, this is the yield recorded in the calculation of their *premia* if no claim was made to the insurance company, or the yield evaluated by the loss adjuster, in cases where losses were claimed. For farmers who did not buy insurance, the database inserts the average of the farmer's historical yields multiplied by a factor which is based on the *comarca*'s annual yield and the historical *comarca*'s yields.
  - Insured yield is the yield the farmer insured, as recorded in ENESA database.

6.2. Statistical description of key variables

Table 5 reports the mean and standard deviation of the three key variables, namely, A_YIELD (actual yields), I_YIELD (Insured yields) and SURF (cereals' surface). Results show that database A and database B provide very similar results, proving that the random selection procedure does not cause biased results.

Each database is analysed by dividing the sample into five subsets: *i)* all observations; *ii)* observations of farms that are not insured; *iii)* observations with any cereals insurance; *iv)* observations with the F&H insurance; and *v)* observations with yield insurance. Comparison of the means across these five subsets reveals that:

- Lowest actual yields are found where no insurance is contracted.
- Highest actual yields are found for farmers that contract F&H insurance.
- Actual yields for farmers contracting yield insurance are significantly lower (500 kg/ha) than those of farmers contracting F&H insurance.
- Only in the last subset (containing observations of farmers that contracted yield insurance) are actual yields A_YIELD found to be lower than insured yields I_YIELD.
- The largest average surface is found in the last group of observations (those with yield insurance).
- The lowest average surface is associated with the fourth group of observations (those with F&H insurance).

Preliminary interpretation of these results suggests that low yield farmers tend to insure less than farmers with average or high yields. However, those that contract insurance with the highest coverage (yield insurance) have lower yields than those that contract insurance covering only crop accidents such as F&H. There are three possible explanations: first, since farmers contract yield insurance on a larger area than other insurance, their decision to contract yield insurance may be accompanied by the decision to put more marginal land under cereal production. The second explanation is that larger farms would be more inclined to contract high coverage insurance. Finally, it may be that farmers invest less effort and resources when they contract yield insurance, and which is confirmed by the fact that, on average, actual yields are smaller than insured yields only in the last subset.

A further caveat needs to be made regarding the database. Actual yields that are below insured yields are always declared by farmers buying yield insurance, but not by those contracting F&H insurance. This is because the latter can only claim an indemnity if an extreme event has destroyed all or part of his crop, but not if their harvest was smaller than expected. As a result, it is likely that the actual yield record of farmers buying F&H insurance only may be overestimated. The extent to which this error of measurement may bias the following econometric result is difficult to ascertain. In rating farmers' risks and policies, ENESA has been able to filter unrealistic insured yields and check county (comarca in Spain) yields against individual yields. This would indicate that the bias is not very important. An alternative, and non excluding explanation, may be that farmers buying F&H insurance may be located in areas less prone to more unstable yields.

Table 5. Statistical description of actual yields, insured yields and cereals' surface

		DATABASE A			DATABASE B		
Case	**Variable**	**N Obs**	**Mean**	**St. Dev.**	**N**	**Mean**	**St. Dev.**
Total	A_YIELD		2315.00	1111.30		2310.20	1112.60
	I_YIELD	87255	2291.50	702.91	87138	2287.90	703.57
	SURF		35.74	49.37		35.75	48.96
No insurance	A_YIELD	29370	2012.60	1073.70	29289	2013.60	1078.60
	SURF		33.17	45.13		33.42	47.35
Any insurance	A_YIELD		2468.40	1098.40		2460.30	1099.30
	I_YIELD	57885	2307.60	705.45	57849	2303.70	708.43
	SURF		37.05	51.34		36.93	49.71
Fire and	A_YIELD		2792.80	900.58		2781.50	893.81
hailstorm	I_YIELD	24176	2387.00	703.15	23822	2380.30	707.53
insurance	SURF		32.10	43.22		32.67	52.29
Yield insurance	A_YIELD		2235.80	1166.50		2235.50	1171.50
	I_YIELD	33709	2250.70	701.61	34027	2250.10	704.12
	SURF		40.59	56.18		39.91	47.59

Key: A_YIELD: Actual or obtained yield (kg/ha); I_YIELD: insured yield (kg/ha); SURF: Cereals acreage of farmer i and season t (ha).

7. Results and discussion

This section begins with a review of the equations that characterise farmers' insurance strategies. The first model looks at the factors that explain the decision to buy insurance and the second model looks at the type of insurance contracted by the growers. The set of results that follow examine the factors explaining farmers' cereal yields. In the last section, the results of the cereals supply equations are reported, providing an alternative view of how insurance policies may affect farmers' behaviour.

This approach presents potential problems of causality, simultaneity and endogeneity. We have opted to estimate each set of equations separately to benefit from the panel structure of the data and to avoid computer limitations. Attempts were made to nest the results of the logit models in the surface and production models so as to eliminate potential endogeneity problems. As this operation significantly increases computer memory demands to the point that we would have had to reduce the size of the database to perform the nested estimation it was decided to estimate insurance demands separately.

7.1. The demand for insurance: modelling farmers' insurance strategies

This section seeks to determine the factors explaining farmers' decisions to buy insurance and to choose among alternative insurance products. Following our simple theoretical model of insurance demand, it is assumed that farmers' insurance strategies are tentatively based on:

- whether or not they are usual insurance contractors;
- their expected yield for the year for which the decision is taken;
- the previous climatic year;
- the expected price for cereals;
- the individual risk rate, as obtained from ENESA's database; and
- expected wealth.

The model specification is as follows:

$$INS_t = a_0 + a_1\ DINS_{it-1} + a_2\ EYIELD_{it} + a_3\ RAIN_{pt-1} + a_4\ INS\_SUBSIDIES_{ct} + a_5\ ACER + a_6\ EP\_CER_t$$

$$+ a_7\ RR_i + a_8\ EW\_HA + \text{Regional Dummies} + \text{Year dummies} + u_{it}$$

Two similar specifications were formulated with INS_YLD and INS_F&H as the dependent variable. Since the dependent variables, INS (buying or not buying any insurance), INS_F&H (purchasing or not purchasing F&H insurance) and INS_YLD (buying yield insurance or buying only F&H insurance), are binary, three Logit models were run. In this case, computer capacity permitted each complete database to be run without splitting the database into geographical subsets. In short, six logit models were run with the following specifications:

- Database A and dependent variable INS (1: buys some insurance: 0 buys no insurance); INS_F&H (1: buys F&H insurance and 0 buys no insurance) and INS_YLD (1: buys yield insurance and 0 buys F+H insurance only)
- Database B: same three models.

The models include lagged dependent variables in their corresponding equations. Although this could present econometric problems, the models allowed us to capture the effects of other key variables that may not be associated with habit formation. Secondly, we introduced dummy variables to control for each year and region. Third, we introduced a variable that captures the individual risk situation of each farmer. This rate risk variable, RR, provides the basis for ENESA to evaluate each farmer's premium rates and has been computed following a multistage process which takes into account individual yield records, yields at the *comarca* level as well as some other factors. Finally, we included lagged annual accumulated precipitation, recorded at the provincial level, as a potential way to represent farmers' perception of the need or appropriateness to buy insurance.

Tables 6a and 6b report the results of the six logit models. Observations for 1990 were eliminated because lagged variables are included in the model.

Table 6a. Logit models explaining farmers' insurance strategies (Database A)

Explanatory variables	MODEL (described by its dependent variable)					
	INS		INS_F&h		INS_YIELD (for all i/ INS_F&h =1)	
	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Lagged dep.variable	1.88170	102.21	1.71380	74.82	3.16750	115.24
EYIELD (Expected yield)	0.00037	23.10	0.00036	18.50	-0.00043	-16.77
$RAIN_{t-1}$ (Lagged accum. Precipitation)	-0.00008	-0.87	0.00050	4.29	-0.00131	-9.56
SUB_F&H (Subsidies F&H)	0.16338	10.35	-0.07225	-3.58		
SUB_YIELD (Subsidies yield insur)	0.02901	10.52			0.04497	11.51
ACER (CAP per hectare payments)	-0.00196	-4.03	-0.00402	-7.35	0.01150	18.11
EP_CER (Cereals' expected price)	-0.01196	-11.15	-0.01520	-12.72	0.02257	16.46
RR (Risk rating coefficient)	0.04055	13.63	-0.04879	-11.70	0.14281	32.33
EW_HA (Expected wealth €/ha)	-0.00013	-7.78	-0.00014	-7.32	0.00010	4.59
DCL (Binary: Castille-Leon =1)	-0.08905	-1.61	-0.07816	-1.18	-0.03985	-0.60
DAR (Binary: Aragon =1)	-0.36165	-4.98	-0.29512	-3.40	0.08808	0.95
DCM(Binary: Castille-La Mancha =1)	-0.11751	-2.02	-0.30712	-4.36	0.53211	7.23
DEX (Binary: Extremadura =1)	-0.37907	-4.68	-0.44839	-4.75	-0.10701	-0.94
D92 (Binary: Year 1992 =1)	-0.54286	-16.65	-1.15260	-27.41	1.28060	23.83
D93 (Binary: Year 1993 =1)	0.42426	10.36	0.21765	4.49	0.52433	9.49
D94 (Binary: Year 1994 =1)	0.08541	2.34	-0.06636	-1.55	0.72107	14.43
D95 (Binary: Year 1995 =1)	-0.30018	-8.39	-0.82634	-18.59	0.84828	16.56
D96 (Binary: Year 1996 =1)	1.42450	27.96	1.35030	23.47	0.00683	0.11
D97 (Binary: Year 1997 =1)	-0.05897	-1.59	-0.11405	-2.63	-0.09908	-2.05
CONSTANT	0.70250	3.59	2.23180	10.07	-6.43430	-25.28
N	77456		46178		52453	
Log-likelihood	-401140		-26064		-22123	
Chow R sq	0.222		0.23		0.453	
% right predictions	77		72		82	

Table 6b. Logit models explaining farmers' insurance strategies (Database B)

Explanatory variables	MODEL (described by its dependent variable)					
	INS		INS_F&h		INS_YIELD (for all i/ INS_F&h =1)	
	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Lagged dep.variable	1.86650	100.98	1.64400	72.39	3.15030	115.33
EYIELD	0.00034	21.229	0.00035	18.23	-0.00044	-17.15
$RAIN_{t-1}$	-0.00005	-0.51993	0.00039	3.43	-0.00143	-10.39
SUB_F&H	0.18383	11.639	-0.06538	-3.27		
SUB_YIELD	0.02193	7.956			0.04402	11.48
ACER	-0.00081	-1.668	-0.00269	-4.98	0.01011	16.01
EP_CER	-0.00948	-8.8832	-0.01303	-11.06	0.02110	15.55
RR	0.03918	13.105	-0.05556	-13.33	0.14812	33.11
EW_HA	-0.00014	-8.2417	-0.00016	-8.54	0.00012	5.61
DCL	-0.09406	-1.7098	-0.12295	-1.88	-0.00048	-0.01
DAR	-0.35854	-4.9422	-0.36082	-4.19	0.12843	1.39
DCM	-0.18533	-3.1924	-0.38934	-5.59	0.57076	7.79
DEX	-0.41867	-5.181	-0.48930	-5.24	-0.14857	-1.29
D92	-0.51375	-15.81	-1.13050	-27.23	1.35120	25.38
D93	0.42908	10.502	0.17410	3.64	0.61730	11.27
D94	0.06018	1.6547	-0.16438	-3.86	0.82832	16.62
D95	-0.36068	-10.105	-0.85783	-19.57	0.82160	16.03
D96	1.40880	27.617	1.25350	21.93	0.18269	3.04
D97	-0.10117	-2.726	-0.23316	-5.42	0.06521	1.36
CONSTANT	0.37758	1.932	2.04040	9.28	-6.22650	-24.58
N	77560		46471		52670	
Log-likelihood	-40101		-26436		-22340	
Chow R sq	0.221		0.23		0.45	
% right predictions	76		71		82	

Since both databases yielded similar results, comments pertain equally to Tables 6a and 6b and refer to each of the three logit models (with dependent variables: INS, INS_F&H and INS_YIELD, respectively). We first discuss the common findings across models. The fit is reasonably good, particularly for model IN_YIELD. More than 72% of the predictions are correct, and Chow R^2 range from 0.22 to 0.45. Model IN_YIELD includes only observations of farmers who bought insurance.

Results confirm the behaviour exhibited by Spanish cereal growers regarding the purchase of insurance: if a farmer buys insurance once, it is very likely he will do so again in subsequent years. The individual characterisation of the latent crop risks, RR, is also a significant variable. The higher the RR, the higher the probability of a farmer switching to the high-coverage insurance policy. This may be explained on two differing grounds. On one hand, it may sign the presence of adverse selection, a hypothesis that could be confirmed if loss ratios of the Yield insurance were found to be consistently worse than F&H insurance's. On the other, it may suggest that farmers follow a learning process that ends when the select their best insurance strategy. Based on this reasoning, it is more likely that farmers elect to expand their coverage through time, switching from F&H to Yield insurance, than to do the opposite. Since RR determines the premium rate for each individual farmer, a positive sign would be an indication that increasing premium subsidies would tend to increase the number of farmers switching from low to high coverage insurance. Because RR is high for farmers subject to larger yield variability, this result confirms the theoretical conclusions about the positive sign of $\partial h^*/\partial \sigma_y$.

It seems, however, that the factors explaining the choice of insurance do not play a similar role in explaining farmers' decisions to buy insurance. The results suggest that higher prices and area payments do affect the decision to switch from basic insurance to yield insurance, but do not do not necessarily provide enough of an incentive to the farmer to purchase the insurance in the first place. This confirms one of our theoretical results, namely $\partial h^*/\partial p > 0$, in the sense that higher output prices result in farmers who already purchase insurance buying higher coverage whereas for growers who buy only F&H insurance, and only rarely, high prices and insurance are substitutes for each other.

In addition, expected cereals price and yields appear with opposite signs in both equations. The results of the buy/no buy equations reveal that if expected yields improve or expected prices go down, farmers tend to buy insurance. These same expectations, however, discourage insured farmers from switching to yield insurance.

Higher per hectare equity values are also followed by a smaller probability of buying any kind of insurance, but it does prompt farmers to switch to more expensive policies in the case where only an F&H policy was previously bought. This suggests that buying insurance may act as an alternative strategy to manage equity reductions due to either lower than expected revenues or to reduced opportunities to use land as collateral in financial markets.

The role of insurance subsidies also differs across model specifications. Clearly, larger insurance subsidies are granted to farmers who switch their F&H insurance to yield insurance. However, we found, in our INS_F&H equations, that larger premia subsidies are negative related to farmers' willingness to buy just F&H insurance. This result may be due to spurious statistical effects, but, in any case, average premia subsidies amount to 1.6 € per hectare, which does not seem high enough to affect farmers' decisions.

The main conclusions of this section are:

- Farmers' insurance strategies seem to be consistent over time.
- Subsidising premia affects farmers' decisions to broaden their coverage levels, but does not seem to influence their decision to purchase basic insurance.
- Farmers tend to buy insurance when the previous year was climatically unfavourable. This is consistent with prospect theory developed by Daniel Kahneman (2002 Nobel Laureate) and Amos Tversky.
- Higher cereal prices are complementary to yield insurance buyers, and substitutive for those buying F&H insurance.
- Previously uninsured farmers decide to buy insurance if prices and farm equity values are expected to fall.
- Larger risk rates are consistently associated with a higher probability of buying an insurance and for choosing high coverage insurance policies.

7.2. Yield regressions

It is hypothesised that each farmer's actual cereal yields will depend on:

- whether or not insurance is contracted and its final cost

- the type of insurance contracted;
- accumulated spring and fall precipitation;
- expected prices and variance for cereal and for competitive crops at farm level; and
- direct CAP subsidies for each crop.

In rain-fed agriculture, yields vary significantly with climatic conditions. Price incentives can explain farmers yields. However, other variables such as per hectare CAP subsidies and those representing farmers' insurance strategies are more subtle incentives.

One would expect that moral hazard implies that a farmer would invest more effort if his insurance policy only covered yield losses caused by extreme climatic events, such as hailstorm or fires, than in the case where his insurance covered yield losses caused by, for example, insufficient precipitation. However, "effort" and yield are not perfectly correlated and only the latter are observed. The fact that a farmer has low yields could be due to poor management, but also to bad luck, bad climate or bad natural conditions.

If a farmer switches from a cheap to an expensive insurance providing better coverage, one would expect lower per hectare yield because of moral hazard perverse incentives. If this is the case, subsidies for high-coverage insurance would be decoupled from production. However, if farmers tend to increase their cereal acreage under the high-coverage insurance, the combined result for total cereal supply would be ambiguous. We will return to this point in the supply model section below.

The empirical specification of the yields equation is as follows (see Appendix 2 for exact variables definition):

$$\text{A\_YIELD}_{it} = a_0 + a_1\text{RAIN} + a_2\,\text{EP\_CER}_t + a_3\,\text{EP\_SUN}_t + a_4\,\text{ACER}_{ct} + a_5\,\text{AOLE}_{ct}$$
$$+\ a_6\text{ALEG}_{it} + a_7\,\text{SUB\_YLD}_{ct} + a_8\,\text{SUB\_F\&H} + a_9\,\text{VARP\_CER}_t + a_{10}\,\text{VARP\_SUN}_{ct} + a_{11}$$
$$\text{VARP\_BEAN}_{ct} + \text{Regional dummies} + u_{it}$$

where EP_SUN_t denotes expected sunflower price; ACER_{ct}, AOLE_{ct} and ALEG_{it}, denote per hectare payments for cereals, oil crops and protein crops; and VARP_CER_t, VARP_SUN_{ct} and VARP_BEAN_{ct} denote expected variances of cereal, sunflower and bean prices (following Chavas and Holt, 1991).

We ran four sets of cross-section and time series models to explain farmers' actual yields; two with database A and two with database B. The two databases were split because of computer capacity constraints and the criteria were purely geographical. The resulting four databases included:

- observations of Castilla-Leon (CL) and database A;
- observations of Castilla-Leon (CL) and database B;
- observations of Aragon, Andalucia, Castilla-La Mancha and Extremadura (Multi-region, MR) and database A;
- observations of Aragon, Andalucia, Castilla-La Mancha and Extremadura (MR) and database B.

Table 7 shows the results of the four regressions. The four-stage procedure suggested by Greene (1991) and Kmenta (1986) for cross-section heteroskedastic and time-wise auto-regressive model, which is the standard procedure using time-series and longitudinal data, was used. The procedure includes: *1)* OLS;

2) use the residuals to compute rho_i; *3)* use the estimated rho_i to transform the observations and apply OLS to the transformed model; *4)* obtained GLS estimates.

Table 7. Regression results of the cereal yields equations

	Castilla-León				Multi-region sample			
	Sample A		Sample B		Sample A		Sample B	
	coef	t-student	coef	t-student	coef	t-student	coef	t-student
RAIN	1.49E+00	36.91	1.48E+00	36.53	3.39E+00	97.60	3.47E+00	97.58
EP_CER	6.86E+00	15.75	6.69E+00	15.37	1.64E+00	3.47	2.00E+00	4.20
EP_SUN	9.29E-01	10.98	9.40E-01	11.12	3.56E+00	44.02	3.54E+00	43.36
ACER	18.95	88.99	1.90E+01	89.42	1.36E+01	70.84	1.36E+01	70.19
AOLE	8.05E-02	9.74	1.07E-01	12.90	-5.74E-01	-60.17	-5.95E-01	-62.12
ALEG	-9.43E-01	-19.87	-1.10E+00	-23.16	4.92E-02	1.01	7.94E-02	1.62
SUB_YLD	5.461	10.41	7.34E+00	13.97	4.20E+00	5.87	4.14E+00	5.78
SUBF_H	72.061	20.39	7.90E+01	21.81	2.12E+02	43.19	2.15E+02	43.69
DAN					5.97E+02	25.73	6.24E+02	26.69
DAR					239.63	11.62	2.39E+02	11.53
DCM					325.91	16.33	3.39E+02	16.91
VARP_CER	-8.18E-02	-11.20	-8.37E-02	-11.42	-6.68E-02	-9.91	-6.71E-02	-9.88
VARP_SUN	9.57E-03	18.63	8.50E-03	16.59	1.51E-02	31.70	1.55E-02	32.33
VARP_BEAN	4.92E-01	33.56	0.52653	35.85	1.55E-01	12.48	0.14074	11.25
CONSTANT	-1644.6	-28.07	-1.63E+03	-27.88	-1466.5	-22.02	-1553.3	-23.18
Nxt	4818 x 8		4813 x 8		4877 x 8		4869 x 8	
Log-Likelihood	-301697		-301164		-311252		-3.11E+02	
F-value	5484.80		5527.70		2401.43		2434.21	
R-square	0.61		0.61		0.46		0.47	

All equations have good statistical properties and most coefficients are significant at 0.01 level. All signs are consistent across databases, except for the Leguminosae's Area payments (ALEG). One caveat is the measurement errors of the variable A_YIELD when farmers contract F&H insurance. We mentioned above that the observation in this case coincides with I_YIELD if no claim was made by the farmer. Reported indemnity claims under F&H insurance occur, however, when all or part of the harvest was seriously damaged by extreme events, but not if real yields were below insured yields for other reasons. For this reason, actual yields for these farmers are approximated by insured yields and the declared expected or actual yields.

Variables SUB_YLD and SUB_F&H only apply for those farmers that purchased the corresponding insurance premia. This means they result from the product of the binary variables and the offered insurance subsidies being zero for those observations in which no insurance is purchased.

RAIN is positive and very significant in all regressions, confirming the dependence of winter cereals on spring precipitation. The coefficient of the expected price of cereals (EP_CER) is also positive as are the elasticities of yields with respect to expected prices in the range of 0.55 and 0.15. Price variances take the expected sign, namely negative for cereals and positive for alternative crops. Clearly, the yields equations do not provide an accurate description of the supply effects of support prices and insurance policies, as farmers may also respond by increasing or reducing their cereals' acreage. However, the results reported in Table 7 seem to suggest that farmers respond to higher price of insurance by decreasing their yields. That is, insurance and other non-land inputs are gross complements in production.

7.3. Production equations

An alternative approach to treating supply effects is to run a model explaining farmers' total production of cereals. The same specification as for the yields equations was used, but with $PROD_{it}$ ($=YIELDS_{it} \times SURF_{it}$) as the dependent variable (Table 8).

Table 8. Regression results of the cereal production equations

	Castilla-León				Multi-region sample			
	Sample A		Sample B		Sample A		Sample B	
	Coefficient	t-student	Coefficient	t-student	Coefficient	t-student	Coefficient	t-student
RAIN	0.10679	46.54	1.02E-01	44.89	8.85E-02	49.23	9.09E-02	49.13
EP_CER	3.09E-01	14.48	3.19E-01	14.94	2.30E-01	12.58	2.21E-01	11.82
EP_SUN	2.47E-03	0.42	9.74E-04	0.16	4.83E-02	13.35	4.97E-02	13.30
ACER	4.32E-01	22.14	4.33E-01	21.65	1.47E-01	13.07	1.52E-01	13.04
AOLE	-1.22E-03	-3.64	-3.25E-04	-1.01	-1.93E-02	-52.18	-2.03E-02	-53.95
ALEG	-7.30E-03	-2.69	-5.82E-03	-2.04	-2.98E-02	-14.50	-2.80E-02	-13.22
SUB_YLD	1.95E-01	8.20	2.08E-01	9.02	3.98E-01	13.79	3.67E-01	12.53
SUBF_H	2.07E+00	12.58	2.10E+00	12.91	4.07E+00	19.11	4.50E+00	20.31
DAN					1.87E+01	9.39	2.00E+01	9.71
DAR					8.2175	4.54	7.78E+00	4.18
DCM					1.92E+01	10.62	1.69E+01	9.10
VARP_CER	-5.56E-05	-0.13	-1.34E-04	-0.30	-7.44E-03	-26.67	-7.23E-03	-25.19
VARP_SUN	1.87E-04	5.16	1.73E-04	4.65	1.03E-04	4.52	1.27E-04	5.39
VARP_BEAN	3.25E-03	4.16	3.77E-03	4.56	1.28E-02	25.47	1.27E-02	24.38
CONSTANT	-64.321	-22.86	-6.68E+01	-23.89	-4.06E+01	-13.71	-38.872	-12.86
Nxt	4818 x 8		4813 x 8		4877x 8		4869 x 8	
Log-Likelihood	-192570		-192070		-193848		-193253	
F-value	3029.9		3150.7		957.9		978.9	
R-square	0.46		0.47		0.26		0.26	

All variables are very significant, with the exception of the expected price of sunflower seeds and the variance of cereal prices in our two models for Castilla-León. Goodness of fit is similar to the yields' equations. All own-price supply elasticities are significant in the range of 0.50 and 0.55.

Perhaps the most noteworthy results of the supply equations are the coefficients of the SUB_YLD and SUBF_H variables. The fact that both are positive and very significant partially resolves doubts raised in the interpretation of the previous regressions. Insurance subsidies are positively correlated with growers' cereals production.

However, the effects of subsidies for both insurance policies should be interpreted in light of the comparisons across different modes of income support or stabilisation. Although the coefficient of the F&H insurance subsidies is about ten times larger than the coefficient of the yield insurance subsidies, in elasticity terms both effects are statistically indistinguishable. Table 9 reports the supply elasticities of cereal prices, cereals area payments and insurance subsidies.

Table 9. Supply elasticities (measured at the mean)

	Castilla-León				Multi-region sample			
	Sample A		Sample B		Sample A		Sample B	
	Elasticity	t-student	Elasticity	t-student	Elasticity	t-student	Elasticity	t-student
EP_CER	0.57	14.48	0.55	14.94	0.603	12.58	0.52	11.82
HACER	0.38	22.14	0.39	21.65	0.15	13.07	0.15	13.04
SUB_YLD	0.0113	8.20	0.0122	9.02	0.0231	13.79	0.0215	12.53
SUBF_H	0.0125	12.58	0.0126	12.91	0.018	19.11	0.019	20.31

The supply elasticities are used to evaluate the absolute and relative effects of alternative income support mechanisms *related to* price support measures. Table 10 reports the results of such comparisons, which have been carried out based on the following assumptions: a cereal productive acreage of 3.91 million hectares with a cereal total production of 10.7 million tonnes; average cereal payments of 150 €/ha; average yields insurance subsidies of 7.84 €/ha and elasticities values reported in Table 8.

In order to compare the impact of different policy instruments it is interesting to compare the production impact on one additional Euro spent in alternative policy instruments. Following OECD's instructions[5], the benchmark of comparison is support provided through higher market prices. The methodology is applied in three steps. *1)* Using estimated equations, the impact of a small increase in price (say 1%) is measured and called Q1. The monetary value of this additional support to producers, M, is calculated as total production times the monetary increase in price. *2)* In order to simulate the same increase in support in the form of another policy instrument (for instance payments per hectare) we introduce an increase in the payment per hectare equal to M over the number of hectares. The corresponding estimated impact on production is Q2. *3)* The ratio Q2/Q1 provides an estimate of the production impact per Euro of support in the form of area payments as compared to the same Euro conceded as market price support. It is, in fact, an estimation of the degree of "coupling" of that policy instrument. This methodology can also be applied to insurance subsidies. To make the policy comparisons more realistic, a further assumption was made as to what would be the largest effect resulting from increasing insurance subsidies. Since in the database the largest overall participation rate, combining yield and F&H insurance, was 71.7%, we multiplied the production ratios of simulation 3 by a factor of 0.717. The results of this exercise are presented in Table 10.

Table 10 shows that the relative effects of yield insurance are of similar magnitude to price support mechanisms of equivalent budgetary cost. More detailed examination of the relative effects of insurance subsidies reveals that such conclusion should be qualified. First, the analysis is performed as if all farmers buy insurance and all eligible production is insured against yield losses. Table 2, however, shows that yield insurance is purchased for only about half of the total cereals acreage covered by insurance of some kind. This assumption clearly leads to some overestimation of the effects of increased insurance subsidies. While the results of our logit regressions show that farmers respond to insurance subsidies, almost all the empirical evidence from elsewhere suggests that the opposite, *i.e.* that agricultural insurance demand is inelastic (Goodwin, 2001)[6]. In our models, the insurance subsidies elasticities range from 0.07 to 0.16.

5 Those included in the Terms of reference for the project

6 In explaining the reasons for increasing overall participation rates in the US, the USDA's Economic Research Service mentions as the main influential factor the reduced insurance costs resulting from

Table 10. Simulated effects of price support versus other policy changes

		Sample A (CL)	Sample A (MR)	Sample B (CL)	Sample B (MR)
Simulation 1: 1% increase in all prices					
Increase in prices	%	1.0%	1.0%	1.0%	1.0%
Increase in support	euros	163	127	160	128
Impact on production	tonnes	0.5	0.4	0.6	0.4
Simulation 2: equivalent increase in Area payments					
Increase in payment	%	5.5%	4.7%	5.5%	4.6%
Increase in support	euros	163	127	160	128
Impact on production	tonnes	2.0	0.5	2.0	0.5
Production ratio		3.7	1.3	3.6	1.4
Simulation 3: equivalent increase in Yield insurance subsidy [1]					
Increase in payment	%	36.8%	34.0%	36.7%	33.8%
Increase in support	euros	163	127	160	128
Impact on production	tonnes	0.4	0.6	0.4	0.5
Production ratio		0.5	1.0	0.5	1.0

The results of Simulation 3 should be taken cautiously. This is because an equivalent amount of support to a price increase of 1% would result in a disproportionate increase in insurance subsidies, both because the participation rates are on average 71% and because per hectare premia are low in comparison with the budgetary requirements of a 1% support price increase.

Secondly, even assuming that all eligible farmers purchase yield insurance, the increase in (M) price support that constitutes the benchmark for the experiment would be translated into an equivalent increase in insurance subsidies of 34-37%. This would imply that farmers would end up paying well below 30% of the actuarially fair yields premia, or virtually nothing if the uptake of yield insurance is assumed at current rates. A parallel evaluation of the effects of subsidies on the basic fire and hailstorm policies would provide nonsensical results. This is because the premia are so small that spending the amount M to subsidise them would result in a net payment to farmers "subscribing" to the policy.

It should be stressed that the supply effects of insurance subsidies result from two compounding effects, both small. One is the insurance demand elasticity, and the other results from the incentives that subsidised premia have to increase cereal yields and/or acreage. Our models have shown that the effects on yields are very small and the production effects a bit larger. But doubts still remain about the production effects until more confidence is built about the measurement of cereals' acreage, especially for farmers that do not always purchase insurance of any kind.

Lastly, the simulation of an equivalent increase in area payments shows suggests that the supply effects may be significantly larger than those related to price and insurance support. Although the area payments production ratios may be overestimated, they indicate that the overall supply effects are primarily caused by farmers' acreage decisions rather than by input levels. In view of the differences in production ratios between insurance subsidies and area payments, we may conclude that yield effects may be much smaller than acreage effects, which reinforces the conclusion that insurance subsidies may be more decoupled than area payments.

incrementing subsidies granted as a result of the Agricultural Risk Protection Act of 2000 (*Agricultural Outlook*, Economic Research Service/USDA, December 2001 and March 2000 issues).

8. Concluding remarks

The above results should be considered with caution as the database includes observed data only when cereal acreage has been covered by an insurance policy in three of the nine years in the database. There are many farmers who grow cereals and who are not included in the database. Furthermore, there may be numerous farmers included in the database who devote land to other crops, which the database does not include. In addition, there may be measurement errors in the actual yields obtained by the sub-sample of farmers that purchase F&H insurance only which need to be investigated in further detail. Despite these data problems, the results reported are robust and qualitatively consistent. Based on observed insurance strategies from a selected set of farmers, we have estimated individual coefficients of relative risk aversion (rr) under the assumptions of Decreasing Absolute Risk Aversion and Constant Relative Risk Aversion. The estimated rr's are in the range of 0 and 4.5, although 70% of the point estimates were between 0 and 1.

Despite the serious limitations imposed by the available database, the three families of econometric models generated illustrate:

- the factors explaining cereal yields;
- the role that insurance plays both in yield and acreage decisions; and
- the key variables explaining insurance strategies.

Although preliminary, these results provide evidence supporting the following conclusions:

- Farmers tend to develop habits regarding their insurance strategies.
- Farmers at greater risk tend to insure more often than those characterised as being less at risk. This effect is even more evident when analysing the option to switch from fire and hailstorm (F&H) insurance to yield insurance.
- Buying yield insurance, as opposed to refusing to do so or contracting only F&H insurance, is associated with obtaining lower yields. It is shown that farmers buying only F&H insurance obtain higher average yields than do those buying yield insurance.
- Subsidies for crop insurance create incentives for production.
- Larger equity values are associated with larger cereals' acreage, both in absolute and relative terms.
- Higher expected cereal yields tend to be followed by contractions in cereal acreage. This reinforces the conclusion that insurance policies have ambiguous effects on total cereal supply.
- Yields respond positively to higher than expected prices and to lower than expected price variance. As a result of this and the previous findings, price support mechanisms seem to provide clearer incentives to increase cereal yields than the various insurance policies available for Spanish cereal growers during the 1990 to 1998 seasons.
- Cereal supply responds to cereals price and area payments/aids, but it is also positively affected by insurance subsidies. This implies that cereal insurance may not fit with a strict notion of 'decoupled policy'. However, in relative terms, insurance subsidies seem to be less influential than area payments and price support mechanisms. This is because not all farmers buy insurance and insurance demand is inelastic.
- A 1% increase in cereal price is equivalent in terms of total support to an increase of about 35% in yield insurance subsidies, and significantly more if the current uptake of insurance

policies is assumed. If only F&H insurance is involved, support equivalent to a percentage increase in market price support would result in subsiding premia to the point of paying farmers to become insured.

- To conclude, insurance premia are likely to have small supply effects among Spanish cereal growers. Results show that yield insurance subsidies provide weaker incentives to increase cereal production than subsidies to low-coverage policies. The main conclusion of this analysis is that yield insurance and other insurance policies providing coverage against yield losses, such as the new yield insurance offered in Spain since 2000, may not result in significant cereal supply response.

APPENDIX 1

Define, *e*, the normalised value of *y*: e=(y- $\bar{Y}$)/σ_Y.

Chavas and Holt (1990) show that:

$Y = \bar{Y} + \sigma_Y.(f(h) + h\,F(h)$, where f(h) and F(h) are the density and probability functions. In addition, it is shown that:

$$\sigma^2_{y^*} = \sigma_Y\,(\,1\text{-}\,F(h) + f\,f(h) + h^2\,F(h) - \bar{e}^2)$$

with, $\bar{e} = f(h) + h\,F(h)$.

$$\pi^e(h) = E(\pi(h)) = p\,[Y + \sigma_Y.(f(h) + h\,F(h)] - \varphi(h)$$

$$\sigma_\pi^2(h) = E(\pi(h)\text{-}E(\pi(h))^2 = p^2\sigma^2_{y^*} = p^2[\sigma^2_Y\,(1\text{-}\,F(h)+h\,f(h)+\,h^2F(h) - (\,f(h))^2 - (h\,F(h))^2 - 2\,hf(h)F(h)]$$

With the expected benefits and the variance of benefits, the utility function takes the following form:

$$U(\pi^e(h),\sigma_\pi^2(h)) = \;p\,[Y + \sigma_Y.(f(h) + h\,F(h)] - \varphi(h)$$

$$0.5\;\alpha p^2[\sigma^2_Y\,(1\text{-}\,F(h)+h\,f(h)+\,h^2F(h) - (\,f(h))^2 - (h\,F(h))^2 - 2\,hf(h)F(h)]$$

A solution to the problem is derived from the first order conditions of the above function:

$$\partial U(\pi^e(h),\sigma_\pi^2(h))/\partial h = p\;\sigma_Y.F(h) - \varphi'\,(h) - \alpha p^2\sigma^2_Y\,(h\,F(h)\,(1 - F(h)) - 2\,f(h)\,F(h) = 0$$

taking in mind that, $f'(h) = -\,hf(h)$ and that $F'(h) = f(h)$. Reordering the FOC, we get:

$$p\;\sigma_Y\,[F(h) - \;\alpha\,p\;\sigma_Y\;\;(h\,f(h)\,(1\;-f(h))\;\;-2\,f(h)Ff(h))] = \;\varphi'\,(h)$$

The RHS is positive for any negative *h*, which means that there exists a solution: $h{=}h^*(\alpha, p,\,\sigma_Y\,)$.

Second order sufficient conditions are investigated by the second derivative:

$$\partial U^2(\pi^e(h),\sigma_\pi^2(h))/\partial h^2 = -\,p\;\sigma_Y\,h\,f(h) - \;\varphi''\,(h) \quad -0.5\;\alpha p^2\sigma^2_Y\,[(1\;\;-F(h))+\,hf(h)(F(h)\text{-}1)+\,F(h) - 2\,f(h)]$$

which are fulfilled for $F(h) > 0.1$. Such a coverage level would be extremely low, and no agricultural insurance policies are typically offered for such levels.

By the implicit function theorem,

$$p\;\sigma_Y\,[F(h^*(\alpha, p,\,\sigma_Y\,)) - \;\alpha\,p\;\sigma_Y\;\;(h^*(\alpha, p,\,\sigma_Y\,)f(h^*(\alpha, p,\,\sigma_Y\,))\,(1\;-f(h^*(\alpha, p,\,\sigma_Y\,)))$$

$$-\,2\,f(h^*(\alpha, p,\,\sigma_Y\,))Ff(h^*(\alpha, p,\,\sigma_Y\,)\,))] - \varphi'\,(h^*(\alpha, p,\,\sigma_Y\,)) \equiv 0$$

Taking derivatives with respect to the parameters (α, p, σ_Y) one by one in the above identity, we get the sought results:[1]

$$\frac{\partial h^*}{\partial p} > 0; \frac{\partial h^*}{\partial \alpha} > 0; \frac{\partial h^*}{\partial \sigma_Y} > 0$$

1. As algebra can be burdensome, the proofs are available on request from the authors.

APPENDIX 2

Variables Definition and Units
(i, farmer; t season)

Abbreviated name	Unit	Description
$SURF_{it}$	ha	Cereals acreage of farmer i and season t
$PCER_{pt}$	€/T	Cereals average price in province p and year t
$PSUN_{pt}$	€/T	Sunflower average price
$PBEAN_{pt}$	€/T	Beans average price
P_LAND_{pt}	€/ha	Land price in province p
V_LAND_{it}	€	Land value = $P\_LAND_{pt} \times SURF_{it}$
A_YIELD_{it}	kg/ha	Actual or obtained yield
I_YIELD_{it}	Kg/ha	Insured yield
$PROD_{it}$	Kg	Farmer i's production on year t. $=A\_YIELD_{it} \times SURF_{it}$
$SURF\_AV_{i}$	ha	The average of insured surfaces of farmer i in the different years from 1990-98 (ha)
E_ICER_{it}	€/ha	$=INS_{it} \times (EP\_CER_{t} \times I\_YIELD_{it}+ACER_{ct})$ + $(1-INS_{it}) \times (EP\_CER_{t} \times ((A\_YIELD_{it-1}+A\_YIELD_{it-2}$ $+A\_YIELD_{it-3})/3)+ACER_{ct})$ Expected revenue of cereals
INS_{it}	0/1	1: buys any insurance; 0, otherwise
INS_YIELD_{it}	0/1	1: buys yield insurance; 0, otherwise
$INS\_F\&H_{it}$	0/1	1: buys F&H insurance; 0, otherwise
EW_HA_{it}	€/ha	Expected per hectare wealth $=(P\_LAND_{pt-1} \times SURF\_AV_{i}+SURF_{it} \times E\_ICER_{it})/SURF\_AV_{i}$
$ACER_{ct}$:	€/ha	CAP aids or area payment for cereals
$AOLE_{ct}$:	€/ha	CAP aids or area payment for oil crops
$ALEG_{ct}$:	€/ha	CAP aids or area payment for Protein crops (leguminous)
$EYIELD\_I_{it}$	T/ha	$=(INS_{it}) \times I\_YIELD_{it}$ Expected yield for those buying insurance
$EYIELD\_NI_{it}$	T/ha	$=(1-INS_{it}) \times (A\_YIELD_{it-1}+A\_YIELD_{it-2}+A\_YIELD_{it-3})/3)$ Expected yield for those not buying insurance
$EYIELD_{it}$	T/ha	Expected yield = $EYIELD\_I_{it}+EYIELD\_NI_{it}$
EP_CER_{t}	€/T	$=12.04+ P\_CER_{t-1}$ Cereals expected price (following Chavas and Holt, 1990)[1]
EP_SUN_{t}	€/T	$=-30.64+P\_SUN_{t-1}$ Sunflower expected price (following Chavas and Holt, 1990)[2]
EP_BEAN_{t}	€/T	$=-7.01+P\_BEAN_{t-1}$ Beans expected price (following Chavas and Holt, 1990)[3]
$VARP\_CER_{t}$	€	$=0.5 \times (P\_CER_{t-1}-EP\_CER_{t-1})^2+0.33 \times (P\_CER_{t-2}-EP\_CER_{t-2})^2$ + $0.17 \times (P\_CER_{t-3}-EP\_CER_{t-3})^2$ Expected variance of cereals' prices.(See Chavas and Holt,1991)
$VARP\_SUN_{t}$	€	Expected variance of sunflower seeds' price
$VARP\_BEAN_{t}$	€	Expected variance of beans' prices

Continued

Variables definition and units
(i, farmer; t season), ***cont***

Abbreviated name	Unit	Description
$RAIN_{pt}$	mm	Total accumulated precipitation in season t, measured at provincial level.
SUB_YLD_{it}	€/Ha	Premium subsidies for farmer i buying yield insurance in year t
$SUB\_F\&H_{it}$	€/Ha	Premium subsidies for farmer i buying Fire and Hailstorm insurance in year t
RR_i	%	Risk rate evaluated by ENESA for each farmer included in the database, as a % of the capital insured.
DAND, DAR, DCM,DCL, DEX	0/1	Regional dummy for Region Andalucía, Aragón, Castilla-La Mancha, Castilla-León, and Extremadura respectively
D92, ..., D97	0/1	Year dummies for each seasons 1992,...,1997

1. Number 12.04 = *E*(Pct-Pct-1)
2. Similarly: -30.64=*E*(Pst-Pst-1)
3. And: -7.01=$E(P_{bt}-P_{bt-1})$

REFERENCES

Antle J.M.; 1987. "Econometric Estimation of Producers' Risk Attitudes" *Amer. J. Agr. Econ. 69 (August 1987.).*

Arrow K.J.; 1965. "Aspects of the Theory of Risk Bearing" - *Helsinki, Finland: Johnsonin Saatie.*

Arrow K.J.; 1971. "Essays in the Theory of Risk Bearing" - *Amsterdam: North Holland.*

Babcock B.A. and D.A. Hennessy; 1996. "Input Demand under Yield and Revenue Insurance." *Amer. J. Agr. Econ. 78 (May 1996): 416-427*.

Binswanger H.P., 1980. "Attitudes Towards Risk: Experimental Measurement in Rural India" *Amer.J. Agr. Econ. 62(August 1980): 395-407*.

Binswanger H.P.; 1981. "Attitudes Toward Risk: Theoretical Implications of an Experiment in Rural India" - *Econ. J. 91: 867-90*.

Burgaz Moreno, F.; 2002. "Algunos modelos de Sistemas de Seguros Agrarios". Presented at the International *Conference: Agricultural insurance and income guarantees*. Madrid, Spain, May 13th-14th.

Chavas J.-P. and M.T. Holt; 1990. "Acreage decisions under risk: The case of corn and soybeans" - *American Journal of Agricultural Economics 72 (August): 529-38*.

Coyle B.T.; 1999. "Risk Aversion and Yield Uncertainty in Duality Models of Production: A Mean-Variance Approach" - *Amer. J. Agr. Econ. 81 (August 1999): 553-567*.

Entidad Estatal de Seguros Agrarios (ENESA) ; Various years' reports. http://enesa.mapya.es/pls/enesa/pwe

Entidad Estatal de Seguros Agrarios (ENESA); 2003. Análisis de la aplicación del sistema de seguros en el sector de los Cereales de Invierno. Madrid.

Goodwin B.K.; 2001. "Problems with market insurance in agriculture" *American Journal of Agricultural Economics 83 (3): 643-649*.

Hamal K.B. and J.R. Anderson; 1982. "A Note on Decreasing Absolute Risk Aversion Among Farmers in Nepal" *Austral. J. Agr. Econ. 26 (December 1982):220-25*.

Horowitz J.K. and E. Lichtenberg; 1993. "Insurance, Moral Hazard, and Chemical Use in Agriculture" - *Amer. J. Agr. Econ. 75(November 1993):926-35*.

Keeton K. *et al*.; 2000. "The Potential Influence of Risk Management Programs on Cropping Decisions at the Extensive Margin" - *unpublished manuscript*.

Little I.M.D. and J.A. Mirrlees; 1974. "Project Appraisal and Planning for Developing Countries" *London: Heinemann.*

Makki S. and A. Somwaru; 2001. "Asymmetric Information in the Market for Yield and Revenue Insurance Products" *Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin Number 1892*.

Myers R.J.; 1989. "Econometric Testing for Risk Averse Behavior in Agriculture" *Appl. Econ. 21 (April 1989).*

Nicholson W.; 1997. "Teoría Microeconómica: Principios básicos y aplicaciones." *McGraw-Hill.*

Saha A. *et al*.; 1994. "Joint Estimation of Risk Preference Structure and Technology Using Expo-Power Utility" *Amer. J. Agr. Econ. 76 (May 1994): 173-184*.

Smith V.H. and B.K. Goodwin.; 1996. "Crop Insurance, Moral Hazard and Agricultural Chemical Use" *Amer. J. Agr. Econ. 78 (2), pp. 428-38*.

Wu J.; 1999. "Crop Insurance, Acreage Decisions and Nonpoint-Source Pollution" *Amer. J. Agr. Econ. (May 1999)*

Wu J. and R.M. Adams; 2001. "Production Risk, Acreage Decisions and Implications for Revenue Insurance Programs" - *Canadian Journal of Agricultural Economics 49: 19-35*.

Young C.E. and M. Vandeveer; 2000. "Measuring Market Distortions of Crop Insurance Subsidies" *Presentations given in organized symposium. 2000 AAEA Meetings, Tampa, Florida.*