Impacts économiques d'une réduction des utilisations agricoles des engrais minéraux et des produits phytosanitaires en France : analyse en équilibre général

Alexandre Gohin, Herve Guyomard, Fabrice Levert, . Ministère de L'Aménagement Du Territoire Et de L'Environnement, Direction Générale de L'Administration Et Du Développement, Paris (fra), Francois Bonnieux

"Pesticide Ban" Workshop. Kiel, Germany. November 11-12

A pesticide ban in the context of intensive cropping technology : the case of the French crop sector

A. Carpentier*

December 1993

1. Introduction: Chemical pesticide use and the adoption of intensive cropping technology

Post World War II, one of the the main objective of the agricultural policy of European Countries was the achievement of food self-sufficiency. Due to a shortage of arable land, the best way to achieve an increase in production was to increase the productivity of land.

The main characteristics of the Common Agricultural Policy (CAP) implemented at the beginning of the sixties were :

- a high price support for farmers,

- reduced agricultural capital cost (through grants for mechanisation),

- subsidies for artificial fertilisers.

The combined effects of subsidies and of high output prices led to an increase in the real cost of land for which there is a physical constraint. This led to a more intense use of land which in turn had a detrimental impact on the environment (Mahé and Rainelli, 1987).

High output prices provided incentives to adopt new techniques developed from agronomic research. These techniques were very efficient in so far as the only objective was to increase land productivity. For example cereal yield has almost risen by 100% during the last 25 years in France. In the case of winter cereals, intensive cropping technology is characterised by (Meynard, 1991) :

- large seed density,

- irrigation,

- high yield seed variety,

- high load of fertiliser per area unit,

- early sowing,

---

* A. Carpentier is a Ph D candidate, EHESS and INRA-ESR Rennes. The author wishes to thank F. Bonnieux, H. Guyomard, C. Le Mouël, P. Rainelli and D. Vermersch, INRA-ESR Rennes; J. Mairesse, EHESS-CREST and the members of the "Pesticide Ban" workshop for helpful comments.

- ...

In this context, pest and disease damage control becomes a crucial issue. The use of the techniques described above makes crops more sensitive to pest infestations. This rests on a set of ecological principles :

- Only a limited number of improved varieties of crops are now widely used. Due to selection choices, these varieties are highly productive but vulnerable to pests and disease.

- Long growing seasons increase the likelihood of severe pest damage.

- Large seed density and irrigation also increase the likelihood of fungic damage.

- ...

Moreover, the use of these techniques allows continuous monoculture. This kind of cropping situation is highly susceptible to severe pest damage and therefore calls for plant protection. For example, this explains the important nematicide use in Dutch potato production (Blom J.C., 1993). Nematode populations are relatively stationary and grow rapidly if their host-plant is planted too often. Also the continuous monoculture (of potatoes in this case) increases the need for nematode control. In this context, crop rotation with non host-plant may limit nematode population growth and, consequently nematicide use (Zacharias and Grube, 1986).

It is now possible to describe the process which led to the high use of chemical pesticides in the French crop sector. The use of intensive cropping techniques creates needs for pest control. The high agricultural prices provided by the former CAP allowed the use of high amounts of industrial inputs. Finally, the rise of organic chemistry gave new solutions to farmers : chemical pesticides. In addition, existing pesticides are (very) effective in controlling many serious threats to production and easy to use. Farmers can easily attain high levels of crop protection, i.e., with only limited knowledge of agricultural technology. They can follow predetermined application schedules, apply a fixed dosage at fixed dates without regard of the actual conditions prevailing in the field. These last two points are the main reasons why there are no viable substitutes for chemical pesticides.

So we can see how this process of intensification has led to a substantial dependence of current (European) agriculture on chemical pesticides. At this stage, it seems important to keep in mind that the increase in pest control needs is solely due to the adoption of intensive cropping technology. The increase in chemical pesticide use is simply a consequence of the rise in plant protection needs, the past economic context, the actual efficiency of the chemical substances intended to prevent or combat pests[1] and the way farmers manage their plant protection.

In the next sections, the dependence of intensive cropping technology on chemical pesticides is analysed through the observed link between fertiliser and pesticide use in the French crop sector. Fertilisers are chosen due to their close relationship with intensive cropping techniques. Firstly, a production function specification for the French crop sector and its estimation are presented. Then the short run effects of a drastic pesticide ban are analysed. In particular, it is intended to show that this measure could substantially reduce the French crop production if current technology was left unchanged. The next section presents a detailed statement of the theoretical background used in this paper.

2. Pesticides, risk and information use: some theoretical considerations

Since Feder (1979), pesticides are treated differently from conventional inputs in production function specifications. This is because the productivity effects of pesticides are measured by the

---

[1] For example, chemical pesticides have helped maintain pest damage at between 5 and 30 percent of potential production in US agriculture (National Research Council, 1989).

reduction in the damage resulting from pests and crop disease, rather than by an increase in potential output. Therefore, pesticides are often considered as risk-reducing inputs (Antle, 1988; Leathers and Quiggin, 1991; ...). Due to the interactions of plant and pest growth with weather and other uncontrollable and unpredictable phenomena, farmers almost always apply pesticides as a precaution. Hence, the farmers' attitude toward risk need to be taken into account to model pesticide demand. For many authors, pesticides are over-used, i.e., used below their marginal cost because of their risk reducing effects and farmer risk aversion. Some of these studies are discussed in Pannell (1991).

Lazarus and Swanson (1983) and Babcock, Chalfant and Collender (1987) show that, under uncertainty, variable input and land allocation decisions of multiproduct farmers have to be studied simultaneously. Using at the same time portfolio analysis and conventional production functions, they show that risk averse farmers may use crop diversification as a risk management strategy. So analysing optimal input choices and ignoring the problem of the allocation of land may lead to erroneous conclusions. Also this would suggest financial crop insurance to be a potential policy to reduce pesticide use (Nelson and Loehman, 1987 and Ramaswami, 1993). In this context pesticide use and crop diversification are viewed as self-protection and self-insurance strategies, respectively.

The way farmers anticipate the productivity effects of pesticides is important (especially when expected utility models are used). It defines the probability distributions used by farmers in their expectations. This depends on the amount of information farmers use when they choose pesticide sprays. The works of Antle (1983) and Antle and Hatchett (1986) on sequential decision making in agricultural production suggest that farmers update their beliefs by incorporing the information (expert predictions, intermediate output levels, disease symptoms,...) generated during the production process. However, agricultural scientists recognise that farmers only moderately use this kind of information (Lichtenberg, Zilberman and Archibald, 1990; Ikerd, 1991). This justifies the will to promote Integrated Pest Management Programmes (IPM). This point is closely related to human capital considerations (education, knowledge and experience).

Using Savage's expected utility models, Pingali and Carlson (1985) point out that farmers' expectations are subjective. They found that the American farmers under their investigation often overestimated expected crop losses due to pest damage. Mumford (1981) obtained similar results in a study of English farmers. The mathematical results of Yaari (1987) show that this overestimation of worst events (infestation in the case of pest damage risks) may lead to an overestimation of farmer risk aversion if a Von-Neumann Morgenstern expected utility model is used. Thus, one must be careful when using this model.

Following the previous literature on pesticide use, this study includes related risk considerations. The role of the chemical pesticides in intensive cropping technology is analysed through the observed link between fertiliser use and pesticide use. A survey of previous works on pesticide demand in the French crop sector allows us to specify some assumptions which reduce the importance of information in the context of this paper. This point is stated more precisely in the inference section because some important econometric assumptions rely on it. Due to economic and econometric limitations, the estimations presented herein must be interpreted carefully. However they provide some insight for the evaluation of the effects of a drastic pesticide ban effects in the French crop sector.

3. The estimation of a production function for the French crop sector

Any ensuing assessment of a policy affecting inputs related to production risks such as pesticides would require sufficiently flexible production function specifications to reflect stochastic input-output relationships. The stochastic specification used in this paper was first developed by Just and Pope (1978).

Firstly, this specification and its properties are presented. Next the estimation procedure is discussed. Finally, the related estimations and economic implications are analysed.

3.1. The production function specification

Just and Pope (1978) showed that the traditional stochastic specifications of production functions (the Cobb-Douglas specification of Zellner, Kmenta and Drèze (1966) is a well known example) impose important restrictions when risk has to be taken into account. Namely, if any input has a positive effect on output, then a positive effect on output variability is also imposed. To avoid this problem, they suggest to use a production function which is flexible enough to permit positive and negative marginal risk (or output variability) effects. The specification they proposed is composed of two parts :

- one which specifies the effects of inputs on the mean of output : *f(.)*

- another which specifies the effects of inputs on the variance of output : *h(.)*.

This function is defined by :

$$y = f(x) + \varepsilon\, h(x) \qquad E(\varepsilon) = 0, V(\varepsilon) = 1 \tag{1}$$

where *y* is the output quantity and *x* is the vector of input quantities[2].

Thus *E(y/x) = f(x)* and *V(y/x)=[h(x)]²*. Marginal effects of any input *k* on the mean and the variance of *y* are :

$$\frac{\partial E(y/x)}{\partial x_k} = \frac{\partial f(x)}{\partial x_k} \tag{2}$$

$$\frac{\partial V(y/x)}{\partial x_k} = 2\frac{\partial h(x)}{\partial x_k} h(x) \qquad k = 1,\ldots,K \tag{3}$$

This function was extended to include a composite error by Griffiths and Anderson (1982). This model is useful when panel data are used, as is the case here. Assuming a composite error structure with fixed time effects and individual random effects, the model [1] can be written as :

$$y_{it} = f(x_{it}) + (\mu_i + e_{it})\, h(x_{it}) \qquad i = 1,\ldots,N \quad t = 1,\ldots,T \tag{4}$$

In [4], μ_i is the permanent error component which is specific to the i^{th} farm and e_{it} is an error component which is random over time and farms and contains pest and disease effects. This specification implies that the variances of both error components are not independent of the (explanatory) variables included in the model. In other words, individual effects μ_i that are not incorporated as independent variables may be partially influenced by the measured input levels. Generally, the specific farm effects are supposed to reflect the managerial ability of the farmer and land quality (Griffiths and Anderson, 1982 ; Wan and Anderson, 1993).

We note $u_{it} = (\mu_i + e_{it})\, h(x_{it})$. The assumed variance-covariance properties of y_{it} can then be summarised as follows:

$$E(\mu_i / x_{it}) = E(e_{it} / x_{it}) = 0 \tag{5a}$$

$$E(\mu_i^2 / x_{it}) = \sigma_\mu^2, \quad E(e_{it}^2 / x_{it}) = \sigma_e^2 \tag{5b}$$

---

2 $V(\varepsilon) = 1$ is only an identification constraint since, if $V(\varepsilon) = \sigma^2$, the *h(.)* function could simply be modified by a multiplicative factor of σ^2 (Just and Pope, 1978).

$$E\left(u_{it}^2 / x_{it}\right) = \left(\sigma_\mu^2 + \sigma_e^2\right) h\left(x_{it}\right)^2 \qquad [5c]$$

$$E\left(u_{it} u_{js} / x_{it}, x_{js}\right) = \sigma_\mu^2 h\left(x_{it}\right) h\left(x_{js}\right) \quad if \quad i = j \; and \; t \neq s$$
$$= 0 \quad if \quad i \neq j \qquad [5d]$$

Assumption [5a] relies heavily on the supposed role of information.

Assumption $E\left(e_{it} / x_{it}\right) = 0$ excludes the possible endogeneity of the input choices with respect to e_{it}. It relies on the fact that farmers are assumed not to use the information generated during the production process. So farmers are assumed to act as if they only based their input choices on the amount of information available before the production process begins. This assumption seems rather strong as is suggested by the works of Antle (1983) and Antle and Hatchett (1986). However French agricultural scientists recognize that many farmers use pesticides or fertilisers following predetermined schedules[3]. This justifies, at least in this study, the input choice exogeneity assumption.

Assumption $E\left(\mu_i / x_{it}\right) = 0$ implies that there is no correlation between the permanent individual efffects μ_i and the input choices x_{it}. Mundlak (1978) and Chamberlain (1982, 1984) provide valuable arguments against this assumption. They argue that if μ_i is unobserved by the econometrician, it may be known by the i^{th} farmer. If so, farmer input decisions would certainly depend on μ_i. Further discussions of these assumptions are out of the scope of this paper, but they may help to clarify the implications of [4] and [5] (see e.g. Hsiao, 1986).

3.2. The estimation procedure

For computational purposes, Cobb-Douglas functional forms are chosen for *f(.)* and *h(.)*. Equation [4] can then be written as :

$$y_{it} = \gamma_t \prod_{k=1}^{K} x_{kit}^{\alpha_k} + \left(\mu_i + e_{it}\right) \Gamma_t \prod_{k=1}^{K} x_{kit}^{\beta_k} \qquad i = 1, \ldots, N \quad t = 1, \ldots, T \qquad [6]$$

The estimation procedure is discussed in Harvey (1976), Just and Pope (1978) and Griffiths and Anderson (1982). To estimate [6], the first step is to obtain primary estimates of the γ_t's and α_k's without considering the heteroskedasticity or composite error structure through the use of a non-linear estimation technique. These estimators are consistent under the conditions derived by Just and Pope (1978). The corresponding residuals, $\hat{u}_{it}$, can be used to estimate the Γ_t's and β_k's applying ordinary least squares to the following equation :

$$\ln\left(\hat{u}_{it}^2\right) = 2 \ln \Gamma_t + 2 \sum_{k=1}^{K} \beta_k \ln x_{kit} + \ln\left(\mu_i + e_{it}\right)^2 \qquad [7]$$

Under the assumption that μ_i and e_{it} are normally distributed, the term $\ln\left(\mu_i + e_{it}\right)^2$ is distributed as the logarithm of a χ^2 random variable with one degree of freedom (Harvey, 1976). The mean and the variance of $\ln\left(\mu_i + e_{it}\right)^2$ are then know and equal to:

$$E\left[\ln\left(\mu_i + e_{it}\right)^2\right] = -1.2704 \qquad [8a]$$

[3] This point is also discussed in section 1.

$$\left[\ln(\mu_i + e_{it})^2\right] = 4.9348 \qquad [8b]$$

Because $(\mu_i + e_{it})$ and $(\mu_i + e_{is})$ are correlated, $\ln(\mu_i + e_{it})^2$ and $\ln(\mu_i + e_{is})^2$ are correlated. Thus, asymptotically more efficient estimates of the Γ_t's and β_k's can be obtained by using the generalised least squares procedure proposed by Griffiths and Anderson (1982). Using these estimated values, it is possible to compute a consistent estimator of the covariance matrix of the u_{it} (described in [5]). Finally, we obtain an asymptotically efficient estimator for the γ_t's and α_k's by using the weighted non-linear least squares procedure suggested by Griffiths and Anderson for model [6].

3.3. Data

The data used in this study include total crops output, chemical pesticide use and fertiliser use in French francs 1987 per are. These data are for 496 farmers from 1987 to 1990. The source is the European Accountancy Data Network. Only two inputs are considered here. Of course many other inputs such as capital or labour should be used. However, for the limited purpose of this study i.e. short run effects of pesticide ban, a focus on the main variable inputs used in the intensive cropping technology may provide sufficient insight.

The sample includes farms from the regions Ile-de-France, Centre and Champagne. These regions are parts of the Paris basin. The main outputs of these farms are cereals and oilseeds produced using intensive cropping technology. The prices used are Paasche indexes. In table 1, summary data of the output and input data are given.

Table 1. Main characteristics of the sample : 1987-1990

Variable	Mean	Standard Deviation	Minimum	Maximum
Sown Area (are)	7994	4616	1000	36400
Yield (Francs 87/are)	78.14	22.83	9.72	171.91
Pesticides (Francs 87/are)	8.48	2.79	1.52	15.03
Fertilisers (Francs 87/are)	10.20	2.55	2.17	23.66

The average sown area of the sample is more than twice that of the average French farm (3000 ares). As was expected for intensive cropping technology users, these farms employ large amounts of fertilisers (10.2 Francs 87 per are in average) and pesticides (8.48 Francs 87 per are in average).

3.4. Results

The results for the output mean are given in table 2 and the estimates for the output variance in table 3. Judging from the residual sum of squares, the model seems to fit rather well. In addition, all the parameter estimates are significant at the 5 per cent level.

The estimated γ_t's show that 1987 and 1988 are characterised by low yield mean and high yield mean, respectively. When the γ_t's are replaced by a linear trend in model [6], the parameter estimates indicate the existence of an exogenous technical progress.

The elasticities of the expected yield with respect to fertiliser and pesticide use are positive and appear reasonable (respectively, +0.13 and +0.30).

Table 2. Parameter estimates for the mean output function

Parameter	Estimation	Confidence interval (95 %)	
Pesticides α_p	0.30	0.26	0.34
Fertilisers α_e	0.13	0.09	0.18
γ_{87}	28.09	25.35	32.43
γ_{89}	32.27	28.34	36.20
γ_{89}	30.78	26.95	34.60
γ_{90}	31.22	27.32	35.13

Total variance 7415 (1984 df)
Residual sum of squares 904 (1976 df).

Table 3. Parameter estimates for the output variance function

Parameter	Estimation	T Student	
Pesticides β_p	-0.16	-1.806	0.04
Fertilisers β_e	+0.19	2.019	0.07
Γ_{87}	2.10	8.45	0.00
Γ_{89}	2.13	8.61	0.00
Γ_{89}	2.25	9.02	0.00
Γ_{90}	2.25	8.97	0.00

Corrected R^2 : 0.77.

As was expected, the elasticity of the yield variance with respect to pesticide use is negative (-0.16). Antle (1988) obtained similar results in the case of Californian tomato production. The existence of this non-positive marginal risk effect suggests the possible superiority of the heteroskedastic model over more conventional ones. Fertiliser use increases yield variance (+0.19). Most of the studies concerned with this aspect of fertiliser use come to similar conclusions (Just and Pope, 1979 ; Babcock, Chalfant and Collender, 1987 ; Love and Buccola, 1991 ; Ramaswami 1992 ; Wan and Anderson, 1993). These results are used in the next section to analyse the implications of a drastic pesticide ban. However they must be interpreted carefully due to specification and econometric limitations.

4. The short-run effects of a pesticide ban

In the short-run, the agrochemical industry is not able to supply adequate substitutes for the banned pesticides, nor are agricultural producers able to adopt a new technology.

In this section, the importance of pesticide use in the context of intensive production is emphasised to show that a drastic pesticide ban might substantially reduce agricultural output. Related risk considerations are also discussed and seem to reinforce this hypothesis.

4.1. The technological aspects

i. The comparative statics results

In order to evaluate the effects of a pesticide ban, the concept of input cooperation in the Rader (1968) sense is used. This concept is appropriate in this context because of two reasons. First, it is a simple concept defined on primal production functions. Second, a ban would have direct impacts on input use levels.

Assuming firstly that farmers are risk neutral, so that related risk effects do not matter. Inputs are said to be cooperant, in the Rader sense, when an increase in the use of one of them increases the marginal productivity of the other[4]. Formally, this implies the following inequality :

$$\frac{\partial^2 f(x)}{\partial x_k \partial x_l} \geq 0 \qquad k \neq l \quad k,l = 1,\dots,K \qquad [9]$$

Assuming that *f(.)* is concave in its arguments, optimal choices of expected profit maximiser farmers are characterised by the following first order conditions:

$$p_o \left.\frac{\partial f(x)}{\partial x_k}\right|_{x^*} = p_k \qquad k = 1,\dots,K \qquad [10]$$

where p_o is the output price and p_k is input k price. Second order conditions for the existence of a unique maximum are supposed to be satisfied. A simple way to evaluate the effects of a pesticide ban with the former model is to consider that pesticide use levels are exogenous, e.g., imposed by policy makers. In the two input case (pesticides and fertilisers), a comparative statics analysis is conducted solely using the first order condition related to fertiliser use. If $\bar{x}_p$ is the maximum pesticide use level authorized by policy makers, [10] becomes:

$$p_o \left.\frac{\partial f(x_e, \bar{x}_p)}{\partial x_e}\right|_{x_e^*, \bar{x}_p} = p_e \qquad [11a]$$

$$\bar{x}_p \leq x_p^* \qquad [11b]$$

where subscript e denotes fertiliser. [11b] simply states that farmer pesticide use is constrained by the considered ban. It comes from [11a] that if fertiliser and pesticide are cooperant then a pesticide ban forces a reduction in optimal production levels. The argument for this is obvious. Before fertiliser use reajustment and because of input cooperation, the reduction in pesticide use decreases the marginal productivity value of fertilisers which falls below the fertiliser price. So fertiliser use must decrease to satisty [11a]. Both input uses also decrease. This leads to a decrease in production.

The previous estimates show that in the French crop sector fertiliser and pesticide are relatively strongly cooperant.

$$\frac{\partial^2 f(x)}{\partial x_e \partial x_p} = 0.057 \frac{f(x)}{x_e x_p} \qquad [12]$$

An decrease in pesticide use of 1 percent leads to a decrease in the marginal productivity of fertiliser of 0.30 percent.

The short-run effects of a drastic ban of pesticides can now be stated more precisely. Since there is no substitute for chemical pesticides and because pesticides and fertilisers are cooperant, a drastic pesticide ban would imply a drastic reduction in the output of those sectors characterised by intensive methods of production. In the medium-run, farmers may adopt technologies less dependent on damage control[5] or may use information as a substitute for pesticide use.

Two major points of this econometric approach have to be discussed. The first is related to the usual problems encountered by standard econometric measurements of pesticide productivity.

---

[4] In this case it is said that technology is "normal" because factors are used in conjunction with each other rather than as substitutes (Rader, 1968).

[5] Such technologies are available at present, but they generally are less productive than the intensive cropping one.

The second is related to the Cobb-Douglas form which imposes co-operation between inputs. Much of the theoretical background used in the discussion may be found in Lichtenberg and Zilberman (1986).

ii. Discussion

The elasticity of the expected yield with respect to pesticide use seems rather high in our estimated model (+0.30). Empirical studies of pesticide productivity often lead to similar conclusions (Carrasco-Tauber and Moffitt, 1992). Recently, Lichtenberg and Zilberman (1986) and Babcock, Lichtenberg and Zilberman (1988) suggested that a key feature in explaining possible overestimates of pesticide productivity in econometric studies is the functional specification employed. They pointed out that the Cobb-Douglas functional form usually used, violates the structural conditions imposed by the fact that damage is limited by potential yield. However empirical results do not provide strong evidence regarding this point (Carrasco-Tauber and Moffitt, 1992). Also, despite econometric limitations, our results highlight the key position of pesticides within intensive production processes, although pesticides are simply protective inputs.

However Lichtenberg and Zilberman's paper is very instructive because it examines the differences and relationships between damage control needs and pesticide uses. Following their approach, a production function specification correctly designed to accommodate the characteristics of pesticides may be written :

$$y = f(x_e)\left[1 - D\,g(x_p)\right] \qquad [13]$$

As previously, the subscripts *e* and *p* denote fertilisers and pesticides respectively. The function $f(x_e)$ is maximum (or potential) yield, while $Df(x_e)$ is potential damage or loss due to pests or disease. This specification states that fertlisers are productive inputs. The function $g(x_p)$ is the abatement function : the proportion of the destructive capacity of the damaging agents eliminated by the use of a level x_p of pesticides. Biological results (Cavelier, 1976) show that $\left[1 - g(x_p)\right]$ must be a cumulative distribution function[6]. This form implies fertiliser and pesticide cooperation and, therefore, justifies the use of the Cobb-Douglas specification as a rough approximation of $E(y/x_p, x_e)$[7].

Thus, in this model, the productivity of pesticides is defined in terms of their contributions to damage abatement services. Also pesticide demand depends directly on the demand for abatement. For example, it is easily seen that an increase in the output price increases the demand for abatement and therefore pesticide use. If the demand for abatement is rigid, then the demand for pesticides is also rigid.

Babcock, Lichtenberg and Zilberman (1992) study one case of inelastic demand for abatement. They demonstrate that pesticides are mainly used on fruits and vegetables to control quality. For example, U.S. regulation prohibits the sale of shipments of apples in which more than 3 % have been found to be wormy. This threshold effect implies that the demand for pesticides to control this problem is highly inelastic. Thus, a ban of these chemical substances would involve dramatic changes for this kind of commodity. The French wine sector could be in the same position.

---

[6] At least in the case of a single pest-single pesticide model.

[7] A stochastic specification of [13] could be derived as follows:

$$y = f(x_e)\left[1 - E(D)\,g(x_p)\right] + \xi f(x_e) g(x_p) \quad \text{where } \xi = D - E(D)$$

This model has the form of a Just and Pope specification. Note that if ξ is homoskedastic, then, in [4], $h(x_e, x_p) = f(x_e)g(x_p)$ can be estimated at low cost. Moreover, the above estimates seem to provide some arguments for this specification. The estimated α_k's and β_k's are relatively close.

A similar analysis can be made in the case of the French crop sector. Agricultural scientists show that the use of intensive cropping techniques increases the likelihood of severe pest and disease damage (Meynard, 1991) and creates abatement needs. This point can be introduced formally in model [13]. Using fertiliser use as a measure of intensification, this characteristic of intensive cropping technology can be written as:

$$y = f(x_e)\left[1 - D\, g(x_p)\right] \qquad [14a]$$

where $$\frac{\partial E(D/x_e)}{\partial x_e} \geq 0 \qquad [14b]$$

Equation [14b] states that fertiliser use increases the expected yield losses due to pests and disease. This explains the dependence of intensive cropping technology on pesticide use: the expected losses are not exogenous with respect to the intensification level. Moreover this strenghtens cooperation effects between pesticides and fertilisers.

The productivity effects are large because they are measured by the reduction in damage whose expected value is increased by intensive cropping techniques. Furthermore, this characteristic may explain some of the usual results on pesticide demand (e.g., Oskam, van Zeijts, Thijssen, Wossink and Vijftigschild, 1992) :

- its low responsiveness to pesticide price variations

- its complementarity with other input demands.

[14] implies that a way to circumvent a pesticide ban is to reduce abatement needs by decreasing the short-run intensification factor levels. This can be achieved by a decrease in fertiliser use, ... which thereby implies a decrease in potential yield.

This model clearly shows a random damage variable. It can thus be used to show how information about sanitary conditions which prevail in the field may be used by farmers. If farmers perfectly anticipate D , then they get information about real effects of pesticide use. In this case, they can save the cost of the unuseful sprays they would have applied following a rigid schedule. Information use may be defined as a substitute for pesticide use in pest damage control processes. This suggests the promotion of information use to be a potential policy of pesticide use reduction. Would it be more efficient than a pesticide ban?

Low human capital is often cited as a key obstacle to information use because it increases the information cost to farmers[8]. Therefore education programmes intended to increase the human capital of farmers may be an efficient pestide use reducing policy. This point and the related considerations on professional pest control consultants are discussed in Lichtenberg, Zilberman and Archibald (1990). In the limited context of intensive cropping technology, conclusions are slightly less optimistic. At present, the information use benefit to farmers is equal to the cost of unuseful sprays because of current high protection levels. Equation [14b] states that increasing intensification levels increase expected damages. Thus, the information use benefit for farmers using intensive cropping technology may be limited by the relatively low expected number of unuseful sprays. The next section deals with another aspect of the lack of information use: risk considerations.

[8] Roughly, this costs include costs of information production (scouting time, ...) and cost of information use (yield losses due to prediction errors, ...).

4.2. Related risk considerations

Due to low information use, farmers almost always apply pesticides as a precaution. Farmers' attitudes toward risk are as important as technological considerations to model pesticide demand. Pesticides may be over-used because of their risk reducing effects on production and farmers' risk aversion. In this section, it is intended to show that the observed link between the demand of fertilisers and pesticides is strengthened by risk considerations. Thus, risk considerations would reinforce the pesticide ban effects analysed in section 4.1.

i. The expected utility model

In the models used below, each farmer is assumed to use the same input productivity probability distributions (the estimated ones). Each farmer's objective function may be represented by a Von Neumann-Morgenstern expected profit utility function. The following assumptions are thus adopted:

- Due to low information use, farmers are assumed to choose their input uses according to their prior beliefs on conditions which should prevail during the growing season.

- All farmers considered herein grow only crops, in a large but homogeneous region. They face the same stochastic technology.

- The period concerned by this study is characterised by a state of relative information equilibrium due to economic stability and absence of technological change. Thus, farmers' subjective expectations may be assumed to converge to the real or objective probability distributions[9] (Antle, 1987 ; Hardakker, Pandey and Patten, 1991).

Following Babcock, Chalfant and Collender (1987) and Love and Buccola (1991) the farmers' utility function is assumed to be negative exponential to permit tractable comparative statics results. However it is important to note that this function imposes constant absolute risk aversion and may lead to erroneous conclusions if farmers actually exhibit, e.g., decreasing or increasing absolute risk aversion (Leathers and Quiggin, 1991). Optimal fertiliser and pesticide levels for producers are found by solving the primal problem:

$$\underset{x_e, x_p}{Max} \; E\left[-\exp(-\lambda\Pi)\right] \qquad [15a]$$

$$\Pi = \left\{p_o\left[f(x) + \varepsilon h(x)\right] - p_e x_e - p_p x_p\right\}L \qquad [15b]$$

where Π is the profit function, L is the fixed sown area and λ is the constant absolute risk aversion parameter of the considered farmer. Assuming, as above, that $\varepsilon \approx N(0,1)$, then the profit is a normal random variable. Its mean and its variance can be written respectively:

$$E(\Pi) = Lp_o f(x) - p_e x_e - p_p x_p \qquad [16a]$$

$$(\Pi) = L^2 p_o^2 \left[h(x)\right]^2 \qquad [16b]$$

[9] Pingali and Carlson (1985) found that human capital plays an important role in the accuracy of subjective expectations. However, the population under investigation in their study was experiencing an information disequilibrium due to an important technological change.

Since $E[\exp(\varepsilon)] = \exp\left[E(\varepsilon) + \frac{1}{2}V(\varepsilon)\right]$ where ε is normally distributed, the expected profit utility is log-normally distributed and its mean is[10]:

$$E[-\exp(-\lambda\Pi)] = -\exp\left\{-\lambda L\left[p_o f(x) - p_e x_e - p_p x_p\right] + \frac{\lambda^2}{2} p_o^2 L^2 [h(x)]^2\right\} \qquad [17]$$

The resulting first-order conditions are:

$$p_o \left.\frac{\partial f(x)}{\partial x_e}\right|_{x^*} = p_e + \lambda L p_o^2 \left.\frac{\partial h(x)}{\partial x_e}\right|_{x^*} h(x^*) = p_e + \lambda L p_o^2 \left.\frac{\partial V(y/x)}{\partial x_e}\right|_{x^*} \qquad [18a]$$

$$p_o \left.\frac{\partial f(x)}{\partial x_p}\right|_{x^*} = p_p + \lambda L p_o^2 \left.\frac{\partial h(x)}{\partial x_p}\right|_{x^*} h(x^*) = p_p + \lambda L p_o^2 \left.\frac{\partial V(y/x)}{\partial x_p}\right|_{x^*} \qquad [18b]$$

The term $\lambda L p_o^2 \left.\frac{\partial V(y/x)}{\partial x_k}\right|_{x^*}$ represents the producer's marginal risk premium with respect to input kMRP_k. If the farmer is risk-averse, he will use more of a risk reducing input (MRP_k < 0) and less of a risk increasing input (MRP_k > 0) than will a risk neutral producer ($\lambda = 0$ then MRP_k= 0).

ii. The comparative statics results

Following the approach developed in 4.1.i., the effects of a pesticide ban are studied considering the pesticide use level as exogenous. The first order condition related to fertiliser use is:

$$p_o \left.\frac{\partial f(x_e, \bar{x}_p)}{\partial x_e}\right|_{x_e^*} - \lambda L p_o^2 \left.\frac{\partial V(y/x, \bar{x}_p)}{\partial x_e}\right|_{x_e^*} = p_o \left.\frac{\partial E(y/x_e, \bar{x}_p)}{\partial x_e}\right|_{x_e^*} - \lambda L p_o^2 \left.\frac{\partial V(y/x_e, \bar{x}_p)}{\partial x_e}\right|_{x_e^*} = p_e \qquad [19]$$

If $\lambda = 0$, [19] reduces to [11a].

[19] suggests the introduction of additional concepts of input cooperation. Rader (1968) developed his cooperation concept solely considering a deterministic output. Here, both the mean and the variance of output are considered. So two concepts may be required: input cooperation in output mean and input cooperation in output variance. Inputs k and l are said to cooperate in output mean if:

$$\frac{\partial^2 E(y/x_k, x_l)}{\partial x_k \partial x_l} \geq 0 \iff \frac{\partial^2 f(x_k, x_l)}{\partial x_k \partial x_l} \geq 0 \qquad [20]$$

According to this definition, cooperation in output mean and cooperation in the Rader sense are equivalent because $E(\varepsilon/x) = E(\varepsilon) = 0$. Similarly inputs k and l are said to cooperate in output variance if:

$$\frac{\partial^2 V(y/x_k, x_l)}{\partial x_k \partial x_l} \leq 0 \iff \frac{\partial^2 [h(x_k, x_l)]^2}{\partial x_k \partial x_l} \leq 0 \qquad [21]$$

---

[10] Since ε is normal, [15] leads simply to the well-known mean-variance model. This model is usually used by financial economists. It is also used by agricultural economists studying farmers' acreage (e.g. Coyle, 1992).

Thus, inputs cooperate in output variance if the use of each of them reduces the marginal impact on output variance of the others. The input cooperation in output variance introduces a relationship between the demands of the different inputs for the management of output risk.

Using these concepts and [19], it is easily demonstrated that risk considerations strengthen the relationship between fertiliser and pesticide demand and may reinforce the reduction in output implied by a pesticide ban. The previous estimates indicate that pesticides and fertilisers are cooperant in yield variance:

$$\frac{\partial^2 V(y/x_e,x_p)}{\partial x_e \partial x_p} = -0.12\frac{V(y/x_e,x_p)}{x_e\, x_p} \qquad [22]$$

So, due to fertiliser and pesticide cooperation in both output mean and output variance, the short-run effects of a pesticide ban on output level are unambiguous if farmers are risk averse or risk neutral. As analysed above, a constraining pesticide ban would reduce the marginal productivity value of fertilisers. It would also increase the marginal risk premium related to fertilisers if producers are risk averse. Thus, fertiliser use would decrease to satisfy [19]. Both input uses would decrease. This would lead to a decrease in output.

At this stage, it seems important to note that if producers are risk neutral the concept of cooperation in output variance is unuseful. Estimation of the absolute risk aversion parameter λ of farmers must be conducted to show that risk consideration do matter. Following Love and Buccola (1991)[11] or Antle (1988), the first order conditions of the input choice problem are directly estimated:

$$p_{oit}\left.\frac{\partial \hat{f}(x_{it})}{\partial x_{eit}}\right|_{x_{it}^{*}} - p_{et} = \lambda_i\, L_i p_{oit}^2 \left.\frac{\partial \hat{h}(x_{it})}{\partial x_{eit}}\right|_{x_{it}^{*}} \hat{h}(x_{it}^{*}) + \upsilon_{eit} \qquad [23a]$$

$$p_{oit}\left.\frac{\partial \hat{f}(x_{it})}{\partial x_{pit}}\right|_{x_{it}^{*}} - p_{pt} = \lambda_i\, L_i p_{oit}^2 \left.\frac{\partial \hat{h}(x_{it})}{\partial x_{pit}}\right|_{x_{it}^{*}} \hat{h}(x_{it}^{*}) + \upsilon_{pit} \qquad [23b]$$

$$E(\upsilon_{kit}/x_{it}) = 0 \quad k = e,p \text{ and } E\left[\left(\upsilon_{pit},\upsilon_{eit}\right)'\left(\upsilon_{pit},\upsilon_{eit}\right)\right] = \Omega \qquad [23c]$$

The functions $\hat{f}(.)$ and $\hat{h}(.)$ are the estimates of $f(.)$ and $h(.)$ respectively. In this case, μ_i is supposed to be unknown by farmers. $\upsilon_{kit}, k = e,p$ represent optimisation mistakes, i.e., random failures to satisfy [23a,b]. Assumption $E(\upsilon_{kit}/x_{it}) = 0$ states that input choices are optimal on average and do not depend on input use levels. Nevertheless, farmers choose their input according to their attitude toward risk. This implies that:

$$Cov\left[\lambda_i, L_i p_{oit}^2 \left.\frac{\partial \hat{h}(x_{it})}{\partial x_{pit}}\right|_{x_{it}^{*}} \hat{h}(x_{it}^{*})\right] = 0 \qquad [24]$$

may not hold. Gouriéroux and Peaucelle (1990) demonstrate that, under some weak assumptions, applying the within estimator for [23] gives a consistent estimate of $\bar{\lambda} = \sum_{i=1}^{N} \lambda_i / N$. However, this results must be interpreted carefully because this estimation depends on the previous ones through $\hat{f}(.)$ and $\hat{h}(.)$.

---

[11] Love and Buccola (1991) point out that estimating [23] jointly with [4] and [5] improve estimation efficiency.

The estimated value[12] of $\overline{\lambda}$ is 1.2 10^{-6}. The null hypothesis test is rejected at the 1% level. So the farmers of our sample appear risk-averse in average. This leads to a marginal risk premium of both inputs equal to 12.5 per cent of their own price. Thus, risk effects seem to be important in this case. Moreover, this suggests that the effects of a pesticide ban on the French crop sector output variance would be moderate. Risk averse farmers regulate themselves output variance.

In these models, the output quantities are represented by the sum of output values in French francs 1987. This aggregation implies that the problem of land allocation is ignored. This has two consequences.

- Farmers' risk aversion may be underestimated because acreage can also be used as a risk management strategy (Babcock, Chalfant and Collender, 1987).

-The above models do not allow us to evaluate correctly the effects of a pesticide ban. A drastic pesticide ban would influence farmers' acreage and, as a consequence, their input demand and output supply.

Conclusions

The major findings of this modelisation relevant to a pesticide ban assessment can be summarised as follows. A pesticide ban would reduce the supply of the French crop sector, in the short run and probably in the medium run. The two main reasons which support this hypothesis are :

- The technology used in the French crop sector is heavily dependent on pesticide use. Agronomic principles state that intensive cropping techniques increase potential damages due to pest and disease. Now chemical pesticides are almost the only damage control agents available for farmers. Therefore the only way for farmers to circumvent a drastic pesticide ban is to reduce their use of short-run intensification factors such as fertilisers. This would reduce not only abatement needs but also potential yields.

- Farmers are shown to be risk-averse. The risk reducing effects of the pesticides allow them to use large amounts of fertilisers which are risk-increasing. A pesticide ban would suppress this possibility of self-protection against production risk. This would strengthen the previous effect.

These results come from an analysis using marginal concepts. As a consequence, they must be used carefully for a drastic pesticide ban assessment.

The models used in this study relies on some strong assumptions related to information use, land allocation, ... Relaxing these assumptions (or, at least testing them) would provide some insight into the evaluation of alternative policies such as information use promotion, financial insurance, ...

References

ANTLE J.M. (1988) "Pesticide Policy, Production Risk, and Producer Welfare." Ed. Resources for the Future, Washington D.C.

ANTLE J.M. (1987) "Econometric Estimation of Producer's Risk Attitudes." American Journal of Agricultural Economics 69(3) pp509-522.

[12] The constraints implied by economic theory for model [23] are imposed.

ANTLE J.M. (1983) "Sequential Decision Making in Production Models." American Journal of Agricultural Economics 65(2) pp282-290.

ANTLE J.M. and HATCHETT S.A. (1986) "Dynamic Input Decisions in Econometric Production Models." American Journal of Agricultural Economics 68(4) pp939-949.

BABCOCK B.A., CHALFANT J.A. and COLLENDER R.N. (1987) "Simultaneous Input Demands and Land Allocation in Agricultural Production under Uncertainty." Western Journal of Agricultural Economics 12(2) pp207-215.

BABCOCK B.A., LICHTENBERG E. and ZILBERMAN D. (1992) "Impact of Damage Control and Quality of Output: Estimating Pest Control Effectiveness." American Journal of Agricultural Economics 74(1) pp163-172.

BLACKWELL M. and PAGOULATOS (1992) "The Econometrics of Damage Control." American Journal of Agricultural Economics 74(4) pp1040-1044.

BLOM J.C. (1993) "Plant Protection in Dutch Agriculture: Policy, Application and Economics." This issue.

BYE P., DESCOINS C. et DESHAYES A. (1991) "Phytosanitaires, Protection des plantes, Biopesticides." Coll. Un point sur ..., Ed. INRA, Versailles.

CARLES R. et BONNY S. (1993) "Perspectives de l'évolution de l'emploi des engrais et des phytosanitaires dans l'agriculture française." Cahiers d'Economie et de Sociologie Rurales 26 pp29-62.

CARPENTIER A. (1993) "La gestion du risque phytosanitaire dans les systèmes de production intensive: une approche économétrique." Mémoire pour l'obtention du DEA Analyse et politique économique, ENSAE-EHESS-DELTA, sous la direction de J. MAIRESSE.

CARRASCO-TAUBER C. and MOFFITT L.J. (1992) "Damage Control Economics: Functional Specification and Pesticide Productivity." American Journal of Agricultural Economics 74(1) pp158-162.

CAVELIER A. (1976) "Cours de phytopharmacie. Tome 1." Institut National Agronomique El-Harrach, Alger.

CHAMBERLAIN G. (1982) "Multivariate Regression Models for Panel Data." Journal of Econometrics 18(1) pp5-46.

CHAMBERLAIN G. (1984) "Panel Data." in Handbook of Econometrics Vol. II, Ed. Grilliches Z. and Intriligator M.D., North-Holland pp1247-1318.

CHRISTENSEN L.R., JORGENSON D.W. and LAU L.J. (1973) "Transcendental logarithmic production frontiers." Review of Economics and Statistics 55 pp28-45.

COLLENDER R.N. and CHALFANT J.A. (1986) "An Alternative Approach to Decisions under Uncertainty Using the Empirical Moment-Generating Function." American Journal of Agricultural Economics 68(3) pp727-739.

COYLE B.T. (1992) "Risk Aversion and Price Risk in Duality Models of Production: A Linear Mean-Variance Approach." American Journal of Agricultural Economics 74(4) pp849-859.

FEDER G. (1979) "Pesticides, Information and Pets Management under Uncertainty." American Journal of Agricultural Economics 61(1) pp97-103.

MEYNARD J.M. (1991) "Pesticides et itinéraires techniques." in BYE P. and alii (1991) pp85-100.

MUMFORD (1981) "Pest Control Decision Making: Sugar Beets in England." Journal of Agricultural Economics 32(1) pp31-41.

MUNDLAK Y. (1978) "On the pooling of time series and cross section data." Econometrica 46(1) pp69-85.

NELSON C.H. and LOEHMAN E.T. (1987) "Further Tooward a Theory of Agricultural Insurance." American Journal of Agricultural Economics 69(3) pp523-531.

OSKAM A.J., van ZEIJTS H., THIJSSEN G.J., WOSSINK G.A.A. and VIJFTIGSCHILD R. (1992) "Pesticide use and pesticide policy in the Netherlands. " Wageningse Economische Studies 26, Wageningen Agricultural University, The Netherlands.

PANNELL D.J. (1991) "Pests and Pesticides, Risk and Risk Aversion." Agricultural Economics 5 pp361-383.

PARKER D.D., ZILBERMAN D. and LICHTENBERG E. (1990) "Equity and Economics Effects of Pesticides Use Restrictions." in ZILBERMAN D. and SIEBERT J. (1990).

PINGALI P.L. and CARLSON G.A. (1985) "Human Capital, Adjustments in Subjective Probabilities, and the Demand for Pest Controls." American Journal of Agricultural Economics 67(4) pp853-861.

RADER T. (1968) "Normally, Factor Inputs are Never Gross Substitutes." Journal of Political Economy 76(1) pp38-43.

RAMASWAMI B. (1992) "Production Risk and Optimal Input Decisions." American Journal of Agricultural Economics 74(4) pp860-869.

RAMASWAMI B. (1993) "Supply Response to Agricultural Insurance: Risk Reduction and Moral Hazard Effects". American Journal of Agricultural Economics 75(4) pp914-925.

SANDLER T. and STERBENZ F.P. (1988) "Externalities, Pigouvian Corrections, and Risk Attitudes." Journal of Environmental Economics and Management 15 pp488-504.

VERMERSCH D. (1989) "Economie et technologie des systèmes céréaliers: une approche duale et économétrique." Thèse de doctorat de l'Université de Rennes I.

VIAUX P. (1993) "Perspectives des systèmes de producyion extensifs en grandes cultures." Contribution au Colloque "Agriculture demain Aliment 2002, 19-20 octobre ITCF.

WAN G.H. and ANDERSON J.R. (1990) "Estimating Risk effects in Chinese Food grain Production." Journal of Agricultural Economics 41(1) pp85-93.

YAARI M.E. (1987) "The Dual Theory of Choice Under Risk." Econometrica 55(1) pp95-115.

ZACHARIAS T.P. and GRUBE A.H. (1986) "IPM Strategies for approximately Optimal Control of Corn Rootworm and Soybean Cyst Nematode." American Journal of Agricultural Economics 68(3) pp704-715.

ZELLNER A., KMENTA J. and DREZE J. (1966) "Specification and Estimation of Cobb-Douglas Production Function Models." Econometrica 34(4) pp784-795.

ZILBERMAN D. and SIEBERT J. (1990) "Economic Perspectives on Pesticide Use in California. A Collection of Research Papers Edited." Working Paper NO. 564, Department of

Agricultural and Ressources and Economics, Division of Agriculture and Natural Resources. University of California, Berkeley.