WEATHER INSURANCE OF WINE
HOW QUANTITY AND QUALITY REGULATIONS AFFECT RISKS

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Abstract

To develop weather insurance, GROUPAMA builds a general model of agronomic crop yield density function. This approach is applied for cereal, industrial products, wine and fruits. From the density function, weather risk premium is computed. The wine-producing practices disturb our approach of risks. First, wine yields are limited by public regulations. Second, some cooperatives applied quality regulations. Then, observed crop yields are not agronomic crop yields needed by the model.

The paper proposes a simulation process to estimate the agronomic parameters of areas crop yields from observed crop yields data. This process is tested on Champagne wine historical data. We measure too the impact of the quantity rules on our estimation of premium. Next, the paper analyses impact on quality on the idiosyncratic risk and on the premium.

It results that agronomic parameters give cheaper premium estimation. Because rigorous growing process is implemented, include quality risk is not systemically more expensive but need to compute an individual analyse.

Keywords:

Weather Insurance, Wine, Quality Insurance, Regulations impacts on Risks

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1   Introduction

To develop weather insurance, GROUPAMA[1] builds a general model of agronomic crop yield density function. This approach is applied for cereal, industrial products, wine and fruits. Model parameters are estimated from historical areas crop yields data. The model integrates trend, mean and standard deviation. Some assumptions by culture let us define an individual crop yield density function. From this individual crop yield density function, weather risk premium is computed.

The wine-producing of "High Quality Wine" (noted AOC or VDQS in French) practices disturb our approach of risks. First, wine yields are limited by public regulations. Second, some cooperatives applied quality regulations according to sugar density, quality control or impurities content. Then, cooperatives calculate an equivalent yield of wine. Quality losses are often due to weather random, GROUPAMA has to include also the notion of 'equivalent crop yield' in the model.

Then, observed crop yields are not agronomic crop yields needed by the model and the questions are: How to include quantity and quality regulations in the model? What are regulations impacts on the premiums?

2   Context

Agricultural insurance is a major subject of agricultural politics and of agricultural economic sciences. In France, the last public agricultural report largely deals with insurance (MORTEMOUSSE D., 2007). Large literature exists on revenue, crop or weather insurance. For example, TURVEY, WEERSINK, and CHIANG (2006) deal with the ice-wine harvest insurance in the Ontario, US. They propose a contract based on the number of hour where temperature is between -8°C and -12°C during the winter harvest season. GROUPAMA, the first French agricultural insurer, aspires to be an active participant in the farm risk protection development.

The wine sector is worth specific developments. First, French wine harvest represents 5,396 billion of litres in 2006, a significant part of French agriculture. Second, wine producers suffer from an international slump. In fact, French people consumed 104 litres of wine per year in 1975 and only 54 litres in 2005. Considered in the past as a food, wine is today a pleasure. Moreover, wineries and distribution industries answer to demand but French farms carry often on the past flavour. Farms are now more sensible to risks and then, need protection from this insurer. The wine industry was mobilising (see for example CESAR *et al* 2005 ; AMORIM,2005). Third and at last, quantity and quality regulations affect risks model and the measure of premium. In fact, public and private rules disturb the data. For example in 1995, the 'Champagne' agronomic yield was estimated at 14 500 kg/ha even else the maximum yield was 11 000 and the observed yield was 10986 (from professional sources).

The model framework could be declined in two parts. On the one hand, the areas crop yield density gets on literature. On the other hand, we present GROUPAMA approach because this study adds up a previous work of GROUPAMA which restricts model choices.

As shown in literature, normal density function does not suit for areas crop yields density function (RAMIREZ *et al*, 2003). Even if right skewness crop density exists, authors present the

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1 Model was developed by the Actuary Service of GROUPAMA SA, 2003.

case of Texas cotton, we observe generally a left skewness (Soybean and corn was analysed in this paper). We found in literature other adapted density functions. For example, Nelson and Preckel prefer beta density function. Ramirez *et al* (1997) argues that the inverse sinus hyperbolic density function better suits.

Figure 1: Illustration of the general crop yield density function.
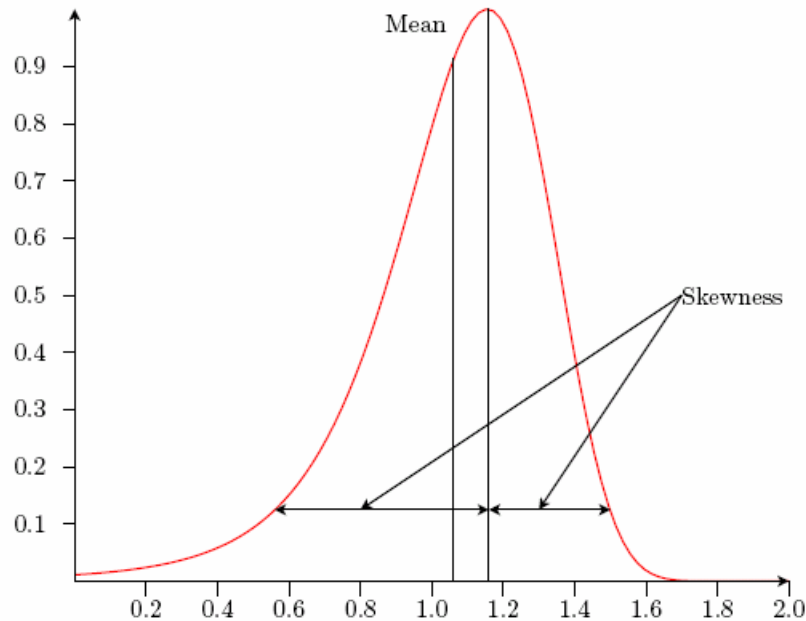
Source: Own representation.

In 2000, the Babusiaux Public Report offered a framework to the crop yield Insurance in France. The state subsidies 35 % of the (25% deductible) premium contract which cover the crop yield loss consecutively to weather random. Price risk is not including.
Then, GROUPAMA had to estimate the risk premium for 60 cultures in 96 countries (department). GROUPAMA insurance contract could be describe as following:

$$I_{i,t} = Max(0, \bar{y}_{i,t} \times (1-D) - y_{i,t})$$

where *I* represents the indemnity, *D* the deductible in % and $\bar{y}_{i,t}$ the expected crop yield.

According the literature model and observed data, GROUPAMA develop his own model of agronomic crop yield density function (see too Odjo H. and V. Ritz, 2006). It uses a function ℓ such as ℓ^{-1} is known and $\ell(y)$ could be described by lognormal density. This density function is illustrated in Figure 1. Algebraic premium estimation could be deduced from our assumptions.

This paper targets to improve the GROUPAMA's model in the wine producer's case, not to revisit it.

3 Preliminaries Calculus: the idiosyncratic risk component

Idiosyncratic risk is the contribution of the farm in risk. This component of risk could be pooled *in contrario* of the systemic risk. As explain by RAMASWANI *et al* (2003), two usual approaches let to include idiosyncratic risk component: the additive approach or the multiplicative approach. Authors confirm that classification of risk as either systemic or no systemic changes with the area size used for computing area yield. For example, MAHUL and WRIGHT (2003) or NELSON and PRECKEL (1989) use the additive approach: [2]

$$y_{i,t} = \phi_i + \beta_i \times y_{a,t} + \varepsilon_{i,t} \text{ where } \beta_i = \frac{E[y_i] - \phi_i}{E[y_a]} \text{ under the constrains } E[\varepsilon_{i,t}] = 0 \text{ and}$$

$$y_{i,t} \geq 0. \tag{1}$$

The multiplicative approach considers $\xi_{i,t}$ as:

$$y_{i,t} = \xi_{i,t} \times y_{a,t} \text{ where } E[\xi_{i,t}] = \frac{E[y_i]}{E[y_a]} \text{ because of the independence between } \xi_{i,t} \text{ and } y_{a,t} \tag{2}$$

Authors conclude: "The literature assumes the Linear Additive Model. […] The Linear Additive Model decomposes individual producer yield into a systemic component due to area yield variation and to an independent additive producer specific component. While previous work has established the convenience for analysing area yield insurance [performance to reduce farm's risk], its theoretical justification has be neglected. In spite of its likeness of the CAPM model of finance, the Linear Additive Model cannot be validated in a similar manner."

Here, the second approach is preferred because:
1) It is an implicit assumption in previous work of GROUPAMA.
2) The multiplicative approach is easier and more logical when lognormal distribution is used.
3) Data confirms that approach suits (see quality analyze in section 5).

Then, from equation 2, we propose the following relation between $y_{i,t}$, $y_{a,t}$ and $\xi_{i,t}$:

$$\ell(y_{i,t}) = \xi_{i,t} \times \frac{E(\ell(y_a))}{E(\ell(y_i))} \times \ell(y_{a,t}), \text{ with } E(\xi_{i,t}) = 1 \tag{3}$$

Where the coefficient $\dfrac{E(\ell(y_a))}{E(\ell(y_i))}$ is introduced to obtain the standardized individual random value $\xi_{i,t}$.

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[2] Please notes the following notations: subscript *t* for the time, subscript *i* for the individual farmers, subscript *a* for the areas.

4   Quantity rules impacts on wine crop yield risk

4.1   Methodology to approach the agronomic crop yield

This paper aims to define the more adapted model parameters in the case of wine quantity regulations. As illustrate in Figure 2, the wine crop limit change the crop yield density function. Usual parameterization of the agronomic density does not suit and then, agronomic parameters are unknown. Limit changes each year and is noted $y_{M,t}$. If we note $\hat{y}_{i,t}$ the agronomic crop yield, we have $y_{i,t} = Min(y_{M,t}, \hat{y}_{i,t})$.

Figure 2:   Illustration of the individual wine yield density function.
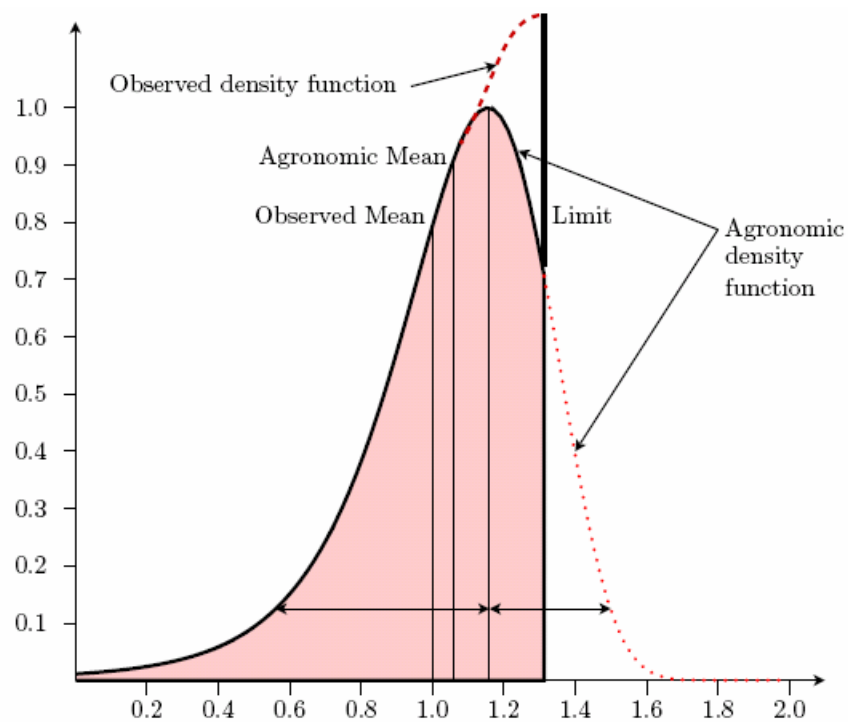
Source: Own representation.

Figure 3:   Relation between agronomic and observed wine crop yields

$$y_{a,t} \longleftarrow \left(\sum_i^n surf_i \times y_{i,t} \right) \Big/ \left(\sum_i^n surf_i \right) \qquad y_{i,t}$$

$$y_{i,t} = Min(y_{M,t}, \hat{y}_{i,t})$$

$$\xi_{i,t} \quad \text{GROUPAMA assumptions}$$

$$\hat{y}_{a,t} \longrightarrow \qquad \hat{y}_{i,t}$$

$$\longleftarrow \left(\sum_i^n surf_i \times \hat{y}_{i,t} \right) \Big/ \left(\sum_i^n surf_i \right)$$
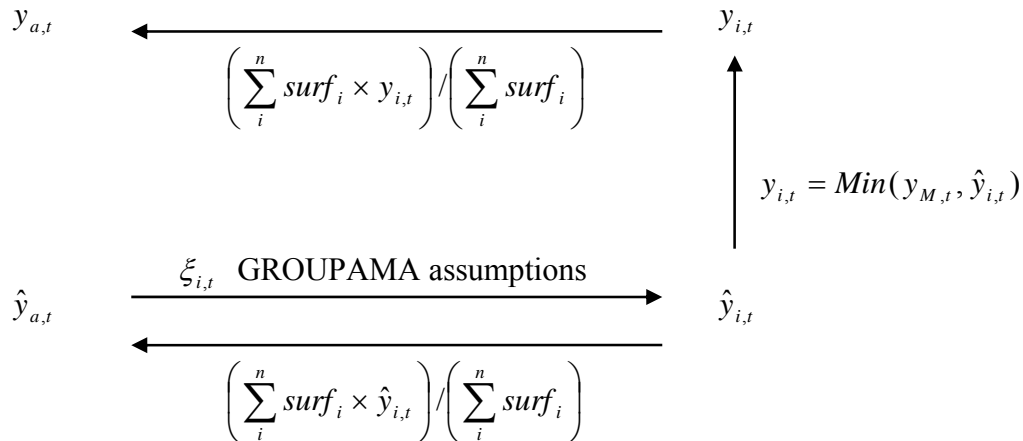
Source: Own representation.

As illustrate in Figure 3, a simple relation exist from $\hat{y}_{i,t}$ to $y_{i,t}$, but not from $y_{i,t}$ to $\hat{y}_{i,t}$. Therefore, with GROUPAMA assumptions, a statistical relation let us approximate $y_{a,t}$ from $\hat{y}_{a,t}$. But the reciprocal relation is not true. According to the complexity of rules, we use simulation to estimate optimal agronomic yields parameters. Then, what are the optimal parameters for $y_{a,t}$ random?

Simulations offer an answer at this question. We could test a large number of assumptions H_j = Arbitrary parameters suit.

H_j is accepted when simulated $y_{a,t}$ mean and standard deviation correspond to observed $y_{a,t}$ mean and standard deviation.

4.2   Historical data of 'Champagne'

Champagne's wine is known through the world. We have crop yield data from 1901 and the limit yield from 1961. We know the agronomic yield during 16 years, too. Then, these data let us to understand how quantity regulation affects the model and control the performance of our simulation process to estimate agronomic yields parameters.

We observed the real difference of the agronomic and observed crop yield statistics (see Table 5). Because of regulations, mean and variability of the observed crop yields are less than agronomic mean and variability. Wine data confirm the pertinence of agronomic trend and the left skewness density of the crop yield.

4.3   Agronomics 'Champagne' wine parameters using simulations

We use the following algorithm to found agronomic parameters:

▲ **Year** from 1990 to 2006
    ▲ **List of** Agronomic parameters Σj
        ▲ **Counter** of areas random a= 1 to Na
        Compute areas random
            ▲ **Counter** of farms random i=1 to Ni
            Compute individual random
            Compute individual agronomic crop yield
            Compute individual observed crop yield
            ▼ **End**
        Compute areas observed crop yield
        ▼ **End**
    ▼ **End**
▼ **End**
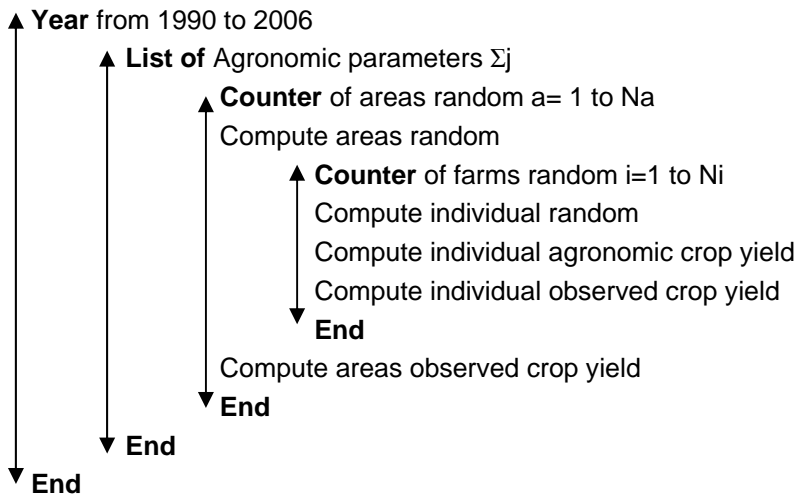
How number simulations are needed? We know the standard deviation of $y_{a,t}$ noted $\sigma(y_a)$. As presented by ELIE and LAPEYRE, (2001), to obtain a mean in $E[y_a] \pm \Delta_a$ with a 95% probability, we have to realize Na simulations:

$$Na = \left(\frac{1.96 \times \sigma(y_a)}{\Delta_a} \right)^2 \tag{4}$$

For $\Delta_a = 1\%$, we need Na=30. Next if we search the same precision (1% $E[\hat{y}_{a,t}]$) of each year on the individual mean $E[y_{a,t}] \pm \Delta_i$, we need Ni=800.

Table 1: Statistic and Results of the Champagne crop wine insurance

Data from 1991	Mean	Standard deviation	Variation coefficient	Skewness
Observed areas crop yield	11 280	1 705	15.11%	-89%
Agronomic Champagne Yield	14 847	3 669	24.71%	29%
Agronomic Champagne Yield minus the linear trend [*]	7	3 486	20.95%	-48%
Maximum crop yield	11 785	1 280	10.86%	
Simulations without trend [***]	21 350	5503	25.77%	
Simulations with knowing trend	22600	5373	23.7%	
Premium [**] using agronomic parameters (without trend)	4.44%	Deductible: Indemnity is paid when crop yield is under 10 000kg		
Premium [**] with observed parameters	7.13%			
Premium [**] without trend	6.79%			
Premium [**] with knowing trend	5.25%			

(*)   The expected value of agronomic crop yield is estimated to 19 360kg in 2005.
(**)   Premiums are without charges and taxes.
(***)   The more pertinent result, convergence is not obtained.

Source: Own representation.

Some conclusion comments:

1. Premium is really minor with the agronomic parameters. Then, quantity regulations have an impact on the premium estimation.
2. If trend is unknown, we do not have the convergence.
3. With trend, simulation approaches the result but not provides exact solution.

Unknown agronomic trend is a real obstacle of our approach; we do not have agronomic data or agronomic trend information for other wine areas.

5   How include the quality of wine?

5.1   Methodology to include quality wine risk

The first risk of many farms production is the quantity risk. Nevertheless, quality risk is a significant risk of wine production. Then, how to include the quality in the insurance contract in the model?

We analyse the case of a French wine cooperative. It provides a book of specifications for wine quality classes and quantity limitation. Before the subscription, the cooperative defines a table which each quality class impact on the price. This impact is represented by a coefficient and depends on the grape density of sugar (or the wine degree) and on the ES index.

Table 2: **Book of specification: Impact of quality on price.**

Degree	ES index = 1	ES index = 2	ES index = 3	ES index = 4
10.90° - 11.40°	>>	>>	0.5	0.0
11.50° - 11.90°	>>	0.8	0.5	0.0
12.00° - 12.50°	1	0.8	0.5	0.0
12.50° - 13.00°	1	0.8	0.5	0.0

Source: Own representation.

Then, we have a quality function noted Q on the price. We could merge quality and quantity results in an equivalent crop yield noted y' calculated as following:

$$y'_{i,t} = Q(Degree_{i,t}, Index_{i,t}) \times y_{i,t}$$

From equation 3, we derive the following relation between $y'_{i,t}$, $y_{a,t}$ and $\xi_{i,t}$ in the case of quantity and quality risk measure:

$$\ell(y'_{i,t}) = \ell(Q(Degree_{i,t}, Index_{i,t}) \times y_{i,t}) = \xi_{i,t} \times \frac{E(\ell(y_a))}{E(\ell(y'_i))} \times \ell(y_{a,t}), \text{ with } E(\xi_{i,t}) = 1 \tag{5}$$

First, we have to describe and analyse the cooperative quantity and quality data. Second, we measure the dependence between $\xi_{i,t}$ and $y_{a,t}$. At last, we have to compound these both risk to define the premium.

5.2 Data of cooperative

Cooperative gets together 140 wine farmers. We have quality and quantity data from 2000 to 2006. Equivalent crop yields are calculated independently for each variety of grapes. We aggregate data by farmers and by year.

The reference price of wine is 140€ per hl.

We deduce from figures 4 and 5 that cooperative farmers are heterogeneous. 43 farmers (33%) have expected revenue more than 8 000€. Nevertheless, these farmers represent 74% of the aggregate expected revenue. Only the farmers that have expected revenue more than 8000€ are considered because:
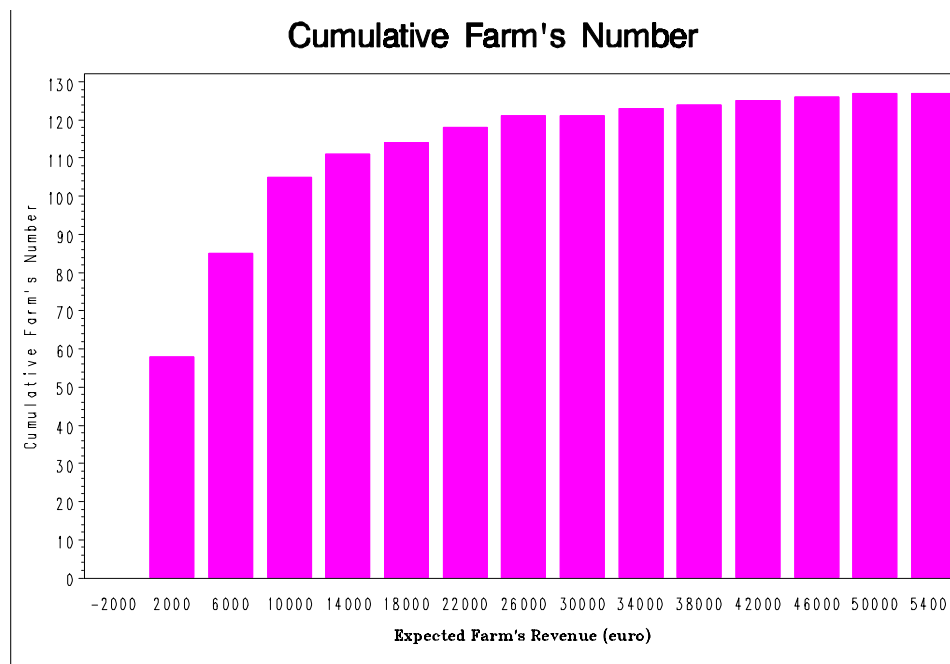
1. Farms are more homogeneous,
2. The liability of yield is better,
3. Insurance contract targets these farms.

Figure 4: **The cumulative farm's revenue in the cooperative.**
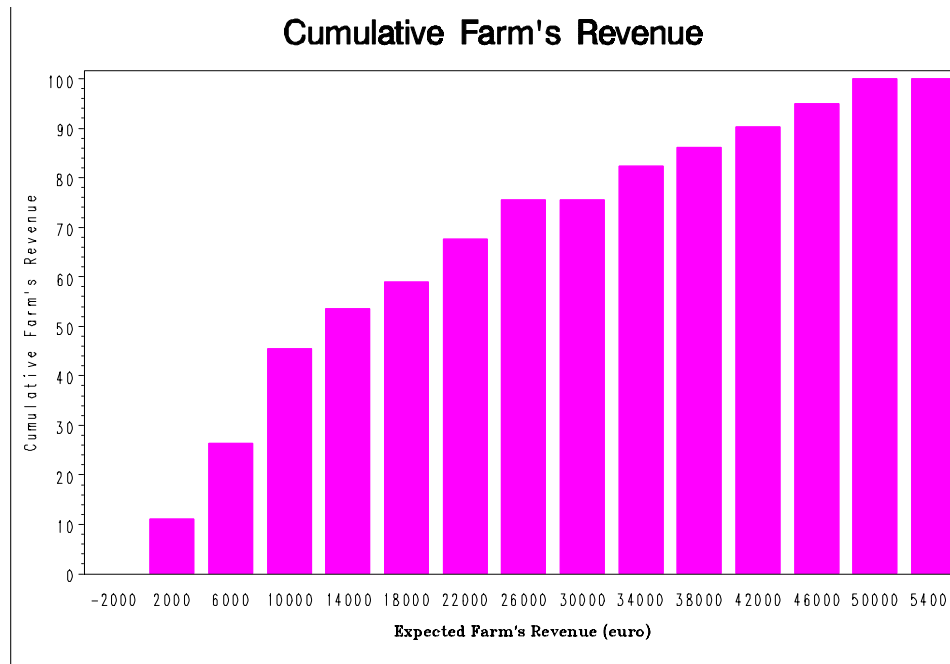
Source: Own representation.

Figure 5: **Cumulative farm's number**

Source: Own representation.

5.3 Individual quality and quantity risk measure and results

We could now testing the log-normality of $\xi_{i,t}$ for the more 8 000€ revenue of the high quality wine farms. SAS let us simply testing the normality of $\exp(\xi_{i,t})$ using the UNIVARIATE procedure.

We obtain (112 values):

Table 3: **SAS results of normality test of** $\exp(\xi_{i,t})$ **.**

Tests for Normality				
Test	Statistic		P Value	
Shapiro-Wilk	**W**	0.982588	**Pr < W**	0.1533
Kolmogorov-Smirnov	**D**	0.057478	**Pr > D**	>0.1500
Cramer-von Mises	**W-Sq**	0.063649	**Pr > W-Sq**	>0.2500
Anderson-Darling	**A-Sq**	0.475492	**Pr > A-Sq**	0.2404

Source: Own calculations.

Therefore, Shapiro-Wilk, Kolmogorov-Smirnov and Cramer-von Mises tests let us accepted the log-normal assumption (see Table 3). The P Value of the Anderson-Darling test is near of the usual trigger 0.25.

Next, we test the dependence between systemic risk component $y_{a,t}$ (areas yields) and the idiosyncratic risk component $\xi_{i,t}$ (individual risk). *Via* a CORR procedure, SAS let us measure the dependence between $\xi_{i,t}$ and $y_{a,t}$ within the meaning of Hoeffning. It results:

Table 4: **SAS results relative to the dependence between** $\xi_{i,t}$ **and** $y_{a,t}$ **within the meaning of Hoeffning.**

Dependence coefficient for Hoeffding, N = 112 Prob > D under H0: D=0		
	Areas Yield	Epsiloni
Areas Yield	0.36053 <.0001	0.00039 0.3280
Epsiloni	0.00039 0.3280	0.99943 <.0001

Source: Own calculations.

From Table 4, the non-dependence assumption is accepted.

We remind of the product of two independent lognormal random is a log-normal where the parameters are $\left(m, v^2\right) = \left(m_1 + m_2, v_1^2 + v_2^2\right)$. We could now compute the premium estimation. Results are shown in Table 4.

Table 5:   Synthetics results of climatic risk premium (deductible 0% relative of the expected yield)

	Mean	Standard deviation
Observed statistic of areas yield	43.05 hl/ha	7.13
Agronomic statistic of areas yield	44.5 hl/ha	7.45
Statistic of $\xi_{i,t}$	1.012	0.0836
Premium rate without agronomic statistics and without quality risk	11.78%	
Premium rate with agronomic statistics and without quality risk	11.91%	
Premium rate with agronomic statistics and with quality risk	9.32%	

Source: Own calculations.

The yield areas mean is largely under the 50 hl/ha limit. Then, the quantity regulation does not affect the areas yield parameters, and does not affect the risk premium. Why? Official's statistics and agronomical experts of GROUPAMA confirm the low number of wine specialist farms. Wine suffers from non-optimal climate and is often only an additional production. Then the productivity is low.

The rate for insurance premium of the quality and quantity risks is minor than only quantity risks. Why?

1. For quantity insurance, our model includes our usual idiosyncratic risk component assumptions. Regard to the specificities of the area study here, our approach is not adapted. Probably, quantity risk is over estimated.

2. Only a little population is selected for the quality. Parameters are not estimated with the same perimeter.

3. Because rigorous grape growing process is implanted, it results probably a better risk control. In this cooperative, the quality process could be reward by a lower premium and a better protection.

To evaluate the quantity and quality risk premium we must compute a specific measure of risk. This measure depends first on the areas variability and on book of specification of the cooperative.

Conclusion

Because of quantity regulations, mean and variability of the observed crop yields of wine are less than agronomic mean and variability. All things being equal, premium decreases with expected yields and increases with variability. Then, the both impacts of regulations are opposed on estimated premium. Nevertheless, results show that estimated premium is really cheaper using agronomic parameters.

When trend of agronomic wine crop yield is known, simulation is powerful. Unknown agronomic trend is a real obstacle of our approach; we do not have agronomic data or agronomic trend information for other wine areas.

Then, we have to include quantity wine regulation in premium estimation. Too, we have to provide our approach to compute agronomic crop yield parameters estimation.

To evaluate the quantity and quality risk premium we must compute a specific measure of risk. This measure depends first on the areas variability and on book of specification of the cooperative. Because rigorous grape growing process is implanted, it results probably a better risk control. In the analyzed cooperative, the quality process could be reward by a lower premium and a better protection.

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