ESTIMATING A PRODUCTION FUNCTION UNDER PRODUCTION AND PRICE RISKS:

AN APPLICATION TO THE SUCKLER COW FARMS IN THE FRENCH CHAROLAIS PRODUCTION AREA

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ESTIMATING A PRODUCTION FUNCTION UNDER PRODUCTION AND PRICE RISKS:

AN APPLICATION TO THE SUCKLER COW FARMS IN THE FRENCH CHAROLAIS PRODUCTION AREA

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Abstract

Suckler cow production in France relies mainly on a relatively extensive management of forage, implying that production risk may be enhanced by the sensitivity of those crops to weather variability. However risk exposure is supposed to be mitigated either through ex-ante decisions concerning pasture area management or through ex-post decisions concerning the purchase of feeds. This paper aims at assessing weather impacts on cattle production level decisions.

Since farmers' decisions depend on farmers' behaviour regarding risks, which are namely production and price risks, we test constant absolute risk aversion, constant relative risk aversion and risk neutrality assumptions. We develop an econometric model encompassing an auto-regressive price function and a production function which allow inputs to affect independently mean and variance of the production. Weather indicators embodied by average regional forage production for current and past years are explicitely introduced as non controllable inputs. The estimation framework consist in conditions on the first and seconf moment of output production, output price and profit. Following, ISIK (2003), additional condition on each of both allocable inputs enable us to take into account risk aversion and both price and production risks in parameters estimation. We use the Generalized Method of Moments in order to make minimum assumptions regarding variable exogeneity and error distribution.

We apply the model to an original panel dataset containing 65 individual yearly observations recorded over the period 1987-2005 on French suckler cow farms of the north of Massif Central. Because of the difficulties to find a relevant set of instruments, these preliminary results do not analyse weather impact on production mean. However we can advance that production decisions depend on price and production risks as farmers are found to be risk averse. Weather variability of the current year increase production risk whereas fertilizer level application slightly increased it. However we did not highlight that weather impact depend on production level.

Keywords

Production function estimation, GMM, weather impact, price and production risks, risk aversion, suckler cow farms, French charolais production area

1 Introduction.

Suckler cow systems consist in calves raising with their mother's milk in order to produce meat. The alimentary needs of the herd are satisfied predominantly through pasture grazing and self produced conserved forages. Regarding their key functions in beef production, rural development and environment protection, it is on public authority's interest to try maintaining these systems sustainable. The 4.3 millions of French suckler cows owned by the 113 000 farms[1], predominantly located in areas where few economical alternatives to livestock farming exist (JAMBOU AND AL, 2001), represent indeed more than one third of all European suckler cows and supply around 60% of the beef production in France. Moreover, their relative extensive management system helps maintaining large areas under grassland which favours biodiversity and limit pollution and erosion (LE GOFFE, 2003). Improving farms' sustainability is monitored not only by controlling farmers' practice or supporting investment but also by ensuring that farms' income remains stable enough regarding risks. Until now, agricultural policy has played a central role in risk management providing market support tools and insurance tools. On one hand, the Common Agricultural Policy (CAP) has controlled beef and veal price fluctuations by constraining prices between a bottom and a ceiling level through intervention mechanisms and subsidized exportations. On the other hand, most of weather hazard damages have been compensated by public insurance funds such as the public FNGCA fund. According to BOYER (2006), half of the French fund is allocated to herbivorous farms and corresponds to damages caused by drought on forages, mainly in the Massif Central area. This reveals the sensitivity of these animal farms to weather hazards. However, current public schemes are to evolve and some optimal combinations of risk management tools mixing on-farm management strategies, private insurance or financial markets have to be found. As a result, it is important for decision makers to assess impacts of price and weather hazards on production and of related risks to farmers' decisions.

The issue addressed in this paper is then to estimate if the weather variability impacts on animal production decisions, in suckler cow farms, which are supposed to depend on price and production risks.

Some prior studies based on mathematical programming have focused either on weather variability impacts on meat and forage production according to agricultural practice or on animal production decisions according to weather risk (GILLARD, 1990; KINGSWELL, 1993; DIAZ-SOLIS 2005). However, if programming methods give valuable insights of potential weather impacts on production and on decisions, as mentioned by JUST (2003b), their implications can not be tested statistically. Econometric models of production are based on statistical inference on historical data and enable then to draw input-output relationships upon a panel data. To date, if some studies have estimated weather impacts on production distribution, they deal exclusively with crop production (CHEN, 2005; ISIK, 2006). Isik and al (2006) found for instance that temperature increases mean yield of most of the studied crops and decrease their variance. They use then estimated function to draw inferences about potential effects of climate change on crop yields. Contrary to crop production, in suckler cow production, the weather dependant variable –forage production- is an intermediary product. Adjustment of input levels and adaptation capacity of the animals may then induce particular pattern of weather responses. Moreover, we are not only interested in weather impacts on production but also on overall risks impacts on production decisions. Until now, very few studies have taken into account risk preference under both production and price risks to estimate production function parameters, except for ISIK (2003). Moreover, none have until now, simultaneously taken into account weather impacts, two sources of risks and the

[1] source RICA 1991

possibility of endogeneity for some explanatory variables (correlation of explanatory variables to the production error term).

We propose to develop an econometric model of production under price and production risks, taking into account weather variability in order to 1) determine if weather variability impact on mean production and production risk, 2) assess if more intensive production systems are more sensitive to weather variability and eventually 3) test if production decisions depend on farmers' risk aversion to price and production uncertainty.

The remaining of this article is organized as follows. We explain the method in the fist section where we discuss first the specificities of weather impacts and production decisions in suckler cow farms and then detail the econometric framework. In the following one, we apply this framework to a panel dataset containing 65 farm observed over the period 1987-2005, we described thus the data and expose results of the econometric model. Eventually, we discuss our method and results.

2 Method

2.2 Conceptual framework of weather impact on production decisions under risks in suckler cow systems

Random events are source of uncertainty which is defined by HARDAKER AND AL (2004) as the imperfect knowledge of the future. Their uncertain consequences constitute a risk that may differ according to farmer's decisions and farms characteristics. Consequently, risk matters in farmer's production decisions if risk distribution is sufficiently known, if decisions may modify risk exposure and if farmers fear production or income losses.

Farmers' decisions related to animal production encompass variable inputs levels and investments. Main variable input decisions concern animal feeding decisions which can be divided into inputs on fodder areas such as seeds, fertilizer or labour and animal feed purchased. Efficiency of inputs can be modified by farms' heterogeneity which can stem from management practices (LIÉNARD AND LHERM, 1986), location characteristics, structural assets or farmers' skills. Moreover, the final production depends on random events. Main risks in beef production are related to output price and to output production.

First, most of animals are sold at market price. Revenue from meat sales is then highly dependant on price fluctuation. In addition to their variability, farmers have to take into account the successive PAC reforms that have caused a declining trend for animal price over the last decades. To lessen risk exposure, few ex-post decisions are possible, though, limited expenditures appear as a possible strategie which can impact on farmers' variable input decisions. Second, random animal biological phenomena are diverse: the number of animals and their effective weight gain varies according random animal genotypic characteristics, parasites and disease occurrence and success of the reproduction process. However, output production risks come not only from source of uncertainty affecting animal biology but also from uncertainty related to forage production. Final forage production depends on random weather conditions, weed invasions and pasture pathogen appearances. We see then that production is subject to numerous sources of uncertainties. In order to study weather impact it will be necessary to isolate its effects.

Variable input decisions related to the feeding system may decrease production risk by different ways. It is broadly admitted for instance that the success of mating is modified by body condition of cows (BLANC, AGABRIEL, 2006) or crop production risk may depend on fertilizer and pesticide applications (JUST AND AL, 1979). Within suckler cows systems, production risks related to weather uncertainty is rather complex as meat production is not necessarily directly affected. Risk of forage shortage linked to weather uncertainty is supposed to be mitigated either through ex-ante decisions or through ex-post decisions. First, anticipations could consist in under utilization of pasture potential in "normal climatic year" in order to withdraw part of the forage produced to constitute fodder stock safety for the following year and to be able to improve potential yield the following year in order to reconstitute forage stock by fertilizing more. Crop diversification and varieties characteristics may also allow better resistance to some weather hazards. Second, in case of feed supply shortage, animals are able to cope temporary with underfeeding without tremendous effect on production, under certain conditions. Suckler cows for instance may use their corporal reserve to support their pregnancy and milk production needs (BLANC, 2004). In the same way, compensatory growth enable stored animals to compensate partially or totally their slightest growth provided that after there is a long enough period where feed is not restrictive (HOCH AND AL, 2003). Another solution is to buy more fodder or concentrate feeds that was planned initially (POTTIER AND AL, 2007). This latter avoids or at least limits underfeeding and production diminution but necessitates additional expenditures to purchase feed supply. We have then to test wether in spite of all these adjustments possibilities weather of the current and past year significantly impacts on animal production and if its impact are directly linked to input use.

2.3 The econometric model

- *Overview*

To understand farmers' production decisions, we assess farmers' behaviour regarding risk preference testing successively a constant absolute risk aversion, constant relative risk aversion and risk neutrality assumptions. We consider two sources of uncertainty –price and production– and we adapt the framework developed by ISIK (2002) to suckler cow production. An auto-regressive price function is chosen to reflect price anticipations by farmers (adaptative anticipations). We use a JUST AND POPE'S production function (1978) considering that variable input decisions affect both the deterministic and the stochastic part of production functions. Variable representing the weather conditions for both the current and the previous years are explicitly introduced as explanatory variables in order to capture weather impact on both mean and variance of production. We extend the literature using the Just and Pope approach by introducing the possibility of endogeneity for some explanatory variables (SHANKAR AND NELSON, 2003). To do so, we estimate the econometric model using an instrumental method based on the iterative generalized method of moments (WOOLDRIDGE, 2002).

- *Production under risks: a mean-variance function approach*

Random variables are characterized by a probability distribution. This distribution is defined by its functional form but the choice of a functional form is usually not obvious. Hence the estimation may suffer from a misspecification of the model (KIM AND CHAVAS, 2002). The distribution function can be summarized by its central moments. We concentrate our analysis on the first two moments of the distribution. Although, it is criticized as it overlooks higher moments and implies that the random variable is normally distributed (ANTLE, 1983, APPELBAUM AND ULLAH, 1997), the two moments approach increases the estimation procedure efficiency as noticed by SHANKAR AND NELSON (2003). Concerning output distribution, defining the way inputs may affect not only the mean but also higher moment orders are at stake in order to better understand farmers' input decisions. We consider then the framework proposed by JUST AND POPE (1978) which consists in appending an additive heteroscedastic variance term to the deterministic mean function (1). This variance specification form allows inputs to impact independently on the mean and on the variance of output. Derived elasticities of variance can be interpreted as risk increasing / decreasing input.

$$y_{it} = f(X_{it}, \beta) + h(X_{it}, \gamma)\varepsilon_{it}$$

With *i = 1,2,...N and t = 1,2,..., T* respectively index to farmers and time, x_{it} is a *K* vector of explanatory variables for mean output and output variance; *β* and *γ* two vectors of parameters respectively associated to the explanatory variables of mean output and output variance, ε_{it} is an error term with variance $h(x_{it,}\gamma)$. (1)

As we aim at explicitly testing weather impact on production distribution, we can not simply add a random time effect as done in JUST AND POPE (1999) or GRIFFITH AND AL (). This latter overcomes multi collinearity effects caused by contemporaneous weather events but do not estimate weather impacts. Weather has then to be introduced as an explanatory variable. CHEN AND AL. (2005) and ISIK AND AL. (2006) introduced rainfall and temperature in both mean and variance of output of the Just and Pope production function. We follow the principle of adding current and past year weather indicators as non controllable inputs. We test as well cross effect of weather indicators and input levels in order to study input levels effects on weather impacts. We have chosen classical linear quadratic functional forms for *f(.)* and *h(.)* functions as:

$$f[X_{it};C_t,] = \begin{cases} \beta_0 + (\beta_1 + \beta_{1c1}C_{1,t} + \beta_{1c2}C_{2,t})X_{1,it} + (\beta_2 + \beta_{2c1}C_{1,t} + \beta_{2c2}C_{2,t})X_{2,it} \\ . \quad + \beta_{11}X_{1,it}^2 + \beta_{22}X_{1,it}^2 + \beta_{12}X_{1,it}X_{2,it} \\ + \beta_{c1} * C_{1,t} + \beta_{c2} * C_{2,t} \end{cases} \quad (2)$$

$$h[X_{it};C_t,] = \begin{cases} (\gamma_1 + \gamma_{1c1}C_{1,t} + \gamma_{1c2}C_{2,t})X_{1,it} + (\gamma_2 + \gamma_{2c1}C_{1,t} + \gamma_{2c2}C_{2,t})X_{2,it} \\ + \gamma_{11}X_{1,it}^2 + \gamma_{22}X_{1,it}^2 + \gamma_{12}X_{1,it}X_{2,it} \\ + \gamma_{c1}C_{1,t} + \gamma_{c2}C_{2,t} \end{cases} \quad (3)$$

where X_1 and X_2 are two allocable inputs, C_1 and C_2 two weather indicators for previous and current year.

- *Price risk: an autoregressive anticipation*

We choose a classical linear autoregressive process for output price expectation function:

$$P_t = \alpha_1 P_{t-1} + \sigma_\theta$$

with P_t the current observed price, P_{t-1} the price at the previous period, α_1 a parameter and σ_θ the homoscedastic variance (4)

Such an autoregressive process reflects adaptative behaviours of farmers, and quite plausible assumptions for French farmers.

- *Specifying farmer's risk preferences*

The utility of wealth depend on farmer' risk preference. The more risk averse is a farmer, the more the expected return must be to forgo for a reduction in risk. This forgone part of expected profit is also called the marginal risk premium. Risk aversion is reflected by the curvature the utility function. The Arrow-Pratt absolute risk-aversion function *Φ* is then defined as follow:

$$\phi_a(W) = -\frac{U''(W)}{U'(W)} \tag{5}$$

with *U'* and *U"* respectively the first and second derivatives of the utility function and *W* the wealth.

The absolute risk aversion may decrease with wealth (DARA), may be constant with wealth (CARA) or may increase with wealth (IARA). In the case of "CARA" preference, a farmer will not modify his attitude toward risk if a constant amount of money is added (such as decoupled subsidies) or subtracted (such as taxes) from his total payoffs. In the DARA case, farmers are supposed to better afford to take risk as they get richer. The relative aversion risk function (CRRA, IRRA or DRRA), defined as follow, uncovers how farmer's decisions are affected if all payoffs are multiplied by a positive constant:

$$\phi_r(W) = W * \phi_a(W) \tag{6}$$

In this paper we consider three preference structures -risk neutrality (equation 7), CARA (eq. 8) and CRRA (eq. 9)- in order to test first if production decisions are affected by production and price risks and second if these decisions are affected by farmers' wealth.

$$\phi_{it} = \frac{\phi_1}{W_{it}} \quad \text{if constant relative risk aversion} \tag{7}$$

$$\phi_{it} = \phi_0 \quad \text{if constant absolute risk aversion} \tag{8}$$

$$\phi_{it} = 0 \quad \text{if risk neutrality} \tag{9}$$

- *The Farmer's optimization program*

Having specified the production function and the farmer's preference, we can proceed to the derivation of the farmer's optimization paragraph, following ISIK (2003). We consider a risk-averse farmer facing both production uncertainty (typically related to weather uncertainty) and output price uncertainty.

The objective function of the farmer under uncertainty consists in maximizing the expected utility of its wealth, where the expectation must be taken with respect to the distribution of all stochastic variables (prices, outputs…). The wealth can be considered as the sum of initial non random wealth plus random current period profit (CHAVAS AND POPE, 1985; COYLE, 1999) or simply as current period profit. However, there is no consensus on what an appropriate measure of initial wealth might be (SHANKAR AND NELSON, 2003). The problem of the farmer writes:

$$\max_x EU\{W\} = EU\{W_0 + (\bar{P}+\theta)\cdot(f(x)+h(x)\varepsilon) - rx\} \tag{10}$$

where for simplicity we have suppressed time and individual indexes.

In (10), θ is an error term affecting the average output price, *x* represents the vector of input quantities and *r* the vector of input prices. Assuming that the second-order condition is satisfied by the parameters of the model, the optimal use of *x* is given by the following first-order condition:

$$\frac{\partial U}{\partial x} = EU\{U_W(W)[(\bar{P}+\theta)\cdot(f_x(x)+h_x(x)\varepsilon) - r\} = 0 \tag{11}$$

where f_x and h_x respectively denote derivatives of *f* and *h* with respect to *x*.

Next, we approximate U_W around the expected post-risk wealth using a Taylor series expansion. We get:

$$U_W(W) = U_W(\bar{W}) + \left\{\bar{P}h(x)\varepsilon + \theta \cdot (f(x) + h(x)\varepsilon)\right\} U_{WW}(\bar{W}) \tag{12}$$

Combining the Taylor series expansion and the previous equation, we can rewrite the first-order condition as:

$$\frac{1}{U_W(\bar{W})}\frac{\partial U}{\partial x} = E\left\{\left[1 - \Phi\left(\bar{P}h(x)\varepsilon + \theta \cdot (f(x) + h(x)\varepsilon)\right)\right] \cdot \left[(\bar{P} + \theta)\left(f_x(x) + h_x(x)\varepsilon\right) - \right.\right. \tag{13}$$

which exactly corresponds to equation (4) in ISIK (2003). Rearranging this condition gives:

$$\begin{aligned}\frac{1}{U_W(\bar{W})}\frac{\partial U}{\partial x} = {} & \bar{P}f_x + h_x E(\theta\varepsilon) - r - \Phi\left\{\bar{P}^2 h h_x \sigma_\varepsilon^2 + f f_x \sigma_\theta^2 + E(\theta\varepsilon)\left[2\bar{P}hf_x + \bar{P}fh_x - hr\right.\right. \\ & \left.\left. + E(\varepsilon^2\theta)\left[2\bar{P}hh_x\right] + E(\varepsilon\theta^2)\left[fh_x + f_x h\right] + E(\varepsilon^2\theta^2)\left[hh_x\right]\right]\right\}\end{aligned} \tag{14}$$

Using the Bohrnsted and Golberger's method for the covariance of products of random variables on the previous condition leads to:

$$\begin{aligned}\frac{1}{U_W(\bar{W})}\frac{\partial U}{\partial x} = {} & \bar{P}f_x - h_x C(\varepsilon,\theta) - r - \Phi\left\{\bar{P}^2 h h_x \sigma_\varepsilon^2 + f f_x \sigma_\theta^2\right. \\ & \left. + C(\varepsilon,\theta)\left[-2Phf_x - Pfh_x + hr\right] + hh_x\left(\sigma_\varepsilon^2\sigma_\theta^2 - 2C(\varepsilon,\theta)^2\right)\right\}\end{aligned} \tag{15}$$

Assuming the statistical independence between ε and θ leads to :

$$\bar{P}_{it} f_x(x_{it};\beta) = \frac{\phi_{it} h(x_{it};\gamma) h_x(x_{it};\gamma)\sigma_\varepsilon^2\left(\bar{P}_{it}^2 + \sigma_\theta^2\right) + r_{it}}{1 - \left[\phi_{it}\sigma_\theta^2 f(x_{it};\beta)/\bar{P}_{it}\right]},$$

where f_x and h_x respectively denote derivatives of *f* and *h* with respect to x_{it}, (16)
input price is r_{it}, output price P_{it} with *var (Pit)=*σ^2_θ, and Φ_{it} is the absolute Arrow-Pratt coefficient of risk aversion, where $\bar{W}_{it}$ is expected profit and U_i is farmer *i* utility function.

- *The estimation procedure*

A problem that must be addressed by the estimation method concerns the possible endogeneity of some explanatory variables. There are two main reasons as discussed in SHANKAR AND NELSON (2003) for inputs to be correlated with production error terms. First, some inputs may be correlated with the unobserved heterogeneity (often interpreted as the technical efficiency of the production function) of the error term. Second, in agriculture, some input-related decisions taken by farmers may be viewed as sequential within a season (see ANTLE, 1983). This is typically the case for irrigation or pesticides which may be used in response to sequentially updated information on water stress or infestations. Antle shows that consistent separate technology estimation is possible only if data on each stage within the season is available. Another way to deal with the endogeneity issue is to use the instrumental variable approach based on the principle of generalized method of moment (GMM) which allow estimating parameters when maximum likelihood estimation requires nonlinear optimization (WOOLDRIDGE, 2002). GMM estimators are known to be strongly consistent, asymptotically normal, and they require minimal assumptions about exogenous variables (FUHRER and al, 1995) contrary to maximum likelihood estimation which necessitates making distributional assumptions about random errors (TAUCHEN, 1986). By this estimation method, observed variables X can be exogenous or endogenous from a statistical point of view that is, they may be correlated with error terms in the final estimating equations.

Suppose we observe exogenous variables denoted W_{it}, a L vector, such that the complete model can be written as a set of exogeneity restrictions as follows:

$$E\left\{\left[P-\bar{P}\right]W\right\}=E\left[\theta|W\right]=0 \tag{17}$$

$$\text{Var}\left\{\left[P-\bar{P}\right]W\right\}-\sigma^2{}_\theta=0 \tag{18}$$

$$E\left\{\left[y-f\right]W\right\}=0 \tag{19}$$

$$Var\left\{\left[y-f\right]W\right\}=0 \tag{20}$$

$$\text{E}\left\{\left[\left(Py-r1x_1-r2x_2\right)-\left(\bar{P}+\sigma_\theta\right)\left(f+h\right)+r1x_1+r2x_2\right]W\right\}=0 \tag{21}$$

$$\text{Var}\left\{\left[\left(Py-r1x_1-r2x_2\right)-\left(\bar{P}+\sigma_\theta\right)\left(f+h\right)+r1x_1+r2x_2\right]W\right\}=0 \tag{22}$$

$$\text{E}\left\{\left[r1-\bar{P}f_{x1}\left\{1-\frac{\phi\sigma_\theta^2 f}{\bar{P}}\right\}\right]+\phi*h*h_{x1}*\sigma_\varepsilon^2\left(\bar{P}^2+\sigma_\theta^2\right)\middle|W\right\}=0 \tag{23}$$

$$\text{E}\left\{\left[r2-\bar{P}f_{x2}\left\{1-\frac{\phi\sigma_\theta^2 f}{\bar{P}}\right\}\right]+\phi*h*h_{x2}*\sigma_\varepsilon^2\left(\bar{P}^2+\sigma_\theta^2\right)\middle|W\right\}=0 \tag{24}$$

*)to ease lecture indexes for farm i and time t have been removed

The first two equations in (17, 18) concern the first- and second-order moments of the distribution of output price. The third and fourth equations (19, 20) refer to the first and second order moments of the distribution of output. The fifth and sixth equations (21-22) are conditions on the first and second order moment of the profit. Equations (23) and (24) are application of previous equation 16 of ISIK (2003) specifying relationships between input level decision on the one hand and on the other hand price and production mean and variance functions, farmer' s risk aversion and to input price. These structural equations explicitly indicate the (non linear) relationship between endogenous and exogenous variables. The basis of the GMM (Generalized Method of Moments, Hansen 1982) estimation method is as follows. Conditioning on *W* means that structural equations in (17-22) above should be uncorrelated with any function of *W*. A necessary condition is thus that *W* itself should not be correlated with structural equations. In the GMM framework, exogeneity conditions constructed from the products between structural equations and *W* are replaced by empirical means.

Let $\xi_{it}, j=1,...,8$ denotes error terms associated with the six equations in the system above. We have

$$E\left(\xi'_{jit}W_{it}\right)=0\approx\sum_{i,t}^{N,T}\xi'_{jit}W_{it},\forall j=1,...8 \tag{25}$$

$$\xi_{1it} = P_{it} - \overline{P}_{it} \tag{26}$$

$$\xi_{2it} = \left[P_{it} - \overline{P}_{it}\right]^2 - \sigma^2{}_\theta \tag{27}$$

$$\xi_{3it} = y_{it} - f(X_{it}, \beta) \tag{28}$$

$$\xi_{4it} = \left[y_{it} - f(X_{it}, \beta)\right]^2 - \sigma_\varepsilon^2 * h^2 \tag{29}$$

$$\xi_{5it} = \Pi - \left(Pf(X_{it}, \beta) - r1x_{1it} - r2x_{2it}\right) \tag{30}$$

$$\xi_{6it} = \left[(Py - r1x_{1it} - r2x_{2it}) - (\overline{P}f - r1x_{1it} - r2x_{2it})\right]^2 - \overline{P}^2h^2\sigma_\varepsilon^2 + f^2\sigma_\theta^2 + h^2\sigma_\varepsilon^2\sigma_\theta^2 \tag{31}$$

$$\xi_{7\text{it}} = r1_{it} - \overline{P}_{it} f_{x1}(X_{it}, \beta)\left\{1 - \frac{\phi_{it}\sigma_\theta^2 f(X_{it}, \beta)}{\overline{P}_{it}}\right\} + \phi_{it} h(X_{it}, \gamma) h_{x1}(X_{it}, \gamma)\sigma_\varepsilon^2\left(\overline{P}_{it}^2 + \sigma_\theta^2\right) \tag{32}$$

$$\xi_{8\text{it}} = r2_{it} - \overline{P}_{it} f_{x2}(X_{it}, \beta)\left\{1 - \frac{\phi_{it}\sigma_\theta^2 f(X_{it}, \beta)}{\overline{P}_{it}}\right\} + \phi_{it} h(X_{it}, \gamma) h_{x2}(X_{it}, \gamma)\sigma_\varepsilon^2\left(\overline{P}_{it}^2 + \sigma_\theta^2\right) \tag{33}$$

The complete system for GMM hence consists in $8 \times \text{L}$ of orthogonality conditions, and the criterion to minimize for obtaining optimal GMM estimates is of the following form:

$$\left(\frac{1}{\sqrt{NT}}\sum_{i,t}^{N,T}\xi'_{it}\tilde{W}_{it}\right)\left[Var\left(\frac{1}{\sqrt{NT}}\sum_{i,t}^{N,T}\tilde{W}'_{it}\xi_{it}\right)\right]^{-1}\left(\frac{1}{\sqrt{NT}}\sum_{i,t}^{N,T}\tilde{W}'_{it}\,\xi_{it}\right), \tag{30}$$

where $\xi_{it} = (\xi_{1t}, \ldots \xi_{8t})'$ and $\tilde{W}_{it} = W_{it} \otimes I_8$

The $(8L \times 8\text{L})$ variance matrix of orthogonality conditions can be estimated from first-step parameter estimates:

$$Var\left(\frac{1}{\sqrt{NT}}\sum_{i,t}^{N,T}\tilde{W}'_{it}\xi_{it}\right) \simeq \frac{1}{NT}\sum_{i,t}^{N,T}\tilde{W}'_{it}\left(\hat{\xi}_{it}\hat{\xi}'_{it}\right)\tilde{W}_{it} \tag{31}$$

Where $\hat{\xi}_{it}$ is computed from preliminary parameter estimates.

The resulting two-step parameter estimates are asymptotically normally distributed under the null hypothesis $H_0 : E\left(\xi'_j W\right) = 0, \forall j = 1,2,...,8$. This assumption can be easily tested by comparing the GMM criterion value with the tabulated chi-square distribution with for degrees of freedom the number of over-identifying restrictions (*8L-K*).

3 Application

3.2 The dataset

The database of the INRA research unit of livestock economics, situated in Clermont-Ferrand-Theix, France, contains technical and economical yearly records of farms specialized in charolais suckler cow production in the North of Massif Central. A panel of 65 individual observations over the period 1987-2005 is extracted from this database. Farms' variables related to the total animal live weight gain, to fodder fertilizer quantity and expenditure, to the additional quantity of feed purchased and to the corresponding expenditure are used to estimate the econometric model. Weather indicators as well as animal price indicators, calculated from national statistics, are added to the dataset.

- *Description of the 65 farms studied over the period 1987-2005*

The 65 farms are located in five "départements" in the herbaceous north of Massif Central within the "Bassin charolais" area. This grazier 'Bassin' is characterized by a semi continental climate and a rather hilly and hedged landscape. This area is still highly dedicated to suckler cow production of the breed "charolais". Farms specialized in beef cattle production account for 60% of the professional farms of the area. They are generally larger than other farms, and present a rather extensive management with 80% of farms having a stocking rate between 0.8 and 1.4 (DUSSOL, 2003).

Compared to the area statistics (table 1), in 2002, farms studied are larger with a higher number of worker units per farm, with a larger useable farm area (UFA), number of cows and number of livestock units (LU). This is due to the initial strategy of sampling of the research unit who focused first on farms slightly larger than the average. However, farms characteristics per worker unit are sensibly equivalent and the stocking rate, although higher, remains synonymous of extensive management.

Table 1: Main characteristics of suckler cow farms in 2002 within the dataset and according to the RICA assessment for the OTEX 42 of Bourgogne.

	dataset°	RICA
WU	2.1	1.57
UFA/farm	152	111
UFA/WU	74	71
MFA/UFA	84	0.91
Number of cows /farms	88	65
LU/farm	175	127
LU/WU	78	81
Stocking Rate	1.3	1.2

*) with WU :worker unit, UFA: useable farm area, MFA: main fodder area, LU: livestock unit

Source: °Own calculations, + RICA OTEX 42 Bourgogne 2002

Average values of the 65 farms and 19 years hide strong trends and important heterogeneity between farms and years (table2).

Main trends are farms enlargement –UFA and LU have been multiplied by around 1.4 between 1987 and 2005-, and production evolution toward the sale of younger animals –LU/cow decreases in average by 3.5% per year-. Regarding gross margin, while the per hectare observations present a low decreasing trend, the per-worker ones has been multiplied by 1.4 between 1987 and 2005. This demonstrates that gross margin per WU increase is essentially due to the farm enlargement. In instances time series standard deviation is high whereas trend is low, between years variations are essentially due to inter year random fluctuations. This is the case for net profit per worker unit or for the gross margin per ha. This seems rather consistent with the fact that they depend on price and production which are supposed to fluctuate contrary to structural characteristics which correspond to long term investment. Farm heterogeneity can be characterized by cross sectional standard deviation divided by panel mean. The main sources of heterogeneity emphasized here concern the largeness of farms, their mean income and above all their production orientation regarding the ratio between the sale of finished animals and stored animals which varies of 72% across farms. Moreover, concerning farm size, cross sectional standard deviation goes up through time emphasizing their different enlargement trajectories.

Table 2: panel dataset characteristics

		Panel mean	Cross sectional standard deviation*		Time series standard deviation*		Annual trend*	
Structural	WU**	2.09	0.68	(33%)	0.04	(2%)	0.004	(0.2%)
	UFA/WU**	69	19	(28%)	7	(10%)	1.23	(1.8%)
	MFA/WU**	55	14	(25%)	9	(23%)	17	(24%)
	Cows/WU**	39	6	(11%)	5	(13%)	7	(10%)
	LU/WU**	71	1.1	(2%)	0.86	(2.2%)	1.27	(1.8%)
Economical	Net profit/WU**	20500	6400	(31%)	3100	(15%)	60	(0.3%)
	GMb/WU**	41400	10500	(25%)	5200	(13%)	700	(1.7%)
	GMb/ha**	760	120	(16%)	74	(10%)	-4	(-0.5%)
Production system	GMb/GMg**	0.72	0.13	(18%)	0.03	(4%)	0.0003	/
	LU/Cow**	1.78	0.21	(12%)	0.05	(3%)	-0.006	(-3.5%)
	Percentage of finished animals sold	44	32	(73%)	3	(7%)	-0. 3	(-0.7%)

*)between parenthesis standard deviation divided by panel mean

**)with WU worker unit, UFA: useable farm area, MFA: main fodder area, LU livestock unit, GMb: gross margin from beef production, ha hectare of fodder GMg: total gross margin (including others activities)

Source: Own calculations

- *Description of the variable used in the estimations*

The output corresponds to the weight of live animals produced per unit surface of fodder area (kg per ha), see table 3. This variable enables us to take into account both the stocking rate per hectare of fodder areas and the weight gain rate per animal. Animals not sold within the current year are included in this indicator. Notice that we have aggregated into single variables the weight of live animals, whatever the animal type considered. The annual beef price index calculated by the National Institute of Economical Statistics (INSEE) is used as the associated output price.

We make the distinction between two kinds of inputs: those related to forage production and those corresponding to feed purchased. We assume that the forage production intensification can be measured by the fertilization level per hectare. As a result, we consider the nitrogen quantity applied on the main fodder area (kg per ha) as our first input. Feeds purchased by the farmer correspond to a large extent to concentrate feeds such as cereals, commercial feeds or soybean meals. Actually, cereals can equally be bought or be self-produced. However, we consider here, since cereals have a commercial value and since they do not depend on forage productivity, that they are separable from livestock production. To a lesser extent, purchased forage is taken into account. This indicator aggregates all feeds that do not come from farms' fodder area production. Concentrate and forage bought per hectare of fodder area are aggregated according to their relative price.

Between year weather variability can be estimated through an aggregated indicator of yearly average forage production. By this way, effects of temperature and rainfall according to the period are simultaneously taken into account. We use statistics from the Department of agriculture (Agreste) that proposes an estimation of forage production per hectare at the "department" level. Two indicators are defined for our econometric model: the current and the previous year forage production.

Concerning the CRRA preference function, we have to decide which variables are the most relevant to represent farmer's wealth. We hypothesize that the forage area available per LU may modify farmers' attitude toward production intensity decision. Farmers may be more likely to increase production intensity per hectare when fodder area per worker unit is more limited. As we have seen previously the area increases a lot with years but farmer's behaviour is supposed constant through time. We test then the mean fodder area per farms, which is well correlated to cross sectional farms' profit, as an indicator of farm wealth.

Estimation of preliminary results

To ease computational process, thanks to the assumption of independence between production risk and price risk, the model is estimated within a two stage approach: first, the price function parameters are estimated through orthogonality conditions ξ_{1it} and ξ_{2it} (equations 26 and 27). Then the parameters estimated are introduced within the overall framework as fixed parameters. The remaining parameters are then estimated in a second stage using four orthogonality conditions $\xi_{3it}, \xi_{6it}, \xi_{7it}, \xi_{8it}$ (equations 28, 31, 32, 33) on output distribution, profit and input levels. Conditions ξ_{4it}, ξ_{5it} (equations 29, 30) on variance of production and on mean profit have been withdrawn from the overall orthogonality conditions in order to meet the Hansen Test. Moreover, to temporary overcome convergence problems, we simplified the mean production removing weather variables. Weather impacts are then analysed at this stage of the study through production variance analysis.

Table 3: descriptive statistics of the variable used in the estimations

		Panel mean	Cross section standard deviation*		Time series standard deviation*		Annual trend*	
output	Y = Kg of live animals per ha	396	80	(4%)	17	(20%)	1,6	(0,4%)
	Price of Y	1,89	/	/	0,39	(21%)	-0,064	(-3,4%)
input	X_1= Units of nitrogen per ha	35,0	24,4	*(70%)*	4,33	*(21%)*	-0,38	*(-1%)*
	R1 =Price of X_1	2,07	1,6	*(77%)*	0,44	*(14%)*	-0,004	*(0,1%)*
	X_2= Kg of feed purchased per ha	799	345	*(43%)*	111	*(21%)*	18	*(2,3%)*
	R2 =Price of X_2	0,19	0,02	*(11%)*	0,04	*(12%)*	-0,0065	*(-3,4%)*
Weather	regional forage production in 100 kg of dry matter per ha for the previous year (C1) and for the current year (=C2)	46	/	/	9,4	(21%)	0,0743	(-0,2%)
Wealth	MFA/WU	55	14	(25%)	/	/	/	/

*between parenthesis standard deviation divided by panel mean

with **WU worker unit, **UFA**: useable farm area, **MFA**: main fodder area, **LU** livestock unit, **GMb**: gross margin from beef production,ha hectare of fodder **GMg**: total gross margin (including others activities)

Instruments used encompass past inputs and squares lagged inputs, lagged output price, time and some other farms characteristics. Two instruments have been employed in the first stage, and 12 in the second one. We have two equations with 2 parameters to be estimated in the first stage and four equations in the second one totalling 17 parameters. Since the number of orthogonality conditions *r* (respectively 4 and 48 for the first and second stage) is greater than the number of parameters to be estimated *p*, we test if the model is not over identified using an Hansen test[2]. As shown in table 3, the risk neutral scenario model is then rejected. Moreover, for both CARA and CRRA assumptions, the estimated model fit the data quite well, as revealed by the adjusted R^2 calculated for each equation by regressing predicted on observed values. In spite of significant coefficient values for price, production and profit equations, the second order conditions on r1 and r2 poorly accounts for their variability.

Table 4: Hansen test and coefficient of determination according to risk preference assumption

parameter	Under CRRA	Under CARA	under Risk Neutrality
J-statistics for stage 1 *	2,02 *(5,99)*	2,02 *(5,99)*	2,02 *(5,99)*
J-statistics for stage 2**	40,8 *(44,99)*	41,2 *(44,99)*	98 *(44,99)*
R^2 value			*not calculated*
Price function	0,87	0,87	
Production function	0,57	0,57	
Second order condition on R1	0,05	0,05	
Second order condition on R2	0,08	0,08	
Profit function	0,50	0,50	

between parenthesis : *)critical χ^2_2 with α=5%, **)Critical χ^2_{31} with α=5%

Price is found to be a positive function of lagged price. The slope is lower than 1 (table 5), then output price has a clear declining trend over time. This is coherent with what we have previously observed in the data analysis. Moreover, the variance parameter is significant which means that regarding our assumption on price anticipation behaviour, price risk does exist.

The average production of live animals per hectare is significantly improved by nitrogen application on forage area and by feed purchased. However the nitrogen efficiency tends to decrease with nitrogen levels as revealed by the significant negative value for nitrogen square parameter. The absence of significant cross term may emphasize that cattle production per hectare may be enhanced through these different way independently i.e. there is no need to purchase feed to improve pasture efficiency or to add fertilizer on pasture to make feed purchase more effective. Comparing the intercept value of the mean production function -256- to the observed panel mean -396-, we can noticed as well that more than half of the production does not depend these inputs. This is not really surprising as cattle can be raised on pasture without fertilizing them or without buying additional feeds.

Variance, at mean values of variables, is positive and equal to 57 which represents around 14% of the average production. Production risk seems then to be a reality. However, few parameters are significant. Inputs do not have a direct significant impact on production variance. We may conclude though these results that nitrogen application tends to have a positive effect on variance and consequently tends to increase production risk. This could be consistent with other studies on fertilizer effects on crop production. In cattle systems, forage production is not the final product; this can be explained by a less significant effect on

[2] The test statistics is computed by multiplying the value of the GMM objective function by the sample size (J_statistics). This statistics follows a chi square with (r-p) degrees of freedom. It can be as well used as a test of overall model specification.

fertilizer application on variance. Weather indicators are significant but with a low probability (10%) for the weather of the previous year. Sign of the current year is positive whereas the lagged year one is negative. Production variability increases then when weather is more favourable. This can be explained by the different management practices occurring when there is a forage production surplus: some production can be lost since first it is very difficult to use efficiently grass available within a short period when growth rate is high, and second farmers have different options to use this surplus. They can constitute more stocks for the following year or they may increase the current beef production if they have the possibility to do so. We can not conclude to any interaction between input risks and weather risks since neither values nor sign of cross input-weather parameters are significant. An exception has to be made for the previous year weather effect crossed with the quantity of feed purchased which is significant and positive. It may be explained by the fact that when previous forage harvest has been good, some farmers might have increased their forage stock and then necessitate buying less feeds. Generally, weather impacts on production variability but these impacts seem not to be proportional to production level.

Table 5: Parameters estimation according

parameter	label	Under CRRA		Under CARA	
		Estimates	*(standard error)*	Estimates	*(standard error)*
Price function					
α_1	Lag price	0,975***	*(0,002)*	0,975***	*(0,002)*
σ_θ	Price variance	0,13***	*0,009)*	0,13***	*0,009)*
Mean production					
β_0	Intercept	256,0***	*(9,136)*	256***	*(9,857)*
β_1	nitrogen unit	1,975***	*(0,294)*	2,004***	*(0,296)*
β_2	Feed purchased	0, 113***	*(0,020)*	0,116***	*(0,021)*
β_{11}	nitrogen ²	-0,017***	*(0,007)*	1.10e-4	*(0,007)*
β_{22}	Feed ²	-1*10e-5	*(3*10e-5)*	-1.10e-5	*(3.10e-5)*
β_{12}	Cross term	2*10e-4	*(5*10e-4)*	2.10e-4**	*(5.10e-4)*
Variance of production					
γ_0	Intercept	-73,82	(85,34)	-84,96	(70,14)
γ_1	nitrogen unit	1,302	*(0,900)*	1, 461*	*(0,771)*
γ_2	Feed purchased	-0,002	*(0,081)*	-0,004	*(0,073)*
γ_{12}	nitrogen *feed	-1.10e-4	*(0,0001)*	-1.10e-4	*(0,0001)*
γ_{c1}	weather year n-1	-1,83*	*(0,972)*	-1,659*	*(0,866)*
γ_{c2}	weather year n	3,603***	*(0,930)*	3,666***	*(0,775)*
γ_{1c1}	nitro*weather n-1	-0,011	*(0,025)*	-0,015	*(0,023)*
γ_{1c2}	nitro *weather n	-0,012	*(0,012)*	-0,012	*(0,012)*
γ_{2c1}	feed*weather n-1	0,002***	*(7.10e-4)*	0,002***	*(7.10e-4)*
γ_{2c2}	feed*weather n	-0,002	*(0,001)*	-0,002	*(0,001)*
Risk preference function					
W0				0.042***	*(0,042)*
W1		2,111***	*(0,356)*		

*** ,** and * indicate that the parameter is significant at 1%, 5% and 10% level respectively

Number of observation is 1225

Eventually, risk aversion appears clearly significant in both CRRA and CARA cases. A Wald test confirms the significance of these parameters. Production risk and price risk jointly impact on production decisions. However, we cannot characterized which farmers' preference specification is the best.

The table 6 summarizes the estimated elasticities of nitrogen application, feed purchased and weather indicators. Due to the numerous interactions, elasticities are evaluated at the mean value of independant variables. These measures allow comparing signs and magnitude of the different effects. Input elasticity signs are consistent because it means that cattle production increase when inputs level goes up. As for the variance elasticity to the different variables, values are very low except for weather indicator of the current year. Fertilizer seems slighly risk increasing whereas feed purchasing appears risk decreasing. However,

Table 6: Elasticities of mean production and variance production to input and weather variables

Mean		Variance	
	Mean	Mean	Standard deviation
f_X1	0,17	h_X1	0,02
f_X2	0,24	h_X2	-0,01
f_c1		h_C1	-0,07
f_c2		h_C2	0,23

4 Discussion

We regret then that the preliminary model specification which includes weather variables in the mean production function has not yet succeeded in converging or in proposing plausible estimates. It would have certainly brought additional precious information. We would have been able to study impact effect on mean production and their crossed effects with inputs levels. We could have compared then past impacts of weather, such as the 2003 drought,with other studies such as VEYSSET AND AL (2007). We are still looking for the adequate instrumental variables. As mentioned by Fuhrer and al (1995), although in principle GMM estimators appear ideal, in practice, they are really sensitive to instruments relevance. Instrumental variable estimators behave badly whe instruments are poor: poor relevance for one regressor can bias all of the parameter estimates. Results are then sensitive to instruments choice and the Hansen criteria soe not appear to us sufficient in some cases to dismiss some models. If GMM presents the great advantage to not necessitate any assumtion neither regarding endogeneity of some explanatory variables nor error distribution, the instrumental framework is very difficult to deal with. In addition, it is likely that a more detailed database related to local weather measurements and above all to the quantity of forage stock could have enhanced the model prediction. In the same way, farms' heterogeneity such as crop variety or soil quality can modify pasture response to inputs and to weather conditions. This has not yet been taken into account in this model in order to keep simple parameters estimates analysis, however it could have improved estimations.

5 Conclusion

Suckler cow systems have a specific link to weather variability. The limited gain of cow-calves productivity conduces farmers to a thrifty management of the herd feed needs. Pasture and forage managements, which are very sensitive to weather variability, are then a key issue. Comparing with other agricultural activities, suckler cow farms have then two particularities, a strong link to forage production but large possibilities to mitigate risk exposure. We were then especially interested in the way farmers can manage these risks through production choice decision: fertilizer application on fodder area and feed purchased.

This paper extend current literature on production risk first to take into account both price risk and production and second by introducing explicit weather indicators. This study highlight that this risk preference framework was relevant. Risk neutrality assumption has been indeed rejected whereas constant risk aversion and a decreasing risk aversion with total fodder area per worker unit were accepted. Both CRRA and CARA model give very similar results it is then difficult to conclude as for the better assumption. Production risks stem mainly from weather indicators. Nitrogen application is found to be a risk increasing input but with a low significance. Forage intensification might be then a risky choice. The absence of significant effect of feed purchased quantities on animal performance variability may be due to the low proportion of finished animal in the farms. The use of additional purchased feed is only a complement. Moreover, weather indicators impact significantly on cattle production variability but its effects do not appear clearly proportional to input levels. This put a different perspective from papers suggesting that low stocking rate and extensive management pasture directly help managing weather risks (VEYSSET, 2007). The link seems not so obvious. It may be possible that the additional quantity to apply is proportional to input level in order to keep constant the animal production. Sequential decisions and endogeneity problems are overcome by the GMM procedure. Yet, these multi collinearity effects caused by contemporaneous weather events are not visible anymore in the variance function.

The next step will be first to success in proposing the complete estimation of the model. Then we will be able to use estimated function to simulate climate change and price distribution change in order to assess their plausible impacts on farmers'decisions and on cattle production. Moreover, as econometric model suppose that technology remains constant through time, a dynamic stochastic mathematial progamming model is in progress to bring additional insights in management of risks linked to price and weather uncertainties.

References

ANTLE, J.M., (1983): Sequential Decision Making in Production Models. American Agricultural Economics Association

ANTLE, J.M., (1983): Testing the Stochastic Structure of Production: a Flexible Moment-Based Approach. Journal of Business and Economic Statistics, l1(3) : 192-201

ANTLE, J.M., CAPALBO, S.M., (2001): Econometric-Process Models for Integrated Assessment of Agricultural Production Systems. Journal of Agricultural Economics Association, 83 (2) : 389-401

APPELBAUM, E., (2003): A framework for Empirical Applications of Production Theory without Expected Utility. Journal of Economics and Business 58 : 290-302

ASCHE F., TVETERAS, R., (1999): Modelling Production Risk with a Two-Step Procedure. Journal of Agricultural and Resource Economics 24 (2) : 424-439

BLANC F., BOCQUIER F., AGABRIEL J., DHOUR P., CHILLIARD Y. (2006): Adaptive Abilities of the Females and Sustainability of Ruminant Livestock Systems. A review. Animal Research 55 (6) : 489-510

BOYER, P.(2006): Assurer les calamités agricoles ?. Proceedings of the COPEIAA-SAF seminar “Gérer les risques : des enjeux cruciaux pour les agriculteurs et pour la PAC”, Paris, France, October 2006

CHATELLIER, V., COLSON, F., GUESDON, J.C., KEMPF, M., LEGENDRE, J., PERROT, C. (1997): La diversité des systèmes d'élevage bovin en France et leur contribution à la production de viande bovine. INRA Production Animale 10 : 227-240

CHAVAS, JP, HOLT, MT, (1990): Acreage Decision under Risk: the Case of Corn and Soybeans. American Agricultural Economics Association
CHAVAS, JP, HOLT, MT, (1996): Economic Behaviour under Uncertainty: a Joint Analysis of Risk Preferences and Technology. the Review of Economics and Statistics, 78 (2) : 329-335
CHEN,CC., CHANG,CC., (2005): The Impact of Weather on Crop Yield Distribution in Taiwan : some New Evidence from Panel Data Models and Implications for Crop Insurance. Agricultural Economics, 33 : 503-511
DI FALCO, S., CHAVAS, J.P., SMALE, M. (2006): Farmer Management of Production Risk on Degraded Lands : the Role of Wheat Genetic Diversity in Tigray Region, Ethiopia. ept discussion paper 153
DIAZ-SOLIS, H., KOTHMANN M.M., GRANT, W.E., DE LUNA-VILLARREAL, R., (2006): Application of a simple ecological sustainability simulator (SESS) as a management tool in the semi-arid rangelands of north-eastern Mexico. Agricultural Systems 88: 514-527
DUSSOL, A.M. (2003): Le bassin charolais, une zone emblématique de l'élevage bovin allaitant, Agreste Cahier 3 : 3-8
http://agreste.agriculture.gouv.fr/IMG/pdf/articles03073A1-2.pdf, the 25th of June 2007
FUHRER, J.C., MOORE, G.R., SCHUH, S.D. (1995): Estimating the Linear-Quadratic Inventory Model Maximum Likelihood versus Generalized Method of Moments, Journal of Monetary Economics 35 : 115-157
GILLAR, G, P., MONYPENNY, R. (1990): A Decision Support Model to Evaluate the Effects of Drought and Stocking Rate on Beef Cattle Properties in Northern Australia. Agricultural Systems 34 : 37-52
HARDBAKER, JB, HUIRNE, RBM, ANDERSON, JR, LIEN, G., (2004): Coping with Risk in Agriculture. 2d ed, CABI publishing
HOCH T., BEGON C., CASSAR-MALEK I., PICARD B., SAVARY-AUZELOUX I.,(2003): Mécanismes et conséquences de la croissance compensatrice chez les ruminants. INRA Production Animale 16 : 49-59.
ISIK, M., (2003): Resource Management under Production and Output Price Uncertainty: Implications for Environmental Policy. American Journal of Agricultural Economics, 84(3) : 557-571
ISIK, M., DEVADOSS, S., (2006): An analysis of the impact of climate change on crop yields and yield variability, Applied Economics, 38: 835-844
JAMBOU, M., MORDANT, J., PORRY, J.L. (2001) : Quel avenir pour l'élevage allaitant ?, comité permanent de coordination des inspections, MAAPAR, 13 décembre 2001, in www.agriculture.gouv.fr/ spip/IMG/pdf/rapportmordant-0.pdf the 25th of June 2007
JUST, R.E, POPE, R.D., (1978): Stochastic Specification of Production Functions and Economic Implications. Journal of Econometrics, 7 (2): 276-284
JUST, R.E, POPE, R.D., (1979): Production Function Estimation and Related Risk Considerations. American Journal of Agricultural Economics 61 : 67-86
KINGWELL, R.S, PANNEL, D.J., ROBINSON, S.D., (1993): Tactical responses to seasonal conditions in whole farm planning in western Australia. Agricultural Economics, 8 : 211-226
KUMBHAKAR, S.C, (2003): TVETERAS, R., Risk Preferences, Production Risk and Firm Heterogeneity. Scand. J.of Economics, 105(2) : 275-293
LE GOFFE, P., (2003): Multifonctionnalité des prairies: comment articuler marché et politiques publiques? INRA Production Animale 16 : 175-182.
LIENARD G., LHERM M., (1986): Bases économiques du choix d'un type de production de viande bovine. Cas des troupeaux allaitants. Production de viande bovine : 273-330.
LIENARD, G., LHERM, M., (1986):Bases économiques du choix d'un type de production de viande bovine. Cas des troupeaux allaitants. Production de Viande Bovine, INRA, 273-

330

LOVE, H.A, BUCCOLA, S.T., (1991): Joint Risk Preference Technology Estimation with a Primal System. American Journal of Agricultural Economics, 73 (3) : 765-774

POTTIER, E., DELABY, L., AGABRIEL, J., (2007): Adaptation des systèmes de production des ruminants à la sècheresse. In : Proceedings of the AFPF seminar "Productions fourragères et adaptations à la sècheresse", Paris, France, March, 2007

RAMASWAMI, B., (1992): Production Risk and Optimal Input Decisions. American Agriculture Association

RIDIER, A., JACQUET, F., (2001): Découplage des aides directes et décisions des producteurs de viande face au risque de marché. In : Proceedings of the 18ème Journées de microéconomie appliquée, Nancy, France, June, 2001

SAHA, A., SHUMWAY,R., TALPAZ, H., (1994): Joint Estimation of Risk Preference Structure and Technology Using Expo-Power Utility. American Agricultural Economics Association

SHANKAR,B., NELSON,C.H., (2003): A Simple Approach to Stochastic Technology Estimation Using Farm Level Data, first draft

VEYSSET, P., BEBIN, D., LHERM, M., (2007): Impact de la sècheresse 2003 sur les résultats technico-économiques en élevage bovin allaitant charolais, In : Proceedings of the AFPF seminar "Productions fourragères et adaptations à la sècheresse", Paris, France, March, 2007

WOOLDRIDGE, J.W, (2002): Econometric Analysis of Cross Section and Panel Data, MIT press