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SOME ISSUES ON PESTICIDE BAN : THE EXAMPLE OF THE FRENCH CROP SECTOR

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SUMMARY

Many health and environmental issues related to pesticides provide valuable arguments for a reduction in its use. The aim of this paper is to provide some insights for the evaluation of the costs encountered by the agricultural sector if a drastic pesticide ban were implemented. In particular, it is shown that these costs may be substantial due to the dependence of the current agricultural production processes on pesticide use. This is illustrated with the case of the French crop sector.

Firstly, a production function specification for the French crop sector and its estimation are presented. Then the medium run effects of a pesticide ban are considered. Following the previous literature on pesticides, risk considerations are important. Consequently, they are taken into account in the econometric models which are estimated. Some implications of this modelisation on policy design are discussed in the last section.

2. 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. Just and Pope (1978) suggest to use a production function which is flexible enough to permit positive and negative marginal risk (or output variability) effects. This function is defined by :

$$y = f(x) + \varepsilon h(x) \quad E(\varepsilon) = 0, V(\varepsilon) = 1 \quad [1]$$

where y is the output quantity and x is the vector of input quantities. Marginal effects of any input k on the mean and the variance of y are :

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

$$\frac{\partial V(y/x)}{\partial x_k} = 2 \frac{\partial h(x)}{\partial x_k} h(x) \quad k = 1, \dots, K \quad [3]$$

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 :

$$y_{it} = f(x_{it}) + (\mu_i + e_{it}) h(x_{it}) \quad i = 1, \dots, N \quad t = 1, \dots, T \quad [4]$$

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, 1990).

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:

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

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

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

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

Assumption [5a] relies heavily on the supposed role of information. Assumption $E(e_{it}/x_{it}) = 0$ 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. French agricultural scientists recognise that many farmers use pesticides or fertilisers following predetermined schedules. This justifies, at least in this study, the input choice exogeneity assumption. Assumption $E(\mu_i/x_{it}) = 0$ implies that there is no correlation between the permanent individual effects μ_i and the input choices x_{it} . 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. Chamberlain, 1984; Hsiao, 1986 and Antle, 1988).

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

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

The estimation procedure is discussed in Harvey (1976), Just and Pope (1978) and Griffiths and Anderson (1982).

The data used in this study include total crop 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, 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

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).

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 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	-2.019	0.04
Fertilisers β_e	+0.19	1.806	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 R² : 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 (Babcock, Chalfant and Collender, 1987 ; Love and Buccola, 1991 ; Wan and Anderson, 1993). These results are used in the next section to analyse the implications of a pesticide ban.

3. THE EFFECTS OF A PESTICIDE BAN

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

3.1. 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. Formally, this implies the following inequality :

$$\frac{\partial^2 f(x)}{\partial x_k \partial x_l} \geq 0 \quad k \neq l \quad k, l = 1, \dots, K \quad [7]$$

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

$$p_o \frac{\partial f(x)}{\partial x_k} \Big|_x = p_k \quad k = 1, \dots, K \quad [8]$$

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, [8] becomes.

$$p_o \left. \frac{\partial f(x_e, \bar{x}_p)}{\partial x_k} \right|_{x_e^*, \bar{x}_p} = p_e \quad [9a]$$

$$\bar{x}_p \leq x_p^* \quad [9b]$$

where subscript e denotes fertiliser. [9b] simply states that farmer pesticide use is constrained by the considered ban. It comes from [9a] 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 satisfy [9a]. 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.

$$\frac{\partial^2 f(x)}{\partial x_e \partial x_p} = 0.057 \frac{f(x)}{x_e x_p} \quad [10]$$

A decrease in pesticide use of 1 percent leads to a decrease in the marginal productivity of fertiliser of 0.30 percent and to a decrease in fertiliser use of 0.34 percent. This implies a decrease in expected yield of 0.34 percent.

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. The second is related to the Cobb-Douglas form which imposes cooperation 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.

However Lichtenberg and Zilberman's paper is very instructive because it examines explicitly the differences and relationships between productive (fertilisers) and protective (pesticides) inputs. Following their approach, the productivity effects of pesticides are measured by the reduction in the damage resulting from pests and crop disease, rather than by an increase in potential output. Since expected potential damage never equals zero, fertilisers and pesticides have to be used in conjunction with each other. Their respective contributions to the production process are strictly complementary. Moreover, agricultural scientists show that the use of intensive cropping techniques increases the likelihood of severe pest and disease damage (Meynard, 1991) and creates protection needs. This reinforces the dependence of intensive cropping technology on pesticide use: the expected damage increases with the intensification level. These biological considerations implies fertiliser and pesticide cooperation and, therefore, justifies the use of the Cobb-Douglas technology as a rough approximation in this context.

3.2. Related risk considerations

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 3.1.

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. Three major 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 (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 results¹. Optimal fertiliser and pesticide levels for producers are found by solving the primal problem:

$$\underset{x_e, x_p}{Max} E[-\exp(-\lambda\Pi)] \quad [11a]$$

$$\Pi = \left\{ p_o [f(x) + \varepsilon h(x)] - p_e x_e - p_p x_p \right\} L \quad [11b]$$

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. 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:

$$E[-\exp(-\lambda\Pi)] = -\exp\left\{-\lambda L [p_o f(x) - p_e x_e - p_p x_p] + \frac{\lambda^2}{2} p_o^2 L^2 [h(x)]^2\right\} \quad [12]$$

The resulting first-order conditions are:

$$p_o \frac{\partial f(x)}{\partial x_e} \Big|_{x^*} = p_e + \lambda L p_o^2 \frac{\partial h(x)}{\partial x_e} \Big|_{x^*} \quad h(x^*) = p_e + \lambda L p_o^2 \frac{\partial \mathcal{V}(y/x)}{\partial x_e} \Big|_{x^*} \quad [13a]$$

$$p_o \frac{\partial f(x)}{\partial x_p} \Big|_{x^*} = p_p + \lambda L p_o^2 \frac{\partial h(x)}{\partial x_p} \Big|_{x^*} \quad h(x^*) = p_p + \lambda L p_o^2 \frac{\partial \mathcal{V}(y/x)}{\partial x_p} \Big|_{x^*} \quad [13b]$$

The term $\lambda L p_o^2 \frac{\partial \mathcal{V}(y/x)}{\partial x_k} \Big|_{x^*}$ represents the producer's marginal risk premium with respect to input k . If the farmer is risk-averse, he will use risk reducing inputs below their marginal costs and risk increasing inputs above their marginal costs.

ii. *The comparative statics results*

Following the approach developed in 3.1.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:

$$p_o \left. \frac{\partial f(x_e, \bar{x}_p)}{\partial x_e} \right|_{x_e^*} - \lambda L p_o^2 \left. \frac{\partial V(y/x, \bar{x}_p)}{\partial x_e} \right|_{x_e^*} = p_o \left. \frac{\partial E(y/x_e, \bar{x}_p)}{\partial x_e} \right|_{x_e^*} - \lambda L p_o^2 \left. \frac{\partial V(y/x_e, \bar{x}_p)}{\partial x_e} \right|_{x_e^*} = p_e \quad [14]$$

If $\lambda = 0$, [14] reduces to [9a].

[14] 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:

$$\frac{\partial^2 E(y/x_k, x_l)}{\partial x_k \partial x_l} \geq 0 \Leftrightarrow \frac{\partial^2 f(x_k, x_l)}{\partial x_k \partial x_l} \geq 0 \quad [15]$$

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:

$$\frac{\partial^2 V(y/x_k, x_l)}{\partial x_k \partial x_l} \leq 0 \Leftrightarrow \frac{\partial^2 [h(x_k, x_l)]^2}{\partial x_k \partial x_l} \leq 0 \quad [16]$$

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 [14], 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:

$$\frac{\partial^2 V(y/x_e, x_p)}{\partial x_e \partial x_p} = -0.12 \frac{V(y/x_e, x_p)}{x_e x_p} \quad [17]$$

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 [14]. Both input uses would decrease. This would lead to a decrease in output.

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)² or Antle (1988), the first order conditions of the input choice problem [13] are directly estimated using the previous estimates of the production function. Additive errors are added to both equations. They represent optimisation mistakes, i.e., random failures to satisfy [13]. Input choices are assumed to be optimal on average and not to depend on input use levels. Also, the added errors are supposed to be i.i.d. and to be null in average. Gouriéroux and Peaucelle (1990) demonstrate that, under some weak assumptions, applying the within estimator for [13] gives a consistent estimate of $\bar{\lambda} = \sum_{i=1}^N \lambda_i / N$. However, these results must be interpreted carefully this estimation depends on the previous one.

The estimated value³ of $\bar{\lambda}$ is $1.2 \cdot 10^{-6}$. 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. A decrease in pesticide use of 1 percent leads to a decrease in fertiliser use of 0.50 percent. This implies a decrease in expected yield of 0.36 percent. Thus, farmers' risk attitudes seem to be important in this case, they reinforce the dependence of the intensive cropping technology on pesticide use primarily induced by technological aspects.

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.

4. IMPLICATIONS ON POLICY DESIGN

The major findings of this modeling exercise pertaining to a pesticide ban assessment can be summarised as follows. The French crop sector is heavily dependent on pesticide use, at least in the medium run. Two main reasons support this statement. Agronomic principles state that intensive cropping techniques increase potential losses due to pest and disease. This creates crop protection needs. Therefore the only way for farmers to circumvent a pesticide ban is to reduce their use of 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 (and more generally intensive cropping techniques) 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 a partial analysis using marginal concepts. Therefore, they must be used carefully. However, further research on this problem suggests that these results may be extended to usual pesticide use reduction measure (taxes, ...). This is mainly supported by two arguments.

Firstly, existing pesticides are very effective in controlling many serious threats to production and are easy to use. Farmers can easily attain high levels of crop protection at relatively low private costs. They can follow predetermined application schedules, apply a fixed dosage at fixed dates without regard of the actual conditions prevailing in the field. These are the main reasons why there are no viable substitutes for chemical pesticides.

Secondly, because chemical pesticides are almost the only damage control agents available for farmers, a forced reduction of pesticide use may provide incentives to adopt technology less dependent on damage control. Such technologies are available at present, but they generally are less productive than the intensive cropping one and require high human capital to be viable.

Also, due to the dependence on current production processes on pesticide use, the absence of viable substitutes for pesticides and the absence of viable alternatives to the current technology, most of the measures which may be proposed in order to reduce pesticide use would have significant effects on the agricultural sector. Therefore, the expected social costs related to these measures (which could be evaluate through a multiplier effect) are substantial.

This suggests that specific regulatory instruments are required for pesticide policy. In this vein, information use promotion, education programmes intended to increase the human capital of farmers may be efficient pesticide use reducing policies. These points and the related considerations on professional pest control consultants are discussed in Lichtenberg, Zilberman and Archibald (1990) and in Ikerd (1991).

¹ 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).

² Love and Buccola (1991) point out that estimating [23] jointly with [4] and [5] improve estimation efficiency.

³ The constraints implied by economic theory for model [23] are imposed.

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