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Risk attitudes in viticulture: the case of French winegrowers*

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Abstract

The aim of this paper is to analyze risk attitudes of winegrowers in France. An interesting feature of French viticulture is that most of the production is carried out under an appellation regime, bearing constraints in terms of maximal yield authorized. We estimate a translog cost function under the constraint of this maximal yield. We jointly estimate cost function parameters, factor share equations and winegrowers' attitudes to the risk function. Our estimates are based on the FADN database (2005-2014), data from the National Cultural Practices survey (2006, 2010, 2013), data from the French National Institute of Origin and Quality (INAO) and data from guides on production costs in viticulture and œnology (from 2005 to 2014). We find that pesticide demand is inelastic and all types of winegrowers are risk-averse. For the majority of them, risk aversion declines with expected profit (DARA), but for the Champagne region, it is the contrary. Expected profit is far higher than in the other regions and these winegrowers are more averse to risk when expected profit increases (IARA).

Key words: Pesticide use, Viticulture, Appellation yield, Risk preferences.

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1 Introduction

The assessment of farmers' risk attitudes is fundamental in agricultural production, in particular regarding the use of inputs such as pesticides (Liu and Huang, 2013; Gong et al., 2016). These chemical inputs play an insurance role on harvests (Carpentier et al., 2005; Carpentier, 2010) and their use, as all insurance system, is related to the risk preferences (Sexton et al., 2007). Moreover, in terms of regulation, farmers risk preferences are essential components through which agro-environmental policies may influence production decisions. These risk attitudes can impose constraints on agricultural support policies (Acs et al., 2009).

Our paper focuses on wine production in France where an important environmental concern is the intensive use of pesticides[1]. Vineyards represent only 3% of the countrys agricultural surface, but winegrowers use 20% of pesticides sold (Aubertot et al., 2007). Due to this intensive use of chemical inputs, agro-environmental policies have recently been drawn up in order to encourage winegrowers to reduce their pesticide use (Ecophyto, 2008; Ecophyto II, 2015). However, pesticide use tends to reduce production uncertainty and viticulture being a cash crop, it involves high returns from the use of chemical inputs. In other words, winegrowers who aim to maximize profit will use them as long as the marginal costs of this usage are lower than the marginal benefits they obtain. Moreover, given the climatic conditions favorable to fungi, there are few viable means to reduce pesticide use in wine growing which do not compromise yield. In doing so, producers have limited flexibility to change their agricultural practices and this change may induce risk of yield losses. This highlights the importance of studying the risk preferences of winegrowers.

[1] The average number of treatments applied annually against each harmful organism such as downy mildew and powdery mildew is about 20 (See annual BVA surveys carried out for firms).

One interesting feature in our analysis is that we consider the appellation regime in terms of maximal production yields (Pennerstorfer and Weiss, 2012; Castriota and Delmastro, 2014). Indeed, most wine in France is produced under appellation minimum quality standards (PDO Protected Denomination of Origin or AOC in French viticulture), PGI Protected Geographical Indication or IGP in French viticulture). These systems are based on the strong link existing between a product and the terroir it comes from. Producer Organizations (POs) specify an appellation by controlling production through three important variables: authorized grape varieties, agronomic practices and maximal yields on a specific and limited area in order to preserve wine quality and volumes on the market. In 2015, the appellation regime in France represented 366 wines and distilled alcoholic beverages and 441200 ha (21.5 billion hl) (INAO[2] data). Since the appellation regime imposes a constraint on production, one should instead study input choices which are conditional on the expected output level.

Especially, we need to estimate the structure of an ex-ante cost function (Pope and Chavas, 1994; O'Donnell and Woodland, 1995). Therefore, unlike some previous work on farmers'risk attitudes, (see, for example, Kumbhakar (2002); Koundouri et al. (2009); Foudi and Erdlenbruch (2012)), our analysis is based on a joint estimation of a production cost, factor share equations and a risk preferences functions. The literature in agricultural economics highlights the fact that the estimation of a cost function under a planned output constraint usually poses the problem of the unobservability of this expected output level (Moschini, 2001; Moschini and Hennessy, 2001). This is not the case in our study since the information relative to appellation yield is available in the specifications of POs. We use them as a measure of planned output. In actual fact, winegrowers appear to target a maximal harvest which is higher than

[2] INAO: French National Institute of Origin and Quality.

the yield imposed by POs. Given the risk of yield losses due to diseases and/or climatic conditions, they behave this way to be certain of achieving the imposed yield. This constraint on production conditions leads us to consider an assumption contrary to those found in the literature. While we can usually read that risk aversion decreases with expected profit (Atanu et al., 1994; Chavas and Holt, 1996), we assume that when production conditions are constrained, risk aversion should increase with expected profit. This can be reinforced by the fact that the vine is a perennial crop, meaning that a pest attack for a given year will influence the production potential of the vine the year after.

Our estimations are based on the FADN database (2005-2014), data from the National Cultural Practices survey (2006, 2010, 2013), data from the French National Institute of Origin and Quality (INAO) and data from guides on production costs in viticulture and œnology (from 2005 to 2014). Our dataset holds a balanced panel of 125 winegrowers over the 2005-2014 period, involving a sample of 1250 observations from the most important wine-producing regions in France and a focus on the Champagne region. We jointly estimate cost function parameters, factor share equations and winegrowers' attitudes to the risk function. We find that all types of winegrowers are risk-averse. For the majority of them, risk aversion declines with expected profit, but for the Champagne region, it is the contrary. In this wine basin, expected profit is far higher than in the other regions and these winegrowers exhibit IARA while the winegrowers in the other basins express DARA.

The paper is structured as follows: in Section 2, we present the related literature. Section 3 provides background information on wine production in France. Section 4 describes data. Section 5 presents the empirical model. In Section 6, we present the main results. Section 7 concludes the paper.

2 Related literature

The issue of farmers' risk attitudes has not yet been examined in viticulture[3]. However, this question has been studied in relation to other types of crops or technology (Moschini and Hennessy, 2001). In this strand of the agricultural economics literature, risk attitudes are studied under the expected utility framework, where farmers behave as if they maximize an expected utility function Meyer (2013). Here, empirical research aims to estimate the farmers' risk preferences where a stochastic production function is assumed (Just and Pope, 1978). For example, Picazo-Tadeo and Wall (2011) give estimates of risk-aversion coefficients of Spanish rice farmers and examine the effects of a series of socioeconomic variables on their risk attitudes. They show that Spanish rice farmers are risk-averse and their risk attitudes are related to a series of socioeconomic characteristics such as age, educational level, the use of fertilizers and pesticides. Similarly, Kumbhakar and Tveterås (2003) estimate risk preferences of Norwegian salmon producers. They find that salmon producers are risk-averse. This risk-averse attitude is due to the existence of sunk costs related to investments in capital equipment and labor training, high operating capital requirements due to the long time lag between the release and harvesting of salmon and use of personal assets as security for loans or investment capital. In terms of policy effects, Koundouri et al. (2009) explore grain farmers risk attitudes in a changing policy environment using a model of production under risk. They focus on decoupled farm payments through the European Union Common Agricultural Policy (CAP). They find that decoupled agricultural payments influence farmers risk attitudes. In the field of irrigation water, Foudi and Erdlenbruch (2012) use French corn growers data in

[3] Aubert and Enjolras (2014) investigate the determinants of chemical consumption by French winegrowers without explicitly addressing the issue of risk aversion.

order to analyze the way farmers manage production risks (with an emphasis on the risk of drought). They show that the use of irrigation water and fertilizers have a significant positive impact on yield variance. These papers do not take into account any constraint on yield through an appellation regime. They consider a stochastic production function that they estimate simultaneously with a risk preferences function. Our approach takes into account this restriction on production.

Wines are mostly delivered with an appellation mentioned on the bottle through a self-regulation process led by POs. These POs define an appellation minimum quality standard, particularly by controlling yield. Under this appellation regime, our estimation approach has to be different to those in the papers we have mentioned above. In fact, in this self-regulation process by POs, winegrowers have to conform to established rules. These regard maximal yield and process constraints enabling the producer to benefit from a premium on a top-market segment (see e.g. Giraud-Héraud and Soler (2003)). Therefore, we need to estimate a cost function that is dual to a stochastic production technology. The reason is that the production constraint will modify winegrowers behavior. They will choose their inputs conditional to planned production. This duality approach to applied production economics has been analyzed, among others, by Pope and Chavas (1994); O'Donnell and Woodland (1995); Pope and Just (1996); Chambers and Quiggin (1998, 2000); Moschini (2001). Pope and Chavas (1994) have characterized cost functions when production is uncertain. They highlight the fact that, under risk aversion, expected output alone does not give a relevant characterization of cost minimization. This is due to the fact that the expected output level is not observable. Pope and Just (1996) provide a solution where the expected output level is jointly estimated with the cost function model. O'Donnell and Woodland (1995) applied this duality approach to wool and lamb production in Australia. They estimate a translog cost function and share equations. Chambers (1988) and Chambers and Quiggin (2000) introduce a state-contingent consideration in the specification of cost minimization. This state-contingent setting provides that outputs are conditional on the states of nature, where each state represents a specific uncertain event (Debreu, 1959). Moschini (2001) focus on input choices and provide conditions that give rise to a non-linear errors-in-variables problem. In these models, it is common to estimate only cost function parameters and share cost equations. These share equations are derived from the cost function using Shephard's lemma. Our analysis proposes a simultaneous estimate of cost function parameters, share cost equations and the risk preferences function. We consider that winegrowers face yield risk. They are able to access a stochastic production technology which is multiplicative. Under these assumptions, they will choose input quantities to minimize production cost under a planned output constraint. More specifically, we split the expected utility of profit maximization into steps. In the first one, the winegrower chooses inputs to minimize the cost of producing the expected output level. Given this minimum cost, we assume, in the second step, that the winegrower chooses the planned output to maximize the expected profit utility. This planned output is not observable. Therefore, in our estimation, we use the maximal yields imposed by POs as a proxy of the expected output level.

3 Wine production in France

French winegrowing represents a significant proportion of the world wine market. Italy, France and Spain are the world leaders in wine production with more than 50% of world production[4]. In terms of consumption, their patterns are similar (PAN Europe, 2008). Europe is the continent that produces and consumes more than two-thirds of the world's wine supply. In France, data show that after the crisis in 2008, market conditions appeared to be continuing to improve up to the end of the 2010-2011 season (Agreste, 2011). In a context of a reduced supply, domestic demand for wines with Protected Designation of Origin (PDO-AOC) and Protected Geographical Indication (PGI-IGP) is increasing, especially in red and rosé wines. Finally, the wine sector plays a major role in French agriculture. It is the leading agricultural sector in value (15% of production value in 2007, INSEE 2007) and the jobs that it generates are considerable and varied (Bastian, 2008).

Table 1: French wine production in 2009 (Agreste, 2010)

	Area (thous. of ha)	Yield (hl/ha)	Production (thous. of hl)
Denomination of Origin Wines			
Total AOC harvest	465.4	50	23347.7
Including AOC which excludes VDN	451.7	51	23060.1
Including VDN in AOC	13.7	21	287.6
Total VDQS harvest	4.6	62	287.5
Total VQPRD harvest	469.9	50	23635.2
OTHER WINES			
Wines for eaux-de-vie AOC	71.3	101	7207.2
Total harvest other wines	244.9	65	15997.6
Including "vin de pays" wines	-	-	12524.9
Including other wines	-	-	3472.7

Besides its economic importance, French viticulture presents a main feature which is related to the AOC. We note that the vast majority of wines (80%) are produced under AOC (Table 1), thus limiting the quantity produced. The definition of AOC was laid down by the law of 6 May 1919. These AOCs may correspond to the name of a country, a region or a

[4] France was the largest producer in volume until 2006 with 19% of world production. Since 2007, it has moved into second place (source: OIV, World Wine Statistics 2007).

locality. They serve to indicate the origin of a product whose qualities and characteristics are due to geographical location (Economie Rurale, 2000) but not only. Based on respect of local uses, loyal and constant, the AOCs come from strictly selected terroirs (Hinnewinkel, 2001) (soil, climate and human know-how). Each appellation is the subject of a decree which defines production conditions (determined by POs and validated by the INAO). These production conditions concern the production area, the authorized varieties, the cultural practices, the density of plantations, the pruning system, the pattern of production, the harvest dates, the minimum alcohol content, and above all restrictions on the authorized yields (source: FranceAgriMer). All wines claiming an AOC are subject to an analytical and organoleptic examination. They are then officially approved by the INAO.

4 Data

Our data come mainly from the European Farm Accountancy Data Network (FADN) and we focus on wine production under appellation systems (AOC and IGP)[5]. The FADN database includes annual farm-level data on surface, yield, value of wine production, working hours and costs on pesticides, fertilizers and labor. Our dataset holds a balanced panel of 100 winegrowers in the main French wine-production basins (called here "other basins") plus 25 winegrowers in the Champagne region over the 2005-2014 period, leading to a sample of 1250 observations. This sample covers the most important wine- production basins in France: Alsace, Beaujolais, Bordelais, Bourgogne, Languedoc-Roussillon (Lang. Rouss.), Provence-Alpes-Côte-d'Azur (PACA), Rhône, Sud-Ouest, Val de Loire and Champagne. Ta-

[5] OTEX 37 and 38 in FADN.

ble 2 presents some descriptive statistics of the sample (size, yield, authorized yield, vineyard gross product). In our model, we isolated the Champagne region because of its vineyard gross product which is far higher here, despite the smaller size of farms, than farms from other regions. The products in Champagne have higher added value which is explained by the type of wine (Champagne being a sparkling wine) and its luxury image. Data we used from the FADN are in line with national statistics (Agreste, 2012).

Table 2: **Descriptive statistics**

	Champagne basin				Others basins			
Variable	Means	S.D.	Min	Max	Means	S.D.	Min	Max
Total farm size (ha)	4.22	1.98	1.06	8.83	18.07	14.30	1.75	87.89
Yield (kg/ha)	12130.70	1755.67	6431.06	15520.83	6694.42	2223.47	0.00	13937.01
Authorized yield (kg/ha)	10770	1608.71	9600.00	15450.00	8333.7	1288.35	4350.00	11850.00
Vineyard gross product (€/year/ha)	37529.36	15367.12	3442.81	103341.02	5499.98	2770.92	13.14	19128.38
Cost of plant protection (€/year/ha)	1907.01	935.65	235.00	7209.71	570.81	284.60	3.54	2165.87
Cost of fertilizers (€/year/ha)	954.23	1145.12	3.39	9110.16	199.56	200.73	0.10	1247.76
Cost for labour (€/year/ha)	10759.88	6617.87	722.92	32151.37	2359.10	1757.82	17.09	12014.18
Pesticide (kg/ha)	65.96	6.94	53.63	75.94	39.55	9.44	15.04	59.61
Fertilizer (units/ha)	60.23	7.53	49.74	74.34	37.07	9.29	15.83	81.36
Labour (hours/ha)	677.47	354.27	49.40	1500	194.04	136.34	1.54	1198.45

The quantities of pesticides and fertilizers used in our analysis were obtained by combining the guide on production cost in viticulture and œnology (from 2005 to 2014)[6] and the National Cultural Practices 2010 Survey[7]. Indeed, these quantities are not available in the FADN database, but we can determine the costs linked to the use of these two inputs. Firstly, following Koundouri et al. (2009), we have deflated these costs using the corresponding price index deflator (Table 7 in the appendix). In other words, these costs were calculated in constant-euros terms. Secondly, we calculated variations for each year of our observation period with 2010 as the reference year. In addition, the 2010 Cultural Practices survey provides quantities of fertilizers used per wine basin. In this way, variations in fertilizer costs

[6] Le Coût des Fournitures en Viticulture et œnologie date (in French) - French Institute of Vine and Wine and Roussillon Chamber of Agriculture, date

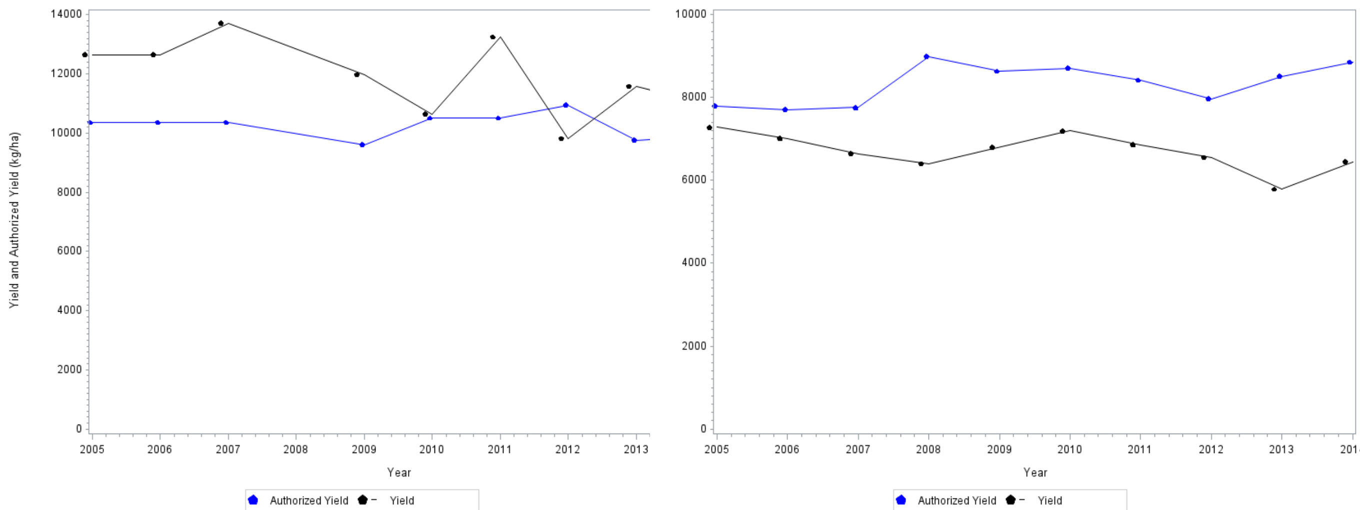
[7] Enquêtes Pratiques Agricoles 2010 - Agreste

were applied to these quantities in order to obtain the average quantities per wine basin over the 2005-2014 period. A similar strategy was used for pesticides with few changes. Unlike fertilizers, the quantities of pesticides are not directly available in the 2010 Cultural Practices survey. This report only indicates the Treatment Frequency Index (TFI) per wine basin[8]. The approved dose is calculated thanks to dierent sources such as the guide on production cost in viticulture and œnology (2010) and the phytosanitary index of plant-protection products (2017). Note that this dose represents the mean of the doses approved for each of the ten main fungicides used in viticulture in France[9]. From TFI and the average approved dose, we derived the applied dose in each wine basin and we multiplied them by the number of phytosanitary treatments of each wine basin to determine the average quantity of pesticides used in 2010. Once these quantities were obtained, we multiplied them by the variations previously calculated to obtain the average quantities over the whole observation period (2005-2014). We also use an additional database from the French National Institute of Origin and Quality (INAO). This database provides information relative to the annual authorized yield in each wine production region in France.

The graph in Figure 1 compares the yield obtained with the authorized yield over the entire sample period. The black and blue curves give, respectively, the average level of production per year and the average authorized yield per year.For the Champagne basin, it can be noted that the average yield obtained is higher than the authorized yield over the period (see Figure 1a). The mechanism of reserve, dedicated toward preserving surplus

[8] TFI is an indicator used to assess the intensity of pesticide use (Muneret et al., 2017). It is the product between the ratio of applied dose and approved dose times the ratio area treated and total area. We assumed that the ratio area treated and total area is equal to one. In other words, we considered that the winegrower treats the whole of his wine farm.

[9] 80% of pesticides used in viticulture in France are fungicides.



(a) Champagne basin

(b) Other basins

Figure 1: Average per hectare of yield and authorized Yield

quantities to compensate for bad years (2012 for example) or to meet demand (high levels of sales) for specific years, only exists in this region and can explain this graph. For the other basins, we observe that the average yield curve is below the authorized yield's one over the entire period (Figure 1b). While every year, wine growers seek to achieve at least the appellation yield, sometimes they are not successful. This confirms the data at national level showing that yields obtained in 2005, 2006 and 2007 were slightly higher than the appellation yields and that from 2008, there was noted a sharp fall with reported yields lower than the regulatory ones, partially because of the re-emergence of wasting diseases in the vineyards (BIPE, 2015).

5 Empirical model

5.1 Production risk model applied to vineyard

Our empirical specification is based on the assumption that there is uncertainty about the level of output related to the level of inputs. We consider a winegrower who makes ex-ante decisions about input quantities. More precisely, he chooses input quantities before the possible output outcomes have become known[10]. Considering that the winegrower does not know the real effect of pesticide use on the reduction, or not, of his yield, we can consider that quantities of pesticides are chosen before output outcomes are known. Therefore, we further assume that the winegrower maximizes his expected profit utility with the decisions program given as follows:

$$\max_{y,x} \left\{ E\left(U(\pi)\right) = E\left(U(py - \omega' x)\right)\right\} \tag{1}$$

where $U(\pi)$ is a *Von Neumann-Morgenstern* utility function form and $\pi = py - \omega' x$ the profit of the winegrower, y represents output, p denotes the price of output, x a vector of variable inputs and ω the vector of variable input prices. We consider the case of multiplicative stochastic production function given by: $y = f(x)\epsilon$ where ϵ is a nonnegative random term. This random term ϵ represents an exogenous shock (for instance, a climatic shock or a disease) that may affect grape production. We assume that $E(\epsilon) = 1$ and $Var(\epsilon) = \sigma_\epsilon = 2$ (Just and Pope, 1978). We denote by $\overline{y}$ the ex ante planned output level. In that context, the expected

[10] Actually, for pesticide use, the winegrower has the possibility to rectify the quantities of pesticides used after the disease contamination (or pests attack) has occurred. In stochastic programming, this is addressed by a "recourse function" that refers to the average value of the decisions made after the first decision (of using pesticides or not) has been made, and new information on its outcome has been revealed to the farmer.

utility-maximizer winegrower will choose his quantities of inputs in order to minimize the cost of producing the expected output level, $\overline{y}$. Thenceforth, the ex ante cost dual to the expected output function is defined as:

$$c(w, \overline{y}) = \min_{x} \{w'x : f(x) \geq \overline{y}, x \geq 0\} \quad (2)$$

This cost function is the minimum factor cost of producing the expected output level $\overline{y}$ when the input price vector is w. The factor share equations are obtained using the Shephard's lemma with $s_i = \partial ln(c(w, \overline{y}))/\partial ln(w_i)$, where s_i represents the cost share on input i. In short, the expected utility of profits maximization can be split into two steps. In the first one, the winegrower chooses the quantities of inputs to minimize the cost of producing the expected output level $\overline{y}$. Given this minimum cost, in the second step we consider that, the winegrower chooses $\overline{y}$ to maximize the expected utility of profits as follows[11] :

$$\max_{\overline{y} \geq 0} \{E\left(U\left(p\epsilon\overline{y} - c(w, \overline{y})\right)\right)\} \quad (3)$$

The first-order condition with respect to the planned output $\overline{y}$ is written as follows:

$$\frac{\partial E(u(\pi))}{\partial \overline{y}} = p\theta(\cdot) - \frac{\partial c(w, \overline{y})}{\partial \overline{y}} = 0 \quad (4)$$

The function $\theta(\overline{y}, w, p)$ represents the risk preferences function which is defined by $\theta(\overline{y}, w, p) = E(U'\epsilon)/E(U')$ where $U'(\pi)$ is the marginal utility of profit. Following Kumbhakar and Tveterås (2003), we approximate $U'(\pi)$ by a second-order polynomial at the point $(\epsilon - 1 = 0)$. This approximation is made under the assumption that $U(\pi)$ is continuous and at least twice

[11] See Pope and Chavas (1994); O'Donnell and Woodland (1995) for more details.

differentiable. This allows us to rewrite the risk preferences function as a function of the Arrow-Pratt measure of absolute risk aversion (ARA), with the variance of winegrower profit ($\sigma_\pi^2 = p^2\overline{y}^2$), the degree of asymmetry or the skewness of the distribution of ϵ ($\gamma = E(\epsilon^3)$), and a measure of downside risk aversion ($DRA = U'''(\pi)/U'(\pi)$). Thus, this risk preferences function can be rewritten as follows[12] :

$$\theta(\overline{y}, w, p) = \frac{1 - ARA\sigma_\pi + 0.5DRA\sigma_\pi^2(\gamma - 3)}{1 + 0.5DRA\sigma_\pi^2} \tag{5}$$

This risk preference function is slightly different from that found in Kumbhakar and Tveterås (2003). The estimation of this risk preferences function requires a parametric form of AR. As Kumbhakar and Tveterås (2003), we define this ArrowPratt measure of absolute risk aversion as: $ARA = \sum_{q=0}^{Q} \delta_q \mu_\pi^q$. This is a flexible parametric function of the winegrower's expected profit μ_π where q is the order of the polynomial and δ_q are parameters to be estimated. In our case, the winegrower's expected profit is defined as: $\mu_\pi = E\left[p\epsilon\overline{y} - c(w, \overline{y})\right]$ which also equal to $\mu_\pi = p\overline{y} - c(w, \overline{y})$.

An important problem arises with our estimation strategy because the planned output ($\overline{y}$) is not observable. In practice, winegrowers expect yields ($\overline{y}$) higher than the maximum yields imposed by the specifications of PDOs and PDIs. Considering the risk of production losses, they behave this way to be more likely to reach the yield imposed by the appellation regime. When they target a higher yield, they may be in overcapacity. In these conditions, the whole realized harvest may in fact not be sold and the difference will be distilled. Therefore, on the one hand, considering that the yield target is not known, we use the appellation

[12] See Kumbhakar and Tveterås (2003) for more details

yield in our estimation as a proxy of the expected output. On the other hand, in order to rigorously implement the gross profit of winegrowers, we assume that the yield corresponds to the minimum level between the yield obtained (y) and the yield of appellation denoted by ($\widehat{y}$) which can not be exceeded in quality viticulture under the appellation system. In other words, $Yield = min(y; \overline{y})$ leading to $\mu_\pi = p \cdot min(y, \widehat{y}) - c(w, \widehat{y})$.

Concerning the measure of downside absolute risk aversion, it can be derived from ARA as follows: $DRA = -\partial ARA/\partial \mu_\pi + ARA^2$ and there is an interest in simultaneously estimating the parameters of the cost function, the factor share equations s_i and the risk preferences function. A positive sign of the derivative of ARA with respect to μ_π indicates an increasing absolute risk aversion, while a negative sign brings out a decreasing absolute risk aversion. When the derivative is equal to zero, we consider absolute risk aversion as constant.

5.2 Specification of the empirical model

We consider parametric forms of the cost function and the factor share equations to estimate the model described above. More specifically, following O'Donnell and Woodland (1995), we assume a translog cost function as follows:

$$ln(c/\overline{y}) = \alpha_0 + \alpha_t t + \sum_{i=1}^{I} \alpha_i ln(w_i) + 0.5 \sum_{i=1}^{I} \sum_{j=1}^{I} \alpha_{ij} ln(w_i) ln(w_j) \tag{6}$$

With c the total costs, w_i the price of input i and $t(t = 1, ..., 10)$ a time trend. This time trend provides a measure of exogenous technical change (TC) defined as $TC = -\partial lnc/\partial t$. The factor share equations, derived from the Shepard's lemma, are given by:

$$s_i = \alpha_i + \sum_{i=1}^{I} \alpha_{ij} ln(w_j) \quad (7)$$

where s_i denotes the cost share input i. Our cost function must satisfy some theoretical properties, in particular the linear homogeneity and the symmetry. These properties are satisfied when: $\sum_{i=1}^{I} \alpha_i = 1$, $\sum_{j=1}^{I} \alpha_{ij} = 0$ and $\alpha_{ij} = \alpha_{ji}$. We need to drop one share equation in order to avoid singularity of the error covariance matrix. Otherwise, we assume that ARA takes a quadratic form[13] : $ARA = \delta_0 + \delta_1 \mu_\pi + \delta_2 \mu_\pi^2$. Consequently, we are able to derive an explicit parametric form for the winegrowers' downside risk aversion and the risk preference function. We then estimate the parameters of the cost function and the share equations simultaneously with the risk preferences function. However, in the empirical framework of simultaneous equation, endogeneity is an important issue which leads to the use of the instrumental variables method. In our analysis, the full system which includes equations 5 and 7 is estimated using a Full Information Maximum Likelihood (FIML) method. This method assumes multivariate normality distribution of residuals[14] and gives consistent parameter estimates (Bera and John, 1983). In addition, FIML approach does not require instrument for endogenous inputs, for which further instrumental variables are needed.

[13] Our estimates do not require an explicit functional form of the utility function, although a parametric form of the ARA function inherently involves some form of the underlying utility function

[14] This is not the case for single-equation methods such as GMM.

6 Results

6.1 Price elasticities, concavity and technical change

We report, in Table 3 below, the estimates of both own- and cross-price elasticities. We can note that all the own-price elasticities are negative. Concerning input demands, they are estimated to be inelastic with respect to their own prices. In particular, in the Champagne basin, the own-price elasticities for pesticide fertilizer and labor are respectively -0.09, -0.28 and -0.16. In the other basins, they are respectively -0.13, -0.38 and -0.12. Our finding relative to the inelasticity of pesticides is in line with other studies (Hoevenagel et al., 1999; Skevas et al., 2012; Lescot et al., 2014; Böcker and Finger, 2017)) highlighting the difficulties of agri-environmental public policies in changing farmers'behavior towards pesticides by using economic instruments such as taxes or subsidies (see Finger et al. (2017) for an interesting discussion on pesticide taxes). Calculated price elasticities of fertilizers are higher. This result may be explained by the fact that wine is a perennial crop with delayed reaction from fertilization practices. Additionally, all estimates of the cross-price elasticities are positive, suggesting that all pairs of inputs are substitutes in production.

Table 3: **Price elasticities of demand**

	Champagne basin			Other basins		
Input quantities	Price of pesticide	Price of fertilizer	Price of labor	Price of pesticide	Price of fertilizer	Price of labor
Quantity of pesticide	-0.09	0.35	0.21	-0.13	0.37	0.10
Quantity of fertilizer	0.34	-0.28	0.42	0.36	-0.38	0.36
Quantity of labor	0.21	0.42	-0.16	0.10	0.36	-0.12

Furthermore, the estimated cost shares must be positive and the estimated cost functions must be concave in order to obtain estimated functions consistent with cost minimization. The concavity of each estimated cost function requires a negative semidefinite Hessian matrix.

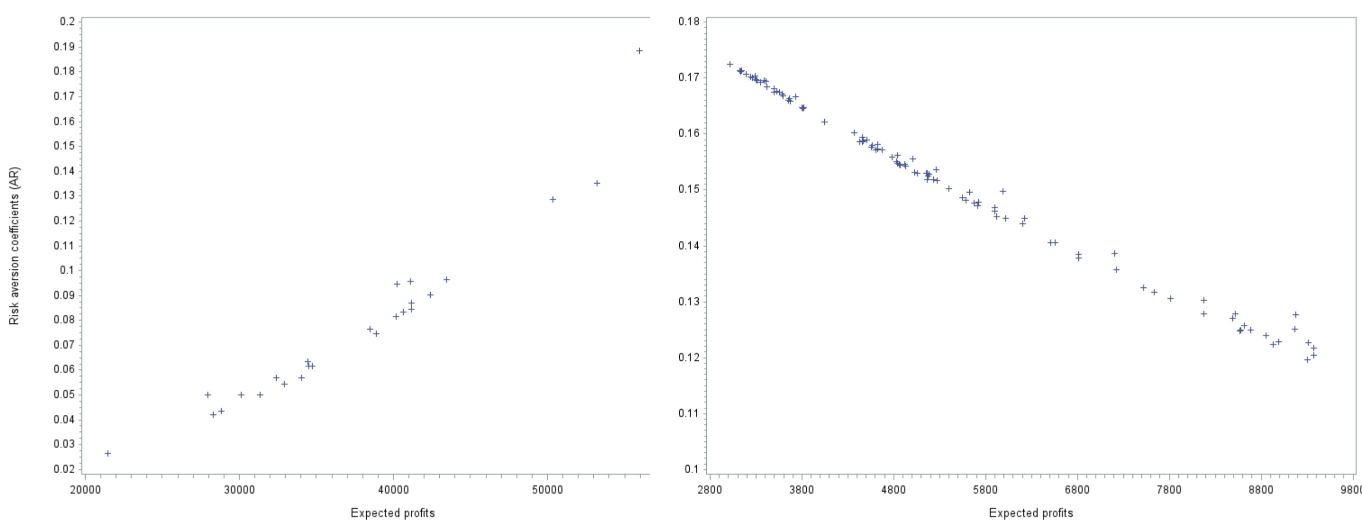
This implies that all of the eigen values must be non-positive as a necessary and sufficient condition. This criterion was investigated at $NX3 = 3750$ sets of representative input prices. All estimates of the cost shares are positive, as expected. This indicates that the estimated cost functions are increasing in input prices. The concavity condition is satisfied in 66.66% of cases. In other words, 2500 out of 3750 eigen values are non-positive.

The coefficient of the time variable (α_t) may be interpreted as the rate of TC as measured by the annual proportional reduction in unit costs (O'Donnell and Woodland, 1995). The rate of TC is estimated at zero in the Champagne basin (the effect is not significant) and 1% in the other basins (highly significant).

6.2 Risk attitudes estimates

Here, we discuss results concerning winegrowers'risk attitude. Even if these risk attitudes are based on the values of the risk preference function (θ), the values of the absolute risk aversion (ARA) and the downside risk aversion (DRA) seem to be more interesting to analyze than the (θ) function. The main reason is that the magnitude of this risk preference function is influenced by the output variance, the skewness of outputs distributions, ARA and DRA. A positive value of ARA highlights risk aversion, where a large positive value indicates a strong aversion to risk. Concerning downside risk, it illustrates the fact that when there is a choice between two output distributions with the same mean and variance, winegrowers will prefer the output distribution which is less skewed to the left (Kumbhakar and Tveterås, 2003). Intuitively, winegrowers are willing to pay a premium in order to avoid particularly bad outcomes (Koundouri et al., 2009). A positive value of DRA would indicate that individual producers are averse to downside risk. A positive value of DRA would indicate that individual producers are averse to downside risk. Another interesting measure of risk aversion is the Relative Risk Premium (RPP) which is: $RRP = \frac{\sigma_\pi^2 ARA}{2\mu} - \frac{\sigma_\pi^3 (E(\epsilon^3)-4)DRA}{6\mu}$ (Antle, 1987). It measures the share of profit that the winegrower is willing to sacrifice to avoid production risk.

We plot the individual ARA points as a function of the expected profit (see figure 2). The goal is to test whether risk aversion is increasing or decreasing with the expected profit. In our sample for other basins, we find evidence that winegrowers display decreasing absolute risk aversion (DARA). This finding is coherent with several empirical analysis on farmers risk attitudes (Koundouri et al., 2009; Foudi and Erdlenbruch, 2012). However, the results for the Champagne region are consistent with our first intuition i.e. when expected profit is very high, the risk aversion increase with the expected profit (IARA) and the behavior of the producers is different from the other regions.



(a) Champagne basin (b) Others basins

Figure 2: Arrow-Pratt coefficient as a function of expected profits

If we now turn attention on risk attitudes according to the main wine basins, we have the following results reported on table 4 below. The ARA value in Alsace, Bourgogne and Rhône is positive (0.14) and it is lower than the AR value of the other basins, even if the difference is not so significant (0.15 or 0.16). The only basin which is different to the others is once again the Champagne one with an AR coefficient equal to 0.08, showing that they are less risk-averse than the others. RRP in all basins ranges from 0.3% to 7% with a maximum for the Champagne basin. Combining these results with results from Figure 2, we can say that the winegrowers from Champagne are less risk-averse than the others but that this risk aversion attitude evolves differently to the others: it increases with their expected profit. We link this observation to the high value of production in Champagne in comparison with production in other basins.

Table 4: **Estimated means by Wine Basins**

	μ_π		ARA		DRA		RRP	
Wine basins	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
ALSACE	6.96	2.81	0.14	0.02	0.03	0.01	0.006	0.008
BEAUJOLAIS	4.24	1.99	0.16	0.02	0.04	0.01	0.004	0.004
BORDELAIS	4.84	2.67	0.16	0.02	0.03	0.01	0.006	0.007
BOURGOGNE	6.63	3.21	0.14	0.02	0.03	0.01	0.013	0.072
LANG.-ROUS.	4.09	1.56	0.16	0.01	0.04	0.01	0.003	0.004
PACA	5.35	2.12	0.15	0.02	0.03	0.01	0.003	0.003
RHONE	6.98	2.48	0.14	0.02	0.03	0.01	0.005	0.003
SUD-OUEST	3.91	1.48	0.16	0.01	0.04	0.01	0.003	0.003
VAL DE LOIRE	4.90	2.42	0.16	0.02	0.03	0.01	0.003	0.002
CHAMPAGNE	37.53	15.36	0.08	0.06	0.00	0.021	0.07	0.37

Table 5 below presents the main results according to the way winegrowers value grape production for winemaking. Accordingly, we distinguish bulk, bottle and mixed (bulk and bottle) winegrowers. We find that all types of winegrowers are risk-averse. All risk attitude coefficients are lower than one and all ARA values are positive. However, we can observe differences between the Champagne basin and the other wine production regions. In the other basins, ARA values are the same, with no behavior differences between the modes of selling the production. However, if we consider the Champagne region, it can be noticed that growers bottling their wine are more risk-averse due to the higher value of their product. This result is confirmed by the higher ARA coefficient they obtained in comparison with other winegrowers (0.15 vs 0.04 or 0.07 respectively for bulk and mixed winegrowers). At the same time, they are willing to pay 50% of their wealth to avoid taking additional risks. Their expected profit is 52320 euros/ha€/ha[15].

Table 5: **Estimated means by type of winegrowers**

	Champagne basin								Others basins							
	μ_π		ARA		DRA		RRP		μ_π		ARA		DRA		RRP	
Wine Region	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
BULK	28.41	1.02	0.04	0.00	-0.00	0.00	0.00	0.00	6.81	2.70	0.14	0.02	0.03	0.01	0.00	0.00
BOTTLE	52.32	22.81	0.15	0.11	0.03	0.05	0.50	1.08	5.27	2.71	0.15	0.02	0.03	0.01	0.006	0.032
MIXED	35.98	13.34	0.07	0.04	0.00	0.00	0.03	0.08	6.66	2.93	0.14	0.02	0.03	0.01	0.008	0.010

Notes: ARA=absolute risk aversion; DRA=downside risk aversion; RRP=relative risk premium

The RRP values for bulk and mixed producers are respectively 0% and 3% in Champagne and 0% and 8% in the other basins. Bottling wine is the more integrated way to make profit from wine production by retaining the added-value within the wine firm. The higher the expected profit is, the more risk-averse winegrowers are. This is, however, only observable for a high profit range, as is the case here for Champagne[16].

Table 6 below reports the results of the risk attitudes by year. It can be noted that for all wine basins (except Champagne), the ARA mean values do not differ between years (unique value of 0.15). There is no difference regarding winegrowers attitude toward risk according to years despite very different epidemiologic pressures. In this respect, in 2007, for all French regions, we observed very high epidemiologic pressure for downy mildew (Plasmopara viticola) and relatively high pressure in 2006, while pressure was very low in years 2007, 2008, 2010

[15]The expected profit is x €/ha for bulk and y €/ha for mixed winegrowers.
[16]to discuss, usually high profit should be less risk adverse.

and 2013. Results appear to signify that winegrowers'risk aversion does not depend on years with their particularities such as climatic conditions, phytosanitary pressure or attacks from pests. We can also note no evidence of the regulatory push-pull effect expected after the Ecophyto plan set up in 2008 which was supposed to provide strong incentives to decrease pesticide use in French agriculture.

Table 6: **Estimated means by year**

	Champagne basin								Others basins							
	μ_π		ARA		DRA		RRP		μ_π		ARA		DRA		RRP	
Year	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
2005	43.82	13.07	0.10	0.06	0.01	0.02	0.10	0.29	5.55	3.24	0.15	0.03	0.03	0.01	0.005	0.007
2006	41.13	10.44	0.09	0.04	0.01	0.01	0.05	0.11	5.19	2.75	0.15	0.02	0.03	0.01	0.004	0.004
2007	54.36	17.04	0.15	0.09	0.01	0.01	0.05	0.11	5.45	2.38	0.15	0.02	0.03	0.01	0.004	0.004
2008	39.28	11.68	0.08	0.04	0.00	0.01	0.03	0.04	5.39	2.89	0.15	0.02	0.03	0.01	0.005	0.007
2009	27.25	11.79	0.04	0.03	0.00	0.00	0.00	0.02	5.30	2.35	0.15	0.02	0.03	0.01	0.014	0.090
2010	41.59	19.72	0.10	0.10	0.01	0.04	0.23	0.91	5.63	2.75	0.15	0.02	0.03	0.01	0.006	0.007
2011	37.74	10.63	0.07	0.04	0.00	0.01	0.03	0.04	5.83	3.19	0.15	0.02	0.03	0.01	0.005	0.004
2012	25.39	12.61	0.04	0.04	0.00	0.00	0.02	0.07	5.63	2.39	0.15	0.02	0.03	0.01	0.006	0.009
2013	31.90	12.64	0.06	0.04	0.00	0.01	0.03	0.08	5.12	2.57	0.15	0.02	0.03	0.01	0.006	0.006
2014	32.52	9.41	0.06	0.03	0.00	0.00	0.01	0.02	5.92	3.03	0.15	0.02	0.03	0.01	0.006	0.009
Mean	37.53		0.08		0.00		0.07		5.50		0.15		0.03		0.37	

Winegrowers risk aversion remained stable. Additionally, in the Champagne basin, high pressure from powdery mildew (Erysiphe necator) occurred in 2010 and 2006 with strong presence of vine moths in 2010. However, for Champagne, and only this region, we note differences in the mean ARA values (ranging from 0.04 to 0.15). If we refer to time, this could be partly explained by climatic/phytosanitary conditions of the year. Accordingly, 2010 has the highest ARA with 0.15. However, the very low level of ARA in 2006 (0.04) may suggest that other factors than phytosanitary concerns may play a role in risk aversion. One of them might be the mode of selling as presented above in Table 4 and particularly the reserve system between years, a system that is a special feature of the Champagne basin.

7 Conclusion

This paper presents an empirical analysis of winegrowers risk attitudes in France. One interesting feature of French viticulture is that most of the production is carried out under an appellation regime which bears constraints in terms of maximal yield authorized. We use a translog cost function under the constraint of the appellation yield. Cost share equations and the risk preferences function are estimated. Our dataset comprises the FADN database (2005-2014), data from the National Cultural Practices survey (2006, 2010, 2013), data from the French National Institute of Origin and Quality (INAO) and data from guides on production costs in viticulture and œnology (from 2005 to 2014). We find that pesticide demand is inelastic and all types of winegrowers are risk-averse. For the majority of them, risk aversion is declining with expected profit (DARA), but for the Champagne region, it is the contrary. Expected profit is far higher than in the other regions and the winegrowers are more averse to risk when the expected profit increases (IARA).

A Appendix

Table 7: **FIML estimation results**

		Champagne basin			Others basins		
Parameter	Variable	Estimated Coef.	S.D.	P-value	Estimated Coef.	S.D.	P-value
α_t	Time trend	0.00	0.00	0.50	0.01	0.00	< 0.0001
Share cost of pesticide							
α_p	Constant	56.53	12.72	< 0.0001	10.38	3.83	0.0069
α_{pp}	Pesticide price	4.82	1.17	< 0.0001	3.07	0.31	< 0.0001
α_{pe}	Fertiliser price	1.78	0.56	0.0019	0.81	0.07	< 0.0001
α_{pl}	Labour price	-6.61	1.58	< 0.0001	-3.89	0.33	< 0.0001
α_{py}	Output	-6.22	1.39	< 0.0001	- 0.99	0.42	0.0201
Share cost of fertilizer							
α_e	Constant	26.52	14.86	0.07	6.48	1.39	< 0.0001
α_{ep}	Pesticide price	1.78	0.56	0.00	0.81	0.07	< 0.0001
α_{ee}	Fertiliser price	3.69	0.77	< 0.0001	0.58	0.06	< 0.0001
α_{el}	Labour price	-5.47	0.90	< 0.0001	-1.40	0.12	< 0.0001
α_{ey}	Output	-2.82	1.58	0.07	0.0600	0.013	< 0.0001
ARA function							
d_0		0.00	0.00	< 0.0001	0.20	0.00	< 0.0001
d_1		0.00	0.00	< 0.0001	- 0.01	0.00	< 0.0001
d_2		0.00	0.00	< 0.0001	0.00	0.00	< 0.0001
γ		1.95	0.03	< 0.0001	3.50	0.00	< 0.0001

Table 8: **Price index of fertilizers and pesticides**

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fer. price index	77.92	82.05	91.42	139.03	115.8	100	123.26	128.99	122.58	116.82
Pes. price index[17]	86.1	87.32	90.89	95.01	100.85	100	101.29	100.94	99.66	100.65

Source: French National Institute of Statistics and Economic Studies (INSEE) database

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