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**CAN WE EXPECT ABATEMENT OF AGRICULTURAL
POLLUTION USING ECONOMIC INCENTIVES ?**

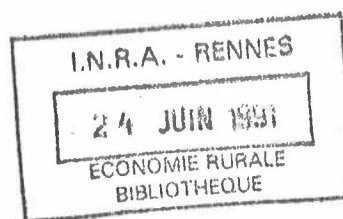
The case of intensive livestock farming in France

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In all developed countries there is a growing concern about the level of nitrates in drinking water. In the European Community the per liter Maximum Admissible Concentration (50 mg of NO₃) is reached in many areas, with peaks over 100 mg in some places. It is significant that the more acute problems occur in regions characterized by intensive farming and thus agriculture liability is clear.

The main sources of nitrate contamination of drinking water are :

- nitrogen fertilizers used to increase crop yields
- animal manure resulting from intensive animal husbandry particularly
- mineralization of nitrogen from the N-pool where agricultural practices play a role
- other sources, including natural sources

In countries where nitrogen fertilizers are heavily used figures show a stagnation since 1980 (W. Germany) or since 1985 (Belgium). In the Netherlands, the country with by far the highest rate of nitrate input per square kilometer, there is even a substantial decrease since 1980 from 56.2 tonnes/km² to 46.7 tonnes in 1988 (OECD, 1991 p. 35). Such a decrease occurred when the Dutch agriculture - environment debate became a central issue. But generally the change of farmers' behaviour needs support from appropriate regulatory measures to provide adequate incentive at the farm level.

Although the fertilizer N use remains worrying this question have received growing recognition and some results are obtained or may be expected. Animal manure is a more acute problem for reasons presented in point 1 where the implementation of the idea of nitrogen excess is also detailed.

Among the economic incentives relevant to improve the situation the analysis emphasizes nitrogen taxation, the most feasible means. It would increase the opportunity cost of organic nitrogen and would encourage a better utilization of manure. To deal with the potential impacts of a tax put on fertilizers we consider nitrogen demand, first using the cost function approach which is a conventional one to derive input demand. After that, a more adapted methodology based on a Tobit specification is discussed. This paper is restricted to the intensive livestock industry. However for arable farming in France it has been shown (Vermersch, 1989) that taxation would be consistent with a process of extensification.

1. FOCUS ON MANURE

Manure is an important concern because

- The N production level per ha in animal manure is generally as the same order as in chemical fertilizers in almost European countries.

- There is a higher long term trend for an increase of quantities of manure applied to agricultural land, than for fertilizers. As a consequence the proportion of N manure in total nitrogen increases (TEAGASC, 1989 p. 24)

- In animal manure production there is a shift from cattle to intensive husbandry (pig and poultry). The liquid manure coming from intensive rearing, especially pigs is less efficient, and a part, in the form of ammonium, can readily volatilize giving acid rains.

- There is a regional concentration of intensive livestock farming which leads to the emergence of so called manure surplus areas.

These factors are leading intensive livestock rearing regions to face difficulties regarding the environment, particularly in the Netherlands. Although the general French situation is pretty good, there are areas experiencing nitrate pollution problems because there is an excessive livestock intensification. Thus, Brittany with less than 5 per cent of the French Utilised Agricultural Area represents about 40 per cent of total intensive rearing output by value. Over fifty per cent, 53 % exactly, of national pig farming is concentrated in this region.

There is a local nitrate problem whenever the nitrogen applied, of one kind or another, is not taken up by plants and reaches ground water aquifers, or is lost in surface run-off. N uptake depends on yield response by the plant, and soil type. The excess is defined in relation with agronomic threshold determined by the self-cleansing capability of the soil (for more details see appendix)

In fact, the effects of nitrogen surplus are more intricate because ground water pollution depends on the nitrogen cycle in the soils. Furthermore the effects of on-site manure spreading are related to the nature and the state of the soil. According to the weather conditions soils can be classified in three kinds : those on which slurry spreading is unsuitable at any time of year, those on which slurry can be spread at any time of year, and those on which it is unsuitable only winter. So the relationship between a certain amount of fertilizers and the consequent damage is not a simple one.

Using the French Farm Accountancy Data Network we have estimated the nitrogen excess at the farm level for intensive livestock rearing farms (over than 1.5 animal units per ha). A panel with 100 holdings has been selected from 1982 to 1986. This panel excludes farms with less than 5 ha.

As indicated in table 1 about 80 % of all farms have an excess of nitrogen. This excess, expressed in kg of N per ha of Utilised Agricultural Area (UAA), varies according to the type of farming. Logically the average surplus is greater for pig and poultry farming than for cattle and dairy holdings : the ratio is from 10 to 1.

Table 1. Distribution of holdings by type of farming according to the importance of N excess (in percent), and level of N excess (kg per ha of UAA).

	Holding distribution			Level of N excess (kg per ha of UAA)		
	Deficit Units	Balanced Units	Excess Units	Deficit	Balanced	Excess
Cattle and dairy	13.9	7.9	78.2	- 37	16	145
Mixed farming	8.8	9.9	81.3	- 30	15	262
Pig and poultry	7.7	7.7	84.6	- 27	14	1457
All farms	12.2	8.5	79.3	- 30	16	226

If mineral nitrogen bought by farmers is not taken into account to estimate the N excess, it appears that only 15 per cent of all farms have surpluses. This proportion is lower for cattle and dairy farming (9 %) but reaches 24 per cent for mixed farming and 59 per cent for pig and poultry farming. This difference between the proportions of holdings with a N surplus means that a large part of the units do not need mineral fertilizers since organic nitrogen can be substituted for bought fertilizers.

Despite huge surplus of animal wastes, an important utilization of artificial fertilizers is made. This behaviour reveals technical and allocative inefficiencies because a cost minimizer would have bought a smaller amount of mineral fertilizer.

Let define for each farm a threshold (nitrogen units which can be spread per hectare without damage) above which there is an excess of nitrogen. Thus it is a farm specific threshold which can be interpreted as an upper bound and therefore farmers are classified into two categories according to whether they respect it or not. This simple typology is instrumental as we will see because response to nitrogen price variations significantly differs according to categories.

2. ESTIMATING NITROGEN DEMAND : A COST FUNCTION APPROACH

Our starting point is a specification of the technical possibilities that intensive livestock farms face. These are summarized by the production possibilities set Y that gives all feasible input and output combinations. Therefore let y denote an r -dimensional vector of non-negative outputs and (x, z) denote an $(m + n)$ - dimensional vector of non-negative inputs. Thus the input vector is derived into two sub-vectors x for variable inputs and z for fixed inputs. Define the variable input requirement set :

$$X(y, z) = \{x ; (x, y, z) \in Y\}$$

which represents the set of all variable - input combinations capable of producing output bundle y using fixed inputs z .

It is well known that if $X(y, z)$ satisfies general properties (see for example Chambers 1988 p. 261-281, Guyomard and Vermersch 1989, Vermersch 1989) there exists a multioutput restricted cost function :

$$CR(p_x, y, z) = \min_x [p_x \cdot x ; x \in X(y, z)]$$

where p_x is a vector of variable input prices. As every cost function CR is non decreasing concave, continuous and linearly homogeneous in factor prices. Furthermore it is positive and non decreasing in outputs and equals zero when $y = 0_m$. Finally it can be shown that CR is non-increasing in fixed inputs.

Also notice that if $X(y, z)$ is a strictly convex set then $CR(p_x, y, z)$ is differentiable in p_x and Shepard's lemma applies. Moreover if it is twice - continuously differentiable, demand elasticities can be derived.

For econometric estimation, we have two outputs : y_1 is pig output whereas y_2 is other animal and crop output, both are measured in monetary terms. Notice that crops only represent a minor share of total production, so the second category y_2 essentially includes livestock and milk output. Four variable inputs are included : fuel and oil, fertilizer, farm capital consisting of buildings and machinery and purchased feed. In the dual approach their prices are used rather than physical quantities or monetary evaluation. We suppose a perfect substitutability between mineral and organic nitrogen so the price of the former equals the opportunity cost of the latter. Finally four fixed

inputs are taken into account : family labour in standard labour units, miscellaneous inputs (pesticides, electricity, maintenance) in monetary terms, livestock in animal units and agricultural land in hectares.

The restricted cost function specified in this paper is a quadratic with an annual index of time. Derived input demand equations are linear in all their arguments, but only nitrogen demand will be reviewed in this paper. Nitrogen demand equals :

$$(1) N = a_0 + \sum_i a_i p_i + \sum_j b_j y_j + \sum_h c_h z_h + u,$$

where $i, h = 1, \dots, 4$; $j = 1, 2$ and u is the error term.

The sample is split down into two sub-samples according to whether the upper bound for nitrogen is respected or not. The former refers to an "efficient" behaviour whereas the latter involves inefficiencies. Moreover in order to deal with farm dimension, an error component model is specified. So the error term is divided into two random components :

$$u_{it} = a_i + e_{it} ; \quad i = 1, \dots, N, \quad t = 1, \dots, T$$

a_i is the farm component, and e_{it} a white noise.

Table 2 shows the estimated coefficients of the nitrogen demand equation for both sub-samples. They are obtained by the quasi - generalized - least - square method which is based on a two stage process. It gives consistent estimators which are asymptotically equivalent with generalized least squares estimators. They are more efficient than "within" estimators for finite values of T with N tending to infinity providing there is no correlation between the explanatory variables and the error term.

Table 2. Estimated equations of nitrogen demand : "efficient" vs "inefficient" farmers.

Parameters	" Efficient"	"Inefficient"
Intercept	- 4 277.39 (2.27)	- 10 923 (1.89)
<u>Variable inputs prices</u>		
fuel and oil	1.33 (0.12)	82.85 (1.70)
nitrogen	- 216.95 (6.10)	- 719.65 (3.73)
farm capital	- 1 073.37 (0.59)	3 039.69 (0.35)
animal feed	- 10.53 (0.92)	172.44 (1.70)
<u>Outputs</u>		
pig	- 0.002 (1.46)	0.001 (0.62)
other animal and crops	- 0.001 (0.43)	- 0.001 (0.17)
<u>Fixed inputs</u>		
family labour	0.35 (1.11)	- 4.45 (2.69)
other materials	0.02 (0.77)	- 0.22 (1.85)
livestock	9.87 (10.69)	6.71 (4.79)
land	1.11 (6.37)	3.27 (3.20)
Time trend	139.69 (2.18)	636.84 (2.43)
nb of farms	70	30
nb of years	5	5
R. square	0.56	0.34

Asymptotic t - ratio in parentheses.

In both estimated equations, the coefficient of mineral fertilizer price is significantly different from zero with the right positive sign. Furthermore family labour, total livestock and available land positively affect demand. So there is some consistency between the two equations but there are also differences. Only in the "inefficient" sub-sample there is a significant impact of the price of fuel and oil, and animal feed on nitrogen demand. The equality between regression coefficients is rejected since the computed F - value (with 13 and 500 degrees of freedom) is 19.56. Thus we can conclude that the two categories of farmers are heterogeneous regarding mineral fertilizer demand. Scale effects are captured through fixed inputs, specially livestock and land, so the influence of outputs is not significant.

Instead of regression coefficients let consider own-price elasticity of mineral nitrogen demand which is the interesting parameter for economic purposes. It is smaller for efficient farms than for "inefficient" farms : - 0.36 and - 0.68 respectively. These

values can be compared with estimates obtained from French aggregate time series : - 0.33 for short run elasticity and - 1.10 for long run elasticity (Bonnieux and Rainelli 1988). Various authors (see Hanley 1990) report figures from - 1.20 up to - 0.08 for European countries (UK, Ireland, FRG and Denmark) on the basis of different methods (econometric and linear programming). But the important point is concerned with the difference in magnitude between the two categories of farms. A similar conclusion has been obtained before in a slightly different context (Vermersch 1989) since elasticities result from a system of factor share equations derived from a restricted translog cost function and estimated on a cross-section. Therefore farmers' response to a uniform tax put on nitrogen would largely vary according to the technical and allocative inefficiencies.

3. ESTIMATING NITROGEN DEMAND : A TOBIT MODEL

The preceding derivation relies on the minimization of a restricted cost function therefore elasticities have to be understood as short-run Hicksian elasticities depending on the level of fixed inputs. Furthermore fixed factors are not required to be at a long-run optimum level and there is some evidence of a disequilibrium for land and family labour. A discussion of this point is helpful to get a better insight of nitrogen issues because they can be considered in terms of a similar disequilibrium.

For each farm, there is a constraint on land availability. If it is binding long-run equilibrium level can be derived (Brown and Christensen, 1981). For instance for arable farming in France, land is a rationing factor, so in the long-run there is a pressure towards an increasing acreage of holdings. So land is a quasi-fixed factor since if the constraint was relaxed farmers would adapt acreage in order to reach the long-run optimal size originating a process which would result into more land under cultivation.

On the labour side, the level of available family labour gives a lower bound for the total amount of labour input. This constraint is not necessarily binding because some farm operators have to hire wage earners because there is not enough family labour available on the farm. If labour is demanded in amount smaller or equal to available family labour then the constraint is binding. The latter case is often observed and involves a low mobility of agricultural labour due to poor job opportunities.

Farms can be classified into two categories according to whether the family labour constraint is binding or not. For the second category for which the constraint is

not effective there is some hired labour on the farm. Therefore given a cost-minimizing behaviour, the optimal level of labour input equals family labour plus hired labour. The basic idea is to use this information to derive the optimal level of input for the first category of farms for which the constraint is binding. A Tobit model can be specified in order to include both categories (Vermersch, 1989).

Regarding manure utilization farm operators face a similar constraint. Let N_0 the provision of nitrogen through liquid manure then, if there is no opportunity to sell it, the farmer has to spread this minimum quantity. The amount of nitrogen effectively spread is :

$$N \geq N_0$$

it includes N_0 plus nitrogen N_C provided by chemical fertilizers.

For a given crop mix there is a threshold above which pollution occurs, so two cases have to be considered :

$$N_C + N_0 \leq N_m$$

$$N_C + N_0 > N_m$$

where N_m equals total nitrogen requirements. For the first case total nitrogen spread respect the threshold and a cost-minimizing behaviour is assumed. So observed amount of nitrogen spread is optimal.

The second case involves nitrogen excess corresponding with technical and allocative inefficiencies since a cost minimizer would have bought a smaller amount than N_C of mineral fertilizers. Both cases can be covered by :

$$N = N_C + N_0 = \begin{cases} N_C^* + N_0 & \text{if } N \leq N_m \\ N_C + N_0 & \text{otherwise} \end{cases}$$

where N_C^* equals the optimum for N_C .

Following Shephard's lemma, derived factor demand is easily obtained. Then equation (1) becomes :

$$(2) N^* = N_C^* + N_0 = a_0 + \sum_i a_i p_i + \sum_j b_j Y_j + \sum_h c_h z_h + dT + u$$

But now the dependent variable N^* is not observed for the whole sample but only for farms below the threshold. A Tobit model can be used to estimate equation (1). The basic idea is to use the "efficient" sub-sample for which observed demand N equals N^* to derive what would be the demand of the other farms if they were efficient. Thus using an exogeneous information, i.e. nitrogen requirements, it is possible to include both categories of behaviours in a single model. The Tobit specification relaxes the cost-minimizing hypotheses for farmers above threshold. It is maintained for the rest of the sample. Table 3 shows the estimated equation for nitrogen demand. The same panel of 100 farms observed during 5 years has been used and an error component structure for the error term has been considered.

Table 3. Estimate equation of nitrogen demand : tobit specification

Parameters	
Intercept	- 5 060.12 (12.37)
<u>Variable input prices</u>	
fuel and oil	15.10 (1.54)
nitrogen	- 220.99 (30.51)
farm capital	- 1 750.71 (0.73)
animal feed	- 9.05 (0.46)
<u>Outputs</u>	
pig	€
other animal and crops	€
<u>Fixed inputs</u>	
family labour	€
other materials	- 0.007 (0.07)
livestock	3.97 (47.21)
land	2.01 (104.61)
Time trend	225.18 (10.46)
Nb of farms	100
Nb of years	5

Chi-square in parentheses. It is used to test the significance of regression coefficients (asymptotic likelihood ratio test). The observed value has to be compared with a critical value for a chi-square distribution with one degree of freedom : for example 6.31 for a 0.90 level of confidence.

The price of nitrogen, the level and livestock and land available affect significantly nitrogen demand whose own-price elasticity equals -0.31. This value is

close to the value obtained from the efficient sub-sample. This is consistent given the rationale of the Tobit approach.

4. FINDINGS AND CONCLUSION

The response to a nitrogen taxation would vary according to farm operators' efficiency. In a first stage a greater decrease in nitrogen demand by the least efficient farmers than by the most efficient ones can be expected. This point can be illustrated on the basis of own-price elasticities obtained for each farm category. A 10 % tax would induce a 3.6 % reduction in the use of nitrogen by farmers who respect nitrogen requirements and do not create environmental damage. But the decrease would be greater and reach 6.8 % in the second category characterized by an excess in nitrogen spread. So if we assume that the sample of farms is representative, a 4.6 % reduction could be expected for the whole population of intensive livestock farms.

The tax on mineral fertilizer would increase the opportunity cost of organic fertilizer and would push farmers towards more efficient practices at the micro level. These practices would involve a smaller amount of nitrogen spread and would be more friendly for the environment. Therefore a tax could help to improve the efficiency of the livestock industry and would be consistent with a policy based on education and extension services. But in a second stage after the elimination of these inefficiencies the response to a 10 % tax would diminish and would be roughly equaled to a 3.1 % decrease.

Efficiency has been defined by using an ad-hoc procedure based on exogenous information. Specific farm thresholds equal nitrogen requirements and are derived from agronomical standards which take into account the assimilative capacity of the environment. Obviously other thresholds could be imagined, consistent with very drastic constraints imposed on the farm sector. An ecological approach expressing environmentalist preferences could be considered. It could for example result in a threshold tailored by location.

Above results are derived under family labour and land fixity. As many people put forward the argument it is true that in the short run the impact of a tax on nitrogen would be moderate. But now if input fixity is relaxed a new equilibrium involving the utilization of less labour and more land would emerge. Long run own-price elasticity of nitrogen demand would be greater than short run elasticity implying a stronger response to a tax.

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APPENDIX : The estimation of N excess

Some holdings do not produce crops and they have only animals. Their acreage is very small, so animal manure is not spread on the spot but transported to other farms. But export flows of manure are unknown. To avoid bias farms with less than five hectares of Utilised Agricultural Area are excluded.

For each farm nitrogen inputs are estimated

- Concerning animal manures, the Farm Accountancy Data Network is used to have the livestock according to 22 categories. For each one a technical coefficient permits to estimate the N production. In fact it is the nitrogen available on the spot which is estimated since volatilisation of ammonia following surface spreading is deducted.

- Concerning artificial fertilizers, N bought by farmers is given directly by the Farm Accountancy Network.

The nitrogen uptaken by plants is a function of the type of soil, the type of plant and the yield. It also depends on temperature, radiation and water supply. The nitrogen export is determined for the 19 types of cultivation as given by the Farm Accountancy Network. For each type of plant, according to the average yield, the nitrogen uptaken is estimated.

If the application rate of total nitrogen from animal or mineral origin is greater than the plant export there is an excess. It is assumed that 30 kg of nitrogen per ha of Utilised Agricultural Area is an agronomic threshold below which there is no utilisation by the crops. There is excess when the surplus of nitrogen is over this threshold.