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Crop Insurance and pesticide use in French agriculture: an empirical analysis

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Abstract – *This paper investigates the factors affecting the demand for crop–hail insurance and explores the potential relation with pesticide use for a sample of French farmers on the period 1993-2004, for the Meuse department. An econometric model involving two simultaneous equations with mixed censored/continuous dependent variables is estimated. Estimation results show that, in the case of rapeseed, insurance demand is significantly and positively related to pesticide use, but that the magnitude of this interaction is quite small. Insurance demand is positively influenced by the coefficient of variation of yield and the loss ratio, and is negatively influenced by Common Agricultural Policy subsidies and diversification of activity at farm level. These results shed light on the determinants of French farmers' decisions related to risk management.*

Keywords: *crop insurance, pesticide demand, risk management, France*

Assurance récolte et utilisation de pesticides dans l'agriculture en France: une analyse empirique

Résumé – Nous étudions dans cet article les déterminants de la demande d'assurance récolte contre la grêle et ses potentielles interactions avec l'utilisation des pesticides pour un échantillon d'exploitations agricoles françaises sur la période 1993-2004, pour le département de la Meuse. Nous estimons un modèle économétrique correspondant à un système de deux équations simultanées où les variables indépendantes sont mixtes (censurée/continue). Les résultats des estimations montrent que, dans le cas du colza, la demande d'assurance est significativement et positivement associée à l'utilisation de pesticides, bien que l'ampleur de cette relation soit faible. La demande d'assurance est influencée positivement par le coefficient de variation du rendement et le loss ratio, et négativement par les aides de la Politique Agricole Commune et la diversification des activités. Ces résultats fournissent un éclairage sur les déterminants des décisions des agriculteurs français liées à la gestion du risque.

Mots-clés : Assurance récolte, pesticides, gestion des risques, France

JEL classification: Q15, Q24, Q22, Q33, C34

1. Introduction

Risk management has always been a prominent issue in agricultural policy, and a major aspect of agricultural production activities and their importance in adaptations related to climate change. Agricultural producers are exposed to a large set of risks such as price, climate, pests and diseases, which makes their profits particularly risky compared to profits in other sectors (World Bank, 2005a, b). Producers' risk aversion due to limited ownership diversification and/or agency conflicts, constitutes a rationale for managing these multiple risks. Risk management by agricultural producers involves a large set of technical and financial decisions (Chavas, 2004): choice of techniques such as crop diversification, selection of more robust varieties, and use of risk-reducing inputs (pesticides, irrigation water). When available, financial instruments such as futures markets, production insurance contracts, and precautionary savings can be used in combination with technical choices, to share the risks among farmers and with other agents in the economy. In recent years, agricultural risk management has become a key part of agricultural policy reforms. The context has indeed changed quite dramatically. Price support policies[1], which as well as income support provide an economic safety net to farmers, tend to disappear under the pressure of world trade liberalization and environmental concerns, highlighting the issue of price risk management in a liberalized world (World Bank, 2005a). At the same time, a substantial number of production risks due to climatic and phytosanitary hazards remain uninsurable without government support for crop insurance (World Bank, 2005b). The importance of climatic and phytosanitary risks in addition to price volatility call for the development of risk sharing/transfer instruments alongside appropriate policies.

In most countries (*e.g.* the US, France and Spain), crop insurance systems involve some form of government intervention, and often government support for example through premium subsidies or reinsurance of last resort. The usual arguments put forward for risk policies in agriculture rely on the incompleteness of contingent claims markets which makes competitive markets inefficient in the short term. In certain circumstances, this inefficiency provides a theoretical argument for second-best Pareto improving government interventions that mimic the absence of contingent claims markets, and restore correct price incentives (Newbery and Stiglitz, 1981; Innes, 1990). In the long term, incomplete insurance and/or credit markets lead to too high, socially inefficient farm turnover, with some viable agricultural firms being artificially unable to survive temporary shocks (Kirwan, 2009). In spite of these well-founded theoretical justifications[2], there is no consensus on the true costs and benefits of real world government crop insurance programmes.

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[1] Through public storage in the European Union or Target Prices in the United States.

[2] Such normative result must be qualified. Indeed, the welfare gains, eventually losses, from risk policies have been shown to be highly sensitive to changes in parameters, especially supply and demand elasticities (Newbery and Stiglitz (1981), Innes (1990).

Firstly, crop insurance markets are often plagued by various kinds of market failures, making the distinction between welfare-enhancing and redistributive objectives particularly difficult. Secondly, it has been frequently pointed out that government risk management programmes (especially crop insurance) can have adverse environmental consequences based on the production incentives they create. In particular, they may incite farmers to produce more, on more degraded land, through use of higher levels of risk-increasing inputs such as fertilizers and shorter crop rotations, the crucial essentials addressed in the classical, price-support based, agricultural policies of the 1970s and 1980s. The European Union (EU) is highlighting weather risks in agriculture within a context of profound reforms to the Common Agricultural Policy (hereafter CAP). In the past, price risks were managed at EU level through guaranteed prices, while weather risks and crop insurance programmes, when they existed, were the responsibility of individual Member States. Guaranteed prices have decreased due to CAP reforms and have been replaced by decoupled agricultural subsidies to support farm revenues, with an *a priori* ambiguous impact in terms of farmers' risk exposure and risk aversion (potentially higher risk exposure due to less price protection, but less risk aversion due to the wealth effect arising from direct payments). This has led Member States to assess the possibility of an EU level crop insurance programme. In practice, each country develops its own national-scale agricultural insurance system, and there are similarities but also significant differences among countries. Enlarging the boundary of mutualization for risks considered systemic on a national scale probably makes economic sense, but at the lessons from costly US experience in this area are inducing prudence in policy makers.

Description of crop insurance programs in France

France has a specific agricultural insurance system to protect against climate risks. The French agriculture sector is characterized by production diversity at the national level, and high levels of regional specialization. Most French crop farms are specialized in a narrow set of crops. The main climate risks are frost, hail and drought. Frost and hail mostly threaten viniculture and arboriculture, while hail and drought are the main causes of non-perennial (mostly cereals) crop losses. Like other countries aiming at stabilizing farmers' revenues, France has adopted a specific agricultural insurance system against agricultural climate risks. This insurance system underwent reform in 2005; the old insurance system included the following elements. First, risks were classified into two categories: insurable and uninsurable. Insurable risks were covered by the private market with no (or very limited) government intervention; uninsurable risks were covered by a public guarantee fund, the *Fonds National de Garantie des Calamités Agricoles* (FNGCA), created by the 1964 law. Thus, private and public coverage coexisted, but did not compete. 'Insurability' criteria were not explicitly defined in the 1964 law, although it stated that the set of insurable risks would likely evolve if the private sector were able to develop its own supply. In this system, hail risk was

the main risk covered by the private insurance market. The demand for hail risk insurance has been quite significant between the 1970s and the late 1990s : the shares of agricultural land areas insured against hail risk over total agricultural land areas represented in 1997 almost 55% for wheat and other cereals, 48% for corn, 64% for rapeseed, with however significant variability between regions, with shares which represented up to 90% in the most specialized regions (Babusiaux, 2000). The public fund used to provide coverage against all other natural risks affecting agriculture that were considered as uninsurable, such as droughts or floods. The FNGCA profoundly differs from the private insurance market. First, it is not financed by actuarially fair premiums, but by a mix of a mandatory contribution in the form of farmers' property/liability insurance contracts, and a government subsidy, shared roughly equally. Thus, premiums are not risk based, and government participation implies a positive redistribution, on average, from the taxpayer to the farm sector. Second, indemnifications are upper-bounded by the amount available in the fund, and so are not contractually pre-specified as in the case of a typical insurance contract. Third, the fund pools several risks (drought, hail, *etc.*) for several products (wheat, maize, fruits, etc.) without the use of risk-based premiums, which is a source of cross-subsidization across farms with different specializations (*e.g.* between maize producers and wine producers). Drought and frost are the main risks covered by the fund, accounting respectively for 57% and 21% of expenses (Babusiaux, 2000). The system clearly has some advantages, notably fact that mandatory participation implies major pooling of diversified risks, but also defaults: the premium is not a function of the risk, which is a source of distortional choices, and levels of indemnifications are low even with the presence of a large amount of government subsidies. Hence, the paradox: if redistribution from the taxpayers to the farmers is positive in the mean, farmers may suffer from low levels of indemnifications (around 30% of expected losses are indemnified). Ultimately, if their risk preferences and opportunities to diversify risks differ, farmers are not free to choose between different levels of coverage.

Related literature

The factors affecting demand for crop insurance from farmers have been investigated in several empirical studies (Just, 2000; Just and Pope, 2003). Many of these studies examine the USA, where crop insurance programmes have been well developed for several decades, and constitute a substantial pillar of farm policy in that country. Similar studies of Europe include Garrido and Zilberman (2008) in the case of Spain and Finger and Lehmann (2012) for Swiss farmers. To our knowledge, the recent paper by Enjolras and Sentis (2011), which investigates the factors affecting national demand for insurance is the only study concerning France. The results from these different studies should be compared with caution, because the contexts differ in relation to farm systems (*e.g.* specialized versus diversified) and agricultural policies. However, all these studies show that the typical explanatory variables predicted by

microeconomic theory influence the demand for insurance: that is, the size of the risk, the cost of insurance, the farm's financial ratios (an imperfect measure of liquidity constraints), wealth, and land ownership, mostly are statistically significant. The set of significant factors as well as their relative importance can differ between studies. Also, some papers point to the role of public support and asymmetric information incentives, notably in the US case where insurance premiums are subsidized (Just et al., 1999). When such public supports represent a significant part of the insurance premium, it can become difficult to insulate and quantify the influence of the traditional factors affecting the demand for insurance. In addition to studying the factors affecting the demand for insurance, a large subset of these papers also investigates the relation between insurance and production choices, in order to shed some light on the possible distorting production effects of crop insurance programmes. In this context, the literature suggests that crop insurance and production decisions are generally endogenously determined by farmers, which in turn suggests some substitutability or complementarity between risk management instruments. In this vein, Horowitz and Lichtenberg (1993) show that crop insurance has encouraged pesticide and fertilizer input use among corn producers in the US Midwest. In contrast, the estimations by Smith and Baquet (1996) show that fertilizer and pesticide inputs made by Kansas wheat producers tend to be negatively correlated with insurance purchases. Wu (1999) extends the analysis to the acreage decision as a risk diversification tool. In his estimation of the effect of crop insurance on crop acreage allocations and pesticide use in the Central Nebraska Basins, he shows that crop insurance participation encourages producers to switch to crops with higher economic value. Also, Goodwin *et al.* (2004) study the acreage effects of crop insurance using the examples of corn and soybean production in the US Corn Belt, and wheat and barley production in the Northern Great Plains. They estimate a simultaneous equation model that takes account of a larger set of endogenous risk decisions of agricultural producers to simulate the possible effects of large premium changes. Their results suggest a relatively modest acreage response to expanded insurance subsidies. In sum, results on the relationships between insurance, input uses and crop acreages are contrasting. These differences may come from the variety of methodological approaches, different sets of explanatory variables considered, and heterogeneity of regional contexts, but the relative importance of these different causes is not easy to determine.

The objective of the present paper is to investigate the factors affecting demand for private hail insurance from farmers in France, and to explore its potential relation with pesticide use. Farms are heterogeneous in terms of their exposure to climatic risks, the financial situation, economic size, and the possibility to diversify risks through an appropriate combination of techniques (risk-reducing inputs, crop diversification, activity diversification, *etc.*). Hence, the motivations for buying crop insurance, and the value added of insurance contracts may differ widely between farms. This can have important implications for assessments of crop insurance policies such as crop insurance

subsidies, and their environmental impacts through pesticide use. We use an individual panel data set of French farms from the Meuse, covering the period 1993 to 2004.

The paper contributes to the literature in four ways. First, instead of relying on aggregated time-series or cross-section data like most previous studies, we use farm-level data which we expect will provide more precise description of individual decisions. Second, we use panel data, which allows us to capture individual farmer effects and to follow the evolution of farmers' choices over a long period of time. By taking account of inter-individual differences and intra-individual dynamics panel data provide several advantages over cross-sectional or time-series data. In our case, the two most important advantages are more accurate inferences of the model parameters and those two advantages control the impact of individual farmer's heterogeneity. Third, we consider the level of insurance coverage; most existing studies focus only on the decision to purchase insurance by considering the demand for insurance as a binary variable identifying whether the farmer participates or not Horowitz and Lichtenberg (1993); Smith and Baquet (1996); Wu (1999). Fourth, this paper contributes to the growing literature on farmers' risk management choices in the case of France and other European countries (Garrido and Zilberman, 2008; Koundouri *et al.*, 2009; Enjolras and Sentis, 2011; Finger and Lehmann, 2012).

The paper is organized as follows. In Section 2 we present the empirical model followed by a description of the data. In Section 3 we present and discuss our estimation results. We conclude in Section 4 with a summary of our results and research perspectives.

2. Empirical model and data

2.1. General background

We first describe hail insurance contracts then present the set of hypotheses we want to test in light of the main results in the microeconomics literature on insurance. We focus on two typical risk management instruments available to farmers[3]: hail insurance and pesticides.

Description of hail insurance contracts

Our dataset covers the period 1993 to 2004, during which French crop insurance contracts were mainly designed to protect against hail risk. We

[3] There is an absent risk management tool in our analysis. Because of unavailable data, price hedging decisions on futures markets have not been taken into account in the analysis. Since what matters to producers is income risk, and price risk is certainly not less important than production risk, incorporating price hedging into the set of risk management tools could have enriched the analysis.

chose to focus on a single crop, rapeseed, in order to simplify the analysis. According to the Babusiaux report (Babusiaux, 2000), the ratio of insured areas to cultivated area for this crop have been fairly stable in France since 1970: 63% in 1971, 62% in 1980 and 64% in 1997. The crop ratio has always been higher for rapeseed than other crops such as wheat (55% in 1997) and corn (48% in 1997). The report also mentions that the ratio of insured areas can vary significantly across regions, reaching up to 90% in some cases. In the early 1990s, a sequence of hail events lead to an increase in insurance premiums and deductibles and an associated overall reduction in hail insurance, which was stabilized by the end of the 1990s. Hail insurance contracts for rapeseed include the following elements. Indemnities are provided if the final yield is below a certain threshold value, freely chosen by the producer as a fraction of his/her reference yield. The reference yield is calculated as the mean of the five preceding years, leaving aside the highest and lowest values. When no yield data are available for an individual producer (*e.g.* if cultivation of the crop is new), the mean yield for the Meuse *département* is used as a proxy. Some standardized values of deductibles are proposed, typically 5%, 10% and 15% of the reference yields for cereals such as wheat and maize, and 10% and 15% for rapeseed. In addition to choosing their deductibles, producers can select the price at which they will be indemnified, up to a maximum value set by the insurer. The insurer provides information on forecast prices to help farmers make their choice. In the case of a yield loss, indemnification is based on plot size, not total farm output for the given product. Thus, if total farm yield *per* acre is higher than the yield level that would trigger an indemnification, but lower *per* a given plot, the indemnification will apply to that plot. In order to control for potential moral hazard problems, audits are conducted to confirm that appropriate agricultural practices are being followed, in particular, use of phytosanitary products.

Insights from microeconomic theory

According to microeconomic theory, the factors that affect demand for insurance are the coefficient of the farmer's risk aversion, the cost of insurance, and the characteristics of the insured risk, such as risk size and other of the characteristics in the risk probability distribution (Henriet and Rochet, 1991; Alarie *et al.*, 1991). The demand for insurance for a given crop can also be affected by the presence of substitutes for insurance, such as prevention techniques, and diversification of crops and activities. Typically, the optimal insurance coverage increases with risk aversion and risk size, and decreases with the cost of insurance. Under the reasonable assumption of decreasing absolute risk aversion (DARA), risk aversion decreases with farmers' wealth, as does the optimal insurance coverage. If wealth increases with farm size, the wealth effect will predict a negative influence on the demand for insurance. However, there is another possible effect, not related to risk: that is, that the commercial efforts of insurance companies will be concentrated on the biggest farms, which would lead to a positive relationship between farm size and the

demand for insurance. Diversification of crops and activities can also reduce the demand for insurance by acting as a substitute for insurance contracts to reduce income risk. Ultimately, what matters to the farmer is the aggregate income risk arising from the combination of activities, farm management practices and financial choices (Mahul and Wright, 2003). These standard predictions from microeconomic theory are not specific, but apply also to crop insurance contracts.

In addition to the factors that influence insurance decisions, we focused our interest in the relationship between risk and input use, in our case pesticide use. The available theoretical predictions on this point are less obvious. The underlying economic mechanisms at this stage in these interactions may differ depending on the theoretical framework considered. As discussed in the literature review, empirical studies of these interactions do not provide clear evidence. Clearly, hail insurance and pesticide use do not target the same risk, but instead are two risks that can be considered statistically independent, that is, hail risk and pest risk. This does not mean than we cannot expect a relationship between demand for insurance and pesticide use. Considering the specific context of our study, we can identify two ways to analyse the interdependence between insurance and pesticide decisions which relate to statistically independent risks. Firstly, since pesticides are considered to be a risk-reducing input, there may be a positive link between insurance and pesticide due to risk aversion. More risk-averse are the farmers, more insurance they will buy and also more pesticides they will use, because both reduce risk. Secondly, there might be a size effect: it is generally recognized that pesticides not only reduce risk, but also increase expected production, thus increasing exposure to the second, multiplicative risk. Intuitively, producers with higher expected production will tend to buy more insurance because the expected value of the output, and so the potential loss, is higher. In other words, pesticides reduce pest risk, but increase exposure to other independent risks by increasing the expected yield exposed to these risks. This suggests some interesting interactions between demand for hail insurance and pesticide use. Hence we propose the following hypotheses derived from microeconomic theory:

In the next section we estimate the reduced form relationship between demand for insurance and pesticide use, in an econometric model involving simultaneous equations.

Hypothesis	The tested effect on insurance demand
H1 :	The demand for insurance increases with the size of the risk(s).
H2 :	The demand for insurance decreases with the cost of insurance.
H3 :	The demand for insurance decreases with farm's wealth.
H4 :	The demand for insurance decreases with income diversification
H5 :	The demand for insurance is influenced by farm's financial characteristics.
H6 :	The demand for insurance is influenced by farm size.
H7 :	There is a potential relation between demand for insurance and pesticide use.

2.2. Empirical model

Our econometric model examines hail insurance and pesticide use decisions. Our data set does not include actual insurance coverage, but includes the insurance expenses for each crop. In the literature, the demand for insurance is usually represented by a binary variable identifying whether the farmer participates or not (Horowitz and Lichtenberg, 1993; Smith and Baquet, 1996; Wu, 1999). This is a limitation, because the focus is on the decision about insurance purchase and does not take account of the level of coverage. Despite missing data, we choose to approximate the demand for insurance by the premium *per* unit area divided by the mean yield *per* unit area. Normalization by the product of the mean allows us to eliminate mechanical increases in premiums deriving from an increase in the value of the insured output in the case of a linear transaction cost function. Following the empirical literature, we consider that the farmers' crop insurance and pesticide input use decisions are made simultaneously. Our econometric model thus corresponds to two simultaneous equations with mixed censored/continuous dependent variables and panel data. The simultaneous equation system can be written as follows:

$$\mathrm{I}^*_{\mathrm{it}} = \mathrm{X}'_{1\mathrm{it}}\beta_1 + \mathrm{P}_{\mathrm{it}}{}'\gamma_1 + \mathrm{w}_{1\mathrm{it}}, \tag{1}$$

$$\mathrm{P}_{\mathrm{it}} = \mathrm{X}'_{2\mathrm{it}}\beta_2 + \mathrm{I}^*_{\mathrm{it}}\,\gamma_2 + \mathrm{w}_{2\mathrm{it}} \tag{2}$$

and the observed counterpart is:

$$I_{it} = \begin{cases} I^*_{it} & \text{if } I^*_{it} > 0, \\ 0 & \text{otherwise.} \end{cases}$$

where I^*_{it} is the latent variable for the farmer's i insurance demand at time t, I_{it} is the observed demand insurance for the farmer i, P_{it} is the pesticide input demand of farm i at time t, X'_{1it} and X'_{2it} are vectors of explanatory variables, β_1, γ_1, γ_2, β_2 are the parameters to be estimated,w_{1it} and w_{2it} are the error terms, $i = 1, ..., N$ indexes the farmers and $t = 1, ..., T$ indexes time period of observation. The error term w_{mit} $(m = 1, 2)$ is decomposed as

$$w_{mit} = \mu_{mi} + \varepsilon_{mit}; \qquad m = 1; 2; \quad i = 1, N; \quad t = 1, ::: \mathrm{T}; \tag{3}$$

where μ_{mi} is the individual effect for the farm i and the variable of decision m and ε_{mit} is an i.i.d. error term for equation m.

We make the following distributional assumptions:

$$\mu_{mi} \to N(0, \sigma^2_{\mu_m}), \quad \varepsilon_{mit} \to N(0, \sigma^2_{\varepsilon_m}), \quad E(\mu_{mi}\varepsilon_{mit}) = 0,$$

$$\text{for all} \quad m = 1, 2, ..., M$$

with

$$E(\mu_{mi}\mu_{kj}) = \begin{cases} \sigma_{\mu_{mk}} & \text{if} \quad i = j, \\ 0 & \text{otherwise,} \end{cases}$$

$$E(\varepsilon_{mit}\varepsilon_{kjs}) = \begin{cases} \sigma_{\varepsilon_{mk}} & \text{if} \quad i = j \quad \text{and} \quad t = s, \\ 0 & \text{otherwise,} \end{cases}$$

for all $m, k = 1, 2, i, j = 1, ...N$, and $t, s = 1, ...T$.

The model (1-2) has a mixed structure since it includes both a latent variable and its dichotomous realization. Models with a mixed structure need, however, to verify the logical consistency conditions, that do not necessarily have a clear economic interpretation (see Maddala, (1983), Section 5.7). In our case, the conditions reduce to $\gamma_1\gamma_2 = 0$. Then, naturally impose $\gamma_2 = 0$ because the objective here is to study the effect of pesticide use on hail insurance demand.

Procedures for estimating simultaneous equation models in which one or more equations contain limited dependent variables were developed by Amemiya (1974), Amemiya (1979) and Nelson and Olson (1978). Nelson and Olson (1978) propose a simple two-stage estimation procedure in which the endogenous variables are replaced by predicted values obtained in the first stage of a regression upon an instrumented set. This two-step procedure has the advantage of yielding consistent estimates of the model coefficients. However Amemiya (1979) shows that this two-step procedure misrepresents the true variances of the parameters. Bootstrapping methods are proposed in the literature to provide more consistent estimates of the parameters of the matrix of variance-covariance.

Following the literature, we estimate our model using a two-stage procedure (Maddala, 1983)[4]. In order to obtain consistent estimates of the parameters of the variance-covariance matrices we use bootstrap methods proposed by Efron (1979) and Efron (1987). The bootstrapping approach consists of drawing with replacement a large number of pseudo-samples of size N (which corresponds to the number of observations in the observed data). The two-step procedure is applied to each sample in order to generate a distribution of consistently estimated parameters. This approach provides consistent variance-covariance parameter estimates that are robust to heteroscedasticity.

[4] Our model corresponds to the model 2 in Maddala (1983).

Since our sample consists of panel data, we have to choose between a random effects (RE) and a fixed effects specification. We decided to us a RE model because the fixed effects specification suffers from the problem of incidental parameters[5]. In the case of a Tobit model, Greene (2004) shows that the incidental parameters problem causes a downward bias in the estimated standard deviations in the Tobit model specification. This could lead to erroneous conclusions concerning the statistical significance of the variables used in the regressions.

The first step in the two-stage procedure consists in estimating the reduced form of the system (1-2) which can be written as follows:

$$I_{it}^{*} = X_{it}' \Pi_1 + \xi_{1it}, \tag{4}$$

$$P_{it} = X_{it}' \Pi_2 + \xi_{2it}, \tag{5}$$

where X_{it}' includes all the exogenous variables in X_{1it}' and X_{2it}'. This first step of the procedure provides us with estimates of the parameters Π_1, Π_2 as well as the matrix of variance covariance of individual effects and iid error terms. In our case, we estimate the equation in (4) by a random effect Tobit model and the equation in (5) by ML-RE model. In the second step, we estimate the equation (1) by RE-Tobit after substituting $\widehat{P}_{it}$ for P_{it} and the equation (2) by RE-ML after substituting $\widehat{I}_{it}^{*}$ for I_{it}^{*}. This two-stage procedure gives consistent estimates of the model coefficients (Maddala 1983), but the estimates of variance of the coefficients may be inconsistent because predicted values of the endogenous variables are used in the second stage of the estimation procedure.

Marginal effects

Computation of elasticity measures requires calculation of marginal effects from the RE-Tobit model[6]. Given the censored nature of insurance demand equation different marginal effects can be computed for each explanatory variable. For each explanatory variable x_j, we calculated the three elasticities at the mean of the sample[7]:

[5] The incidental parameters problem of the maximum likelihood estimator in the presence of fixed effects (MLE/FE) was first analyzed by Neyman and Scott (1948) in the context of the linear regression model.

[6] As proposed by Wooldridge (2002) the marginal effects were estimated by making the normalization of the individual-specific effects such as E $(\mu) = 0$.

[7] see Greene (2008).

1. Conditional elasticity: which measures the elasticity of the expected insurance demand given that the farmer holds an insurance contract.

$$Ela_{conditional} = \frac{\partial \ln E(I \mid I >, x = \bar{x})}{\partial \ln x_j} = \beta_j \frac{x_j}{E(I \mid I >, x = \bar{x})} \tag{6}$$

2. Probability elasticity: which measures the elasticity of the probability that a farmer holds an insurance contract.

$$Ela_{proba} = \frac{\partial \ln Pr(I > 0 | x = \bar{x})}{\partial \ln x_j} = \frac{\partial Pr(I > 0 | x = \bar{x})}{\partial x_j} \frac{x_j}{Pr(I > 0)} \tag{7}$$

3. Unconditional elasticity: which measures the elasticity of the expected insurance demand

$$Ela_{unconditional} = \frac{\partial \ln E(I \mid x = \bar{x})}{\partial \ln x_j} = \beta_j$$

$$\times Pr(I > 0 \mid x = \bar{x}) \frac{x_j}{E(I \mid x = \bar{x})} \tag{8}$$

Since we have

$$E(I \mid x = \bar{x}) = Pr[I > 0 \mid x = \bar{x}] \times E[I \mid I > 0, x = \bar{x}], \tag{9}$$

we can easily show that for each explanatory variable, total elasticity is the sum of probability elasticity and conditional elasticity:

$$Ela_{unconditional} = Ela_{conditional} + Ela_{proba} \tag{10}$$

2.3. Data description

The study is conducted on a sample of French farmers from the Meuse *département*. Our data are provided by the Management Centre (*Centre de Gestion de la Meuse*). Agricultural land in the Meuse represents 54% of the department's overall area: 36% is arable land and the remaining 18% is grassland. Cereals and oil crops are the main agricultural products and account for 81% of the arable area. Our sample is an unbalanced panel observed between 1993 and 2004. An interesting feature of our database is that it contains detailed information on major inputs for each crop: fertilizers (nitrogen, phosphorous, potassium -NPK), pesticides (herbicides, fungicides,

insecticides, growth regulators) and insurance. The sampled farms mainly produce grain crops. The most frequent crop rotation observed in our sample includes wheat, barley and rapeseed. In this paper we focus on rapeseed because it is one of the riskiest crops - on one hand because of its high yield variability and on the other hand because of its sensitivity to climate hazards.

Table 1 shows that approximately 88% of the farmers in our sample have hail insurance contracts. This proportion was almost constant over the observation period 1993-2004, varying between a minimum of 81.9% in 1993 and a maximum of 91.25% in 2002.

Table 1. **Farms who hold a hail insurance contract**

Year	Total number of farmers	% of farmers who hold hail insurance contract
1993	442	81.90%
1994	432	83.56%
1995	450	85.33%
1996	451	85.36%
1997	483	87.78%
1998	489	88.34%
1999	487	90.14%
2000	481	89.39%
2001	459	89.10%
2002	446	91.25%
2003	392	89.79%
2004	161	89.44%
Total	5173	87.55%

Table 2 presents summary statistics showing that, on average, farmers with rapeseed hail insurance contracts receive lower CAP subsidies than farmers without hail insurance contracts. They are also more specialized in rapeseed production and have lower (relative to their total revenue) revenue from animal production.

2.3.1. Choice of explanatory variables

According to the literature, demand for crop insurance and risk-reducing inputs can be influenced by farm characteristics such as farm diversification, wealth and liquidity constraints. We construct some proxies for these variables as explanatory variables of insurance demand.

Diversification

The degree of farm diversification is expected to have a negative effect on insurance demand and pesticide use since it can be considered as risk management instrument and a substitute for insurance. We consider two forms of farm diversification: crop diversification, which refers to the classical

Table 2. **Descriptive statistics for the independent variables**

		Insurance=0	Insurance=1
Variable	**Definition**	**Mean (std. dev.)**	**Mean (std. dev.)**
premium	premium *per* unit area / mean yield	0	0.008
		(0)	(0.005)
pesticides	pesticide demand *per* ha	1.574	1.635
		(0.493)	(0.469)
CAP	CAP subsidies *per* ha	4.734	4.672
		(0.917)	(0.788)
share_anim	share of animal revenue	0.564	0.455
		(0.226)	(0.259)
share_rapeseed	share of rapeseed production	0.246	0.287
		(0.099)	(0.099)
loss_ratio	sum of indemnities / sum of premium	0.259	0.791
		(0.74)	(1.409)
debt_ratio	debts / assets	0.158	0.183
		(0.131)	(0.138)
land_rent	=1 if land renting	0.991	0.995
		(0.096)	(0.073)
farm_labor	percent of family labor	0.933	0.906
		(0.132)	(0.158)
CV	Coefficient of variation of rapeseed yield	0.399	0.275
		(0.457)	(0.278)
price_lag	log rapeseed lagged price	-3.166	-2.447
		(4.455)	(3.309)
area	Total farm area	165.931	197.643
		(76.455)	(99.797)

Data source: *Centre de Gestion de la Meuse.*

rotation choice, and activity diversification, which refers to the relative share of cropping activity in the overall sources of farm revenue, *i.e.* livestock in our sample. Several indices provide consistent measures of diversification degree, for example, the Herfindahl index and the Theil index of entropy. Computation of these indices reveals that they are highly correlated. Since we are investigating only two activities, relative shares in the farm's total output, although not a direct measure of diversification, constitute a simpler approach that relates to the composition of activities in the farm. Since we have only three crops and two activities (cropping and livestock), we thus consider as an explanatory variable the share of rapeseed in total crop production (*share_rapeseed*), and the share of livestock in total farm production (*share_anim*)[8].

[8] In terms of interpretation, it is important to recognize that these shares are related but not equivalent to diversification indices. The relation between a share and a diversification index is non-monotonic: a higher share of rapeseed when this share is already very small

Wealth

If farmers display absolute decreasing risk aversion, then wealthier farmers may perceive reduced need to insure. There is no consensus in the literature on building a proxy for wealth in similar studies (the farm's net present values, a size index such as land area). We include the following proxies: *Farm size.* Many studies include a measure of farm size to proxy for wealth. It also captures the effect of economies of scale on the demand for insurance. We include agricultural area (area) as an explanatory variable. *CAP income support*. Agricultural income support policies contribute a major part of farmers' revenues and, therefore, are a large component in farmers' wealth effect. We include CAP subsidies to proxy for farmers' wealth through the explanatory variable CAP.

Financial characteristics

The farm's financial characteristics, such as debt and liquidity constraints, are expected to strongly affect insurance and input choices through their impact on farmers' risk aversion. A firm which is more indebted, or have less liquidity may behave as if it was more risk averse, because the need for external financing following a crop loss due to a weather event could be more costly than relying internal financing. More liquidity constrained farmers will choose more insurance *ceteris paribus*. We built a debt ratio defined as ($debt_ratio = \frac{debt}{assets}$) which we expected to have a positive effect on insurance demand. For the same liquidity constraint reasons, farmers who rent land are expected to buy more insurance and use more pesticides because they are more leveraged (Wu, 1999). We thus include a rent index ($land_rent$) as explanatory variable of insurance demand.

Loss ratio

The demand for insurance is expected to depend on the expected return from the insurance (usually negative), which includes premiums and expected indemnities. To capture this factor, we use the individual farmer's loss ratio ($loss_ratio$), a variable that is equal to the total indemnities divided by the total insurance premiums for the available years. Since our panel is unbalanced, differences due to catastrophic events occurring in some years can be a source of bias for farmers (Goodwin, 1993). However, since excluding these years from our analysis would also create some bias and would weaken our analysis, we retained all the available years in our sample. Heterogeneity in loss ratios can be the result of asymmetric information if farmers are better informed than insurers about

means more diversification, while a higher share when this share is already high means less diversification.

the distribution of their yield risk. Goodwin (1993), Just *et al.* (1999), and more recently Goodwin *et al*. (2004) provide empirical evidence in the US agricultural context of the importance of this factor on the incentive to insure.

Yield variation

In order to capture the effect of crop risk on insurance and pesticides, we follow most of the literature[9] and include the individual coefficient of variation of yield (*CV*). Intuitively, a high coefficient of variation reflects higher exposure to crop risk and, thus, an incentive to take insurance.

Labour composition

Total labour includes hired labour and family labour. The composition of total labour is illustrative of the nature of the farm's management. We build an index, $farm_labour$, which is equal to the share of family labour in total farm labour (Wu, 1999).

Concerning the pesticide demand equation, we included an explanatory variable the log of rapeseed price as suggested by the microeconomic theory of production. We have used the lag of this variable to take into account the adaptative expectations assumption usually assumed in the literature. We have also included year dummies (ann3–ann11) in order to capture all the omitted variables which depend on time and which could affect pesticide demand, such as changing agricultural regulations or varying meteorological events.

3. Estimation results and discussion

Are insurance demand and pesticide use endogenous? The Durbin-Wu-Hausman test

To test the simultaneous equation specification adopted in our model, we performed a Durbin-Wu-Hausman[10] test for the hypothesis that: (1) crop insurance decisions are exogenous to pesticide use, and (2) pesticide use is exogenous to crop insurance decisions. The test results are presented in Table 3 and show that the exogeneity hypothesis is rejected for the variable pesticide input in the insurance demand equation and for the insurance demand in the pesticide input equation. These results suggest the existence of some unobservable factors that might influence both crop insurance demand and

[9] See for example Goodwin *et al*. (2004).

[10] The "Durbin-Wu-Hausman" (DWH) test is numerically equivalent to the standard "Hausman test" obtained in which both forms of the model must be estimated. Under the null hypothesis, it is distributed Chi-squared with m degrees of freedom, where m is the number of regressors specified as endogenous in the original instrumental variables regression.

Table 3. **Durbin-Wu-Hausman test results**

Null hypothesis	DWH statistic	DF	Test result
crop insurance demand is exogenous to pesticide use	14.05	7	Rejected at 5% level of confidence
pesticide use is exogenous to crop insurance demand	19.43	9	Rejected at 2% level of confidence

pesticide use. Therefore, we need to control for correlation between these unobservables and crop insurance demand and pesticide use, which is a strong motivation reason for our simultaneous equation model.

Model estimation

We estimate a simultaneous equation model of crop insurance demand and pesticide use for rapeseed using the two-stage procedure proposed by Nelson and Olson (1978) with a bootstrapping method to estimate consistent parameters of the variance-covariance matrices. Estimations are made on rapeseed only because this crop exhibits higher coefficients of variation than wheat or barley. Table 4 presents the estimation results. Inspection of these results shows the significant variances in individual RE, confirming the advantages of panel data and modelling individual effects. We conclude that the classical regression model with a single constant term is inappropriate, and that in the data there exists individual heterogeneity which is captured by individual RE.

Concerning the parameter estimates, a first important result is that the quantity of pesticides ($\widehat{pesticides}$) used by farmers increases with the demand for insurance (*premium*) and demand for insurance increases with pesticides. This is in line with the size effect interpretation described above: in contrast to previous empirical studies[11], hail insurance is not an alternative to pesticide use. While in the US, multi-peril crop insurance provides coverage against a variety of hazards including pest risks, hail insurance provides coverage only against hail risk. Although hail and pest risks are independent, the use of pesticides reduces the probability of pests and, thus, increases the

[11] As we have noted earlier, the empirical literature provided no consensus on the sign and magnitude of the effects of insurance on pesticide use. Horowitz and Lichtenberg (1993) results suggest that crop insurance has encouraged the chemical input use for corn producers in the U.S. Midwest. However, Smith and Goodwin (1996) demonstrated that fertilizer and chemical use for Kansas wheat producers tended to be negatively correlated with insurance purchases. Wu (1999) has focused on the effect of crop insurance on crop patterns and chemical use in Central Nebraska Basins. The results show that crop insurance participation encourages producers to switch the crops in higher economic values. Thus, the expected relationship between insurance participation and input use is unclear. The results of Goodwin *et al*. (2004) suggest a relatively modest acreage responses to the increases in crop insurance participation.

Table 4. **Rapeseed insurance demand**

	premium
pesticides	0.00344***
	(5.34)
CAP	-0.000211*
	(-2.04)
share_anim	-0.00312***
	(-4.13)
share_rapeseed	0.00218*
	(2.32)
loss_ratio	0.000664**
	(2.96)
debt_ratio	-0.000857
	(-0.93)
land_rent	0.00360***
	(3.67)
farm_labor	-0.000660
	(-1.31)
CV	0.00838***
	(6.49)
	-0.00348
_cons	(-1.74)
sigma_u	0.00811***
	(12.08)
sigma_e	0.00317***
	(22.85)
$(N \times T)$	5127

t statistics in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

expected yield given no occurrence of hail, but simultaneously increases the extent of the damage in the case of a hail event. This may explain why risk-averse farmers decide to complete their pesticide use by investment in a hail insurance contract. In this case, pesticide use and hail insurance are complementary risk management instruments for farmers exposed to both pest and hail risks.

Our estimation results for the effects of diversification on insurance demand are in line with our hypothesis. The variable *share_rapeseed*, which measures the share of rapeseed in total crop production, has a positive and significant effect on insurance demand. Similarly, the variable *share_anim*, which measures the share of livestock activities in the farm's revenue, has a negative and significant effect on insurance demand. Although these variables do not capture directly a diversification effect, these results taken together suggest that the composition of activities at the farm level plays a significant role in insurance demand. These results are more broadly related to the idea that activity diversification reduces risk aversion and, thus,

Table 5. **Rapeseed pesticide use**

	pesticides
premium	4.850*
	(2.00)
price_lag	0.0105***
	(5.27)
area	0.000445***
	(5.03)
ann3	-0.296***
	(-15.74)
ann4	-0.129***
	(-7.99)
ann5	0.0220
	(1.25)
ann6	-0.0638***
	(-4.07)
ann11	0.108***
	(4.55)
_cons	1.575***
	(66.19)
$(N \times T)$	5127

t statistics in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

farmers' demand for insurance. Wu (1999) and O'Donoghue *et al*. (2009) find a statistically significant negative effect of crop diversification on crop insurance demand. Goodwin (1993) finds no statistical negative relationship between the extent of diversification into livestock and the tendency to insure. The results for diversification should be interpreted with caution. For example, a negative correlation could be explained as a substitution effect amongst risk management tools, but a positive correlation, if it arises, could be explained by heterogeneity in farmers' risk aversion: *ceteris paribus*, more risk averse farmers will diversify more, buy more insurance, and use more risk-reducing inputs. Which of these effects dominates is likely to depend on the particular application and data set. As expected, CAP subsidies have a negative and significant effect on demand for insurance, which can be interpreted as a wealth effect. The effect of direct payments on farmers' risk preferences was estimated by Koundouri *et al*. (2009) using a structural model to estimate risk preferences and technology parameters simultaneously. They show that direct payments substantially decrease farmers' degree of risk aversion. Our estimation results show that a higher yield coefficient of variation of rapeseed (*CV*) appears to be positively and significantly correlated with higher demand for insurance. This positive relationship is in line with the intuition. However, the coefficient of variation in part is endogenous due to inputs use (in particular pesticides) and crop diversification. For example, more risk averse farmers might insure more

against hail risk while using more pesticides to reduce pest risk, resulting in a lower coefficient of variation of yield, and calling for more cautious interpretation. The parameter estimate of the composition of total labour ($farm_labour = family_labour/professional_labour$) has a negative sign, but is statistically insignificant at 10%. As expected, land ownership also affects farmers' insurance decisions ($land_rent$). Farmers who rent land tend to exhibit higher demand for insurance. Another result that is in line with our hypothesis is that a higher loss ratio is significantly and positively correlated with higher demand for insurance. As discussed in Goodwin *et al.* (2004), the fact that both higher loss ratios and higher yield coefficients of variation are positively correlated with insurance demand suggests that the cost of insurance and the size of the risk reduction do matter for the farmer's insurance decision. Finally, the parameter associated to the debt ratio ($debt_ratio$) is not significant.

Marginal effects

The elasticities $Ela_{unconditional}$, $Ela_{conditional}$ and Ela_{proba} (equations 6-8) are computed by the mean of all variables and are presented in Table 6.

Table 6. **Marginal effects: elasticities at the sample mean**

x_j	$\frac{\partial \ln E(I\|x=\bar{x})}{\partial \ln x_j}$	$\frac{\partial \ln E(I\|I>0,x=\bar{x})}{\partial \ln x_j}$	$\frac{\partial \ln P(I>0\|x=\bar{x})}{\partial \ln x_j}$
pesticides	0.056**	0.030**	0.026**
	(2.36)	(2.35)	(2.36)
CAP	-0.192***	-0.104***	-0.088***
	(-5.77)	(-5.76)	(-5.67)
share_anim	-0.161***	-0.087***	-0.074***
	(-4.40)	(-4.43)	(-4.32)
share_rapeseed	-0.023	-0.012	-0.010
	(-0.84)	(-0.84)	(-0.84)
loss_ratio	0.049***	0.026***	0.023***
	(3.75)	(3.76)	(3.71)
debt_ratio	0.004	0.002	0.002
	(0.35)	(0.35)	(0.35)
land_rent	0.305**	0.164**	0.140**
	(2.29)	(2.29)	(2.29)
fam_labor	-0.079	-0.043	-0.037
	(-1.49)	(-1.49)	(-1.49)
CV	0.255***	0.138***	0.117***
	(13.34)	(13.75)	(11.81)

t statistics in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

These elasticities are computed to obtain some insights into the magnitude of the relations among the variables. First, we note that the magnitude of the relation between insurance and pesticides is quite small:

the probability of buying insurance increases by 0.026% when pesticide use increases by 1%. Unconditional elasticity, which measure the elasticity of the expected insurance demand, is equal to 0.056 %. These figures should be interpreted with caution since they could be the result of several effects, some of them acting in opposite directions, such as heterogeneity in farmers' risk aversion (unobservable), size effect, background risk effect, *etc*. In addition, a low elasticity value might be explained by unobservable heterogeneity in pesticide productivity. As a consequence, predictions about the consequences of crop insurance reforms in France on pesticide use should take these limits into account. During the period 1993-2004, available private insurance contracts protected against hail risk only. Other production risks, such as drought, were managed through the public fund FNGCA. Expanding the number of risks insured by private insurance contracts would give farmers more freedom to choose their own combination of risk management tools at farm level. This might increase the magnitude of the relation between insurance demand and pesticides.

Concerning the factors affecting demand for insurance, these can be classified according to the value of their probability elasticity and unconditional elasticity. In decreasing order, we get (1) the rent index, (2) the coefficient of variation of yield, (3) CAP subsidy *per* ha, (4) the share of livestock in total farm production, and (5) the loss ratio. The values of the elasticities of the coefficient of yield variation (CV , 0.117 and 0.255) confirm the effect of farmers' heterogeneity in relation to risk exposure, on insurance demand. The other explanatory variables have some interesting consequences for agricultural policy. First, CAP subsidies (CAP) have a negative, but quite small impact on the probability to insure (-0.088), but a rather large impact on total insurance demand (-0.192). This suggests that the wealth effect due to farmers' income support plays a non-negligible role in reducing the consequences of income shocks due to weather events, which is in line with the findings in Finger and Lehmann (2012). If this income support was to decrease as a result of future CAP reforms, the farmers in our sample would be more likely to increase their demand for risk management tools such as insurance against weather events. The estimated elasticities of activity diversification ($share_anim$) are of the same order of magnitude as the CAP subsidies (-0.074 and -0.161), suggesting that income diversification is also a substantial substitute for crop insurance in our sample. Estimated elasticities of loss ratios ($loss_ratio$), considered as a proxy for the cost of insurance, are quite small (0.023 and 0.049 respectively). This suggests that a crop insurance policy based on premium subsidies should not lead to huge changes in the demand for insurance against hail risk. These results are in line with previous studies on the US where only high levels of premium subsidies increase the rate of penetration of insurance at the national level. Also, in many cases, in the US the expected indemnities are higher than the premiums, rendering insurance contracts valuable even for risk-neutral producers.

The situation in France is quite different; hail insurance is a 'mature' market with high rates of penetration and decades of existence without any government subsidy (the average loss ratio in our sample is 0.791). Hence, it is not so surprising that the impact of a change in the cost of insurance has only modest effects on insurance demand. Intuitively, this impact might be more substantial for multiple peril crop insurance contracts, introduced through a public-private partnership in France in 2005, since they provide coverage against an extended set of risks, some of which show strong spatial correlation, and hence demand higher premiums. From a theoretical perspective, the literature shows that a risk-averse individual[12] will always insure against a low probability-high loss event if he also buys insurance for any other risk with the same expected loss. This suggests that crop insurance contracts extended to low frequency risks (typically drought) will always be bought by farmers who already have hail insurance contracts, under identical transaction costs. However, there are several factors that might curb the demand for insurance for this extended set of risks. First, these risks might differ not only in their distribution but also in their transaction costs. Insurance premiums are more difficult to calculate for lower frequency risks, and spatial correlation as well as ambiguity may imply premium overloading by insurers. Second, there is substantial empirical evidence showing that individuals are in fact reluctant to buy insurance against low probability events, or even do not consider risks under a certain probability threshold. Third, the insurance decision requires processing of information and learning, so emerging insurance contracts may involve a time lag before adoption.

4. Conclusion

This paper investigated the determinants of hail insurance and pesticide use decisions using an individual panel dataset of French farms for the period 1993-2004. Statistical tests show that pesticide use and insurance demand are endogenous to each other. We estimated an econometric model involving two simultaneous equations with mixed censored/continuous dependent variables. The originalities of our study are: (1) considering individual farm-level data which provides a more precise description of individual decisions; (2) using panel data which allows us to capture individual farmer effects; (3) considering the level of insurance coverage which contrasts with most existing studies.

The results of our estimations are twofold. First, we find that insurance demand is positively correlated with pesticide use. However, the magnitude of this relation, measured by elasticity, is quite small. There are several possible explanations for this result: presence of countervailing incentive effects of insurance (risk reduction and moral hazard); ambiguous role of risk-decreasing

[12] In fact, any individual having preferences that display the second-order stochastic dominance property.

inputs on the variance of yield; and preponderance of the expected profit motive versus the risk-reducing motive in the farmer's pesticide use decision. From an environmental policy perspective, this suggests that reforms aimed at facilitating access to insurance against an expanded set of risks, or reducing the cost of insurance, may have positive but modest effects on pesticide use. In the case of monoperil, hail insurance contracts, moral hazard temptations concerning the use of pesticides may be easier to control than in the case of multiperil crop insurance contracts, for two reasons. For example, estimating the relative impact of pest and climate shocks on final yield may be more difficult if multiple climate shocks enter the insurance contract. Also, multiple peril insurance contracts, that increasing the number of risks covered might increase the correlation across individual claims and, thus, lower the probability of audit.

Second, the analysis of the explanatory factors of insurance demand confirm the theoretical predictions and have some interesting consequences for agricultural policy analysis. CAP subsidies have been shown to have a statistically significant and negative influence on insurance demand and, in turn, on pesticide use. This is in line with the assumption that farmers' preferences are characterized by decreasing absolute risk aversion, confirming the results of several other studies on France and other countries. From an agricultural policy perspective, this suggests that decreasing the CAP subsidy would increase farmers' propensities to pay for risk management instruments, underlying the need for an integrated approach to income support and risk management policies in this sector. Activity diversification has also a statistically significant and negative influence on insurance demand, which confirms the assumption that whole-farm diversification is a substitute for insurance and risk-reducing inputs. More surprising is that crop diversification is not statistically significant. This result might be due to the fact that, in our case, crop diversification might be justified more by agronomic reasons than by a risk-diversification targeting strategy. This raises some interesting questions related to environmental policy in the agricultural sector. Our results show that farmers with riskier yields tend to buy more insurance, which is in line with the theoretical predictions. The loss ratio has a significant but smaller magnitude effect on insurance demand, suggesting low price elasticity of demand for insurance. Thus, crop insurance premium subsidies might have only a small impact on insurance demand. However, it should be noted that the insurance contracts analysed in the present study are not the same as those actually subsidized in France which cover multiple risks. Finally, we showed that financial ratios are not statistically significant, suggesting that the financial characteristics of the farm play a quite limited role in insurance demand in our sample.

In this paper, we estimated a reduced form model which has the advantage of keeping the analysis relatively simple. However, it would be interesting to build a structural model that would allow joint estimation of technology and

preferences. This would require a more thorough theoretical analysis of the joint demand for insurance and pesticides with two independent risks.

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