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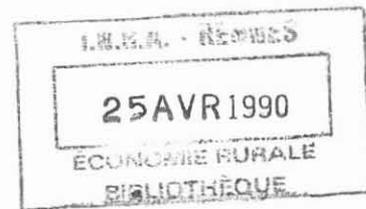
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INTERNALIZING LIQUID MANURE EXTERNALITIES :
A CASE STUDY IN FRANCE

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The sharp growth of intensive stock-keeping occurred in France in the western part of the country, namely in Brittany, in the 1950's for poultry and the 60's for pig and vealer calves. This development may be ascribed to several economic and social factors.

Intensive breeding could not have come about without the profound change in French society over that period. An industrial leap forward contributed to accelerated urban development and led to sweeping changes in food habits. Poultry consumption changed direction accordingly, with a steep increase of industrial poultry consumption among clerical and non active groups while professional, managerial and blue collar-groups tended to increase their consumption of pork (Saunier and Schaller, 1978, p. 62).

On the supply side, the most dynamic farmers with small holdings in areas without employment opportunity in the industrial sector have specialized in poultry and pig meat production. This specialization and expansion of intensive farming has also been considerably supported by the powerful agro-food complexes which supply animal feed and process meat products. The high degree of organization of the farmers in Brittany and a strong relationship between suppliers and processing industries has abetted this development.

During the seventies cheap import of feedstuffs contributed to the possibilities for development in intensive animal husbandry. But the intensification has led to surplus and to lower profit margins, so that the scale of operations increased.

As table 1 shows the average number of sows and pigs for fattening enlarges between 1981 et 1988 in specialized holdings in Brittany especially for farrow-to-finish producers and concerning the average number of sows.

Table 1. Specialized holdings with pigs in Brittany (1981-1988)

	feeder pig finishing		feeder pig production		farrow-to-finish	
	1981	1988	1981	1988	1981	1988
number of holders	2379	2341	3000	1435	4098	4648
average number of						
- sows	-	-	41	44	67	96
- pigs for fattening	363	401	1	2	415	504

feeder pig finishing holders have 0 sow and > 150 present pigs for fattening

feeder pig production holders have > 20 sows and < 5 present pigs for fattening

farrow-to-finish holders have > 20 sows and > 120 present pigs for fattening

Source : Le cheptel porcin en Bretagne. Effectifs au 1/12/1988. Statistique Agricole de Bretagne, n°2, 1989.

The three types of producers represented 71 % of the total sows in 1981 and 90 % in 1988. Concerning pigs for fattening the proportion was 88 % in 1981 and 96 % in 1988. During the same time a geographical concentration of the production happened. From 1959-60 to 1988-89 the share of Brittany in total French pig production increased from 20.1% to 50.0 % while the share for poultry did from 15,2 % to 26,5 %.

The tremendous growth of intensive livestock farming has been very positive for consumers because the price of meat, specially chicken meat, has declined. But it has led to an increasing concentration in a region with small holdings and therefore has added a special feature to pollution problems. In the old days manure was valued for its ability to increase crop production levels. Today with the use of chemical fertilizers and with the segregation of the traditional mixed farms in specialized arable farming and specialized livestock production, manure is applied to the land in too large quantities. As a consequence serious environmental problems have arisen.

The first part of this paper deals with a general review of pollution due to intensive livestock farming. The second part is devoted to a specific discussion of the manure problem at the farm level.

1. INTENSIVE LIVESTOCK FARMING AND ENVIRONMENTAL STRESS

Nitrogen supplied by manure do not tell the whole story about the environmental impact of intensive livestock farming but it is the major source of pollution. Figures in table 2 are based upon standards and are concerned with nitrogen emissions from animal wastes. They are calculated by applying conversion factors to head of livestock and places available in specialized buildings. The availability of fertilizer components of animal origin has been assessed in Brittany for a geographical division into four units.

Table 2. Nitrogen units from animal wastes according to the origin (metric tons in 1988)

	Côtes-d'Armor		Finistère		Ille et Vilaine		Morbihan		Brittany	
	units	%	units	%	units	%	units	%	units	%
cattle	31103	53.6	28788	56.2	37514	79.4	25350	58.8	122765	61.4
pigs	14000	24.1	12886	25.1	6415	13.6	6785	15.7	40086	20.1
poultry	12087	20.8	9071	17.7	2344	5.0	10266	23.8	33768	16.9
others	894	1.5	534	1.0	951	2.0	755	1.7	3134	1.6
total	58084	100	51279	100	47224	100	43166	100	199753	100

As shown in table 2 cattle total theoretical nitrogen availability accounts for a noteworthy proportion : 61,4 % regionally, varying from 53.6 % in Côtes-d'Armor to 79.4 % in Ille-et-Vilaine and therefore represents a considerable "background noise". Concerning intensive stock-keeping total nitrogen represents 40 per cent at the regional level (less than 19 per cent in Ille-et-Vilaine and 45 percent in Côtes-d'Armor).

The importance of the amount of cattle manure means that slurry pollution problems cannot be considered independently of whether there are cattle or not and it is indeed the combination of the two types of production which accounts for the magnitude of the nitrogen load in Nord-Finistère, whereas in the East of the Côtes-d'Armor departement pig farming is the main source.

Table 3. Nitrogen units from animal wastes, export through crops and contribution through fertilizers (per ha usable agricultural area in 1988)

	Côtes d'Armor Finistère Ille-et-Vilaine Morbihan Brittany				
export through crops availability	129	126	113	124	123
animal waste	118	116	90	105	107
fertilizers	67	136	151	74	108

Table 3 suggests that it would not take too much to balance nitrogen units exported through crops and those available on site through animal wastes. But there are agronomic reasons for substituting animal waste nitrogen for only about one third of mineral nitrogen when cereals are grown. For health reasons no more than one third of mineral nitrogen can be substituted for in vegetable growing. Taking all these considerations into account available nitrogen still exceeds exports in many places. If nitrogen from bought fertilizers is taken into account there is a theoretical excess of nitrogen varying from 44 units per ha in Côtes-d'Armor and Morbihan to 127 units in Finistère and Ille-et-Vilaine (average about 92 units for Brittany).

There are several different ways in which intensive livestock production units can pollute the environment. First, the mere presence of such units creates local problems through noise and smell, while the visual landscape is also affected since it is spoilt by the buildings and facilities. Second, specific problems arise from the storage and spreading of effluents, either through run-off or leaching of manure components into the soil and also through the emission of acidic gasses into the air.

Apart from neighbourhood or aesthetic problems, manure pollution can affect health, specific local ecosystems and ecosystems in general. Most of the effects on health concern the deterioration of the drinkable water supply, whether surface or ground water, through nitrates which may be

converted into carcinogenic compounds harmful to babies and pregnant women. Consequently, the Commission of the European Communities has laid down a guideline of 25 mg of NO_3 per litre and a permissible level of 50 mg for potable water supplies. It should also be noted that nitrates are harmful when ingested by animals. Nitrites as micro-pollutants are also hazardous as such. Pathogens in manure have also been suspected of contaminating shellfish.

Local effects on ecosystems of intensive animal production include ammonia emissions, which are toxic to neighbouring vegetation, including conifers. Soil contamination by trace elements, chiefly copper and zinc, which occur in animal feed and therefore also in manure, has been observed. Following these observations, regulations to reduce the quantity of zinc and copper in animal feed have been introduced in several countries. The next most important nutrient after nitrogen, phosphorus from manure remains in the soil since plant uptake is low relative to the quantities supplied. In the long run, phosphorous accumulation may lead to crop yield reductions.

Diffuse effects on ecosystems include losses of ammoniacal nitrogen through volatilization and ensuing acide precipitation, which in turn acidifies the soil in other places. Nitrogen and phosphorus may be transported by run-off water and leakage from improperly constructed manure tanks can lead to the eutrophication of slow-running water. This affects the ecosystems in rivers and also makes the treatment of potable water more complex. Eutrophication of estuarine and coastal waters may also occur, with the possibility of algae blooms.

Table 4 sets out the factors associated with intensive animal production which cause pollution, their effects and consequences as pollutants.

Table 4. Pollution from intensive animal husbandry : factors, effects and consequences

Factors	Effects	Consequences
1. Siting of the buildings	Noise, appearance smell	Neighbourhood and aesthetic problems
2. Run-off from Spreading operations Nitrogen infiltration	Smell, Production of nitrates	Neighbourhood and tourism problems Drinking water quality
3. Leaching of organic matter, nitrogen and phosphorus	Oxygen absorption in flowing water, Eutrophication of slow- running water and possibly estuarine and coastal water	Disruption of river ecosystems Potable water quality
4. Transport of pathogens	Bacterial contamination of shellfish	Effects on human health and shellfish marketing
5. Atmospheric emission of ammonia	Acidification of the environment through depositing and leaching	Toxic effect on plants, Effects on the soil
6. Manure storage facilities capacity	Spreading at sub-optimal periods, seepage from tanks	All of above

2. NITROGEN EXCESS AT THE FARM LEVEL

In order to assess nitrogen excess at the farm level we consider recommended nitrogen requirements and nitrogen provision by liquid manure and through bought mineral fertilizers. The demand side corresponds to recommended requirements and takes into account losses due to leaching so it is greater than nitrogen fixed by plants. It is calculated by using technical coefficients, crops being distributed across main categories. Supply via liquid manure is calculated in a similar way. For each livestock category there is a specific standard to transform effluent into nitrogen units. Purchased fertilizers are provided in value and volume by farm records so the second supply component is easily determined.

The data originate from the farm accountancy data network and two samples are selected. The first one is a panel which consists of 489 farms with more than 1.5 animal units per hectare. Farms are observed from 1982 to 1986 and are dispersed across the different regions in France, 128 are located in Brittany but only 47 are specialized in intensive livestock systems based on purchased feed. So the second sample is selected to supplement this information. It only concerns Brittany and intensive animal systems. It consists of three cross-sections from 1984 to 1986 with sample sizes equal to 135, 128 and 153 respectively.

In both samples some holdings do not produce crops they only have dairy cows, pigs or poultry. Their acreage is very small and for some of them the agricultural used area is zero so animal manure is not spread on the spot but transported to other farms. But export flows of manure are not known therefore farms with zero (or negligible) available land are excluded from the samples and are not taken into account in results reported below.

Table 5 provides the evolution of nitrogen excess (in kg of mineral nutrient per ha) for the panel data. Surpluses reach high values since the grand mean equals 130 kg. However these figures are smaller than comparable results reported by other authors as for instance Becker (1989) who did similar calculations for Lower-Saxony in FRG. Moreover surpluses have declined since 1983 and there is a 10 % decrease for the whole period.

Table 5. Nitrogen excess in kg of mineral nutrient per ha (panel data)

1982	1983	1984	1985	1986	Total
134	135	132	127	120	130

Some information on the distribution of farms according to excess values is reported in table 6. The number of deficit farms (negative excess) has increased significantly from 9,9 % up to 12,4 % while the number of high polluting farms (excess greater than 200 kg/ha) has declined from 24,9 % to 18,4 %. These evolutions manifest a slight improvement but the manure problem still remains since more than half the farms are beyond 100 kg/ha, a level being considered as a weak utilization of nitrogen on permanent grassland.

Table 6. Frequency distribution (%) of manure excess (panel data)

Excess Kg/ha	1982	1983	1984	1985	1986	Total
+ 500	2.9	4.1	2.1	2.9	3.0	3.1
+ 200	24.9	23.1	20.0	21.0	18.4	21.6
+ 100	54.0	55.9	57.5	54.6	53.5	55.2
+ 50	75.6	77.1	75.6	75.1	75.2	75.8
+ 0	90.1	90.9	91.1	89.1	87.6	89.8
negative	9.9	9.1	8.9	10.9	12.4	10.2

A more detailed analysis by type of farming shows marked differences in terms of manure surpluses. The average for the whole period ranges from 71 kg/ha in cattle farming to 125 kg/ha in intensive dairy farming and 158 kg/ha in intensive pig farming. Moreover for the latter system total nitrogen surplus has significantly increased from 1982 to 1986. So let us focus on high intensive livestock farms and now consider the Brittany sample because there is the highest concentration of livestock systems based on purchased feed in this region.

In Brittany manure surpluses are greater than in the rest of France since the average excess equals 300 Kg/ha. Figures

in table 7 are based on a pooling of the three cross-sections and can be compared with figures in table 6, moreover there is a breaking-down by acreage category.

Table 7. Frequency distribution (%) of manure excess (Brittany data)

Excess kg/ha	acreage			Total
	0-15 ha	15-30 ha	+ 30 ha	
+ 500	24.4	2.6	0.0	9.5
+ 200	55.0	22.0	8.7	30.7
+ 100	76.3	52.9	27.5	56.3
+ 50	90.1	75.4	52.2	76.2
+ 0	95.4	86.9	81.2	88.8
négative	4.6	13.1	18.8	11.2

Differences between Brittany and the rest of France do not concern deficit farms but high polluting units (more than 200 kg/ha) : 30,7 % against 21,6 %. Moreover in Brittany the average surplus in the last category (excess greater than 500 kg/ha) reaches 1980 kg/ha while it equals 1063 kg/ha in the panel. A simple inspection of table 6 indicates a negative relationship between nitrogen excess and farm size : the number of deficit farms decreases with acreage whereas the number of high polluting farms increases. A more detailed analysis run for each cross-section would show a distorsion of the frequency distribution towards higher surpluses from 1984 to 1986 which means a worsening of the situation resulting into an increase of environmental stress.

In 1990 there has been is a peak of concern because nitrate concentration is above 50 mg/l in several areas in Brittany. Nitrate concentration of water bodies is mainly considered as a local problem at present since it only concerns restricted areas. But it must be seen as a potential problem to be solved in the future on a broader geographical basis because a long time delay could occur between pollution emissions and contamination of drinking water.

Investments for drilling deeper wells, for blending water, connecting local supply to long distance water sources, and for installing denitrification plants, are being made. These investments are expected to improve the situation in the future. But policy instruments meant to reduce polluting emissions have to be considered too, in order to achieve an efficient balance between the economic system and the environment. Economists see environmental pollution as a market failure problem, originating in the lack of clearly defined private property rights in environmental media. So since farmers can use the environment freely, this implies overuse and misuse, and finally damages suffered by the society.

Therefore there are strong arguments underlying a policy against pollution which would be based upon the polluter-pays principle. It has been used as a legal background in France, since a legislation passed in 1964 has defined a system of effluent charge fee for each of France's six major hydrographical networks. Moreover this principle is consistent with recommendations made by the OECD and also the European Community in its Green Book devoted to Environment and the CAP (1987). However this policy has not been implemented for intensive livestock farming.

For a given technology, polluting emissions are closely dependent on output level. The initial effects of the operation of the polluter-pays principle fall on the farm sector. The less efficient farms leave the industry and the end result of this burden will depend on the ability of the farm sector to shift the cost burden to consumers by raising prices (Bonnieux and Rainelli, 1988). A tax would imply a decrease of animal wastes through a decline of total output, therefore it would affect international trade, and could produce adverse effects since France is a net importer of pigs.

This argument not only assumes a rigid technology, but also assumes that such a technology is immutable and unchanging in the face of economic incentives. Again, technological innovation in production is widely observed and the assumption of an immutable technology therefore inappropriate. Abatement technologies, concerning storage facilities and manure spreading are still available. In the future the utilization of amino acids in feedstuffs is expected to reduce nitrogen level in animal wastes. Innovations could be induced by an effluent charge according to economic theory. Moreover a tax or a quota on mineral fertilizers would increase the opportunity cost of liquid manure and would encourage its utilization on arable land. For environmental reason it must be stressed however, that dressing for arable crops should take place in spring therefore large storage facilities are needed.

This argument also assumes that farmers are efficient. The estimation of a stochastic production frontier can help us to examine this crucial hypothesis. The empirical exercise is based on a Cobb-Douglas with five inputs : fertilizers, other materials, land, labour and capital (including machinery and buildings). This functional form is a compromise, however some indication of its appropriateness was obtained from an examination of Box-Cox transformations, which permits greater generality of the specification.

The production function itself is not the focus of this paper, it is a means to the end of obtaining measures of technical efficiency. So we only report an estimation of total variation in output from the frontier which is attributable to technical inefficiency and an estimation of average technical efficiency (see the annex).

Table 8. Technical efficiency

Types of farming	(1)	(2)
cattle and dairy	0,60	0,62
pig	0,16	0,74
poultry	0,05	0,94

(1) Estimation of total variation in output due to technical inefficiency

(2) Estimation of average technical efficiency.

Figures reported in table 8 are fragile and must be considered as provisional, it seems there are significant differences between types of farming. Results do not show any positive relationship between technical efficiency and manure excess, since pig farming which is the most polluting system reaches a quite high level of efficiency as compared with cattle and dairy farming. Again poultry farming which pollutes a lot, seems to be very efficient. Technical efficiency seems to be closely linked with the technology. For instance poultry systems are based on a very homogeneous technology while several rather heterogeneous technologies are available for cattle and dairy farming. Pig production appears to be an intermediate case in terms of technology. But up to now it is only an hypothesis.

*

Nitrate concentration in drinking water has increased a lot during the last decade in Brittany. There is a close relationship between this contamination and the rapid growth of intensive livestock farming. According to the opinion of experts in environmental questions it is one of the most urgent environmental damages caused by modern agriculture. Nevertheless nitrate concentration is only one of the components of the damage function. Present emphasis on this point can lead to an under estimation of pollution and to neglect other facets of the stress that could reveal very detrimental in the future.

Since total damages are not known the social optimum cannot be determined. The socially efficient allocation is not aimed at since the analysis of externalities proceeds in a partial-equilibrium framework. Moreover flows of pollutants come from non-point sources so it is very difficult to tailor well-adapted economic incentives and to enforce policy instruments because slurry spreading can have different consequences, through infiltration and run-off water, on the quality of the water or the disruption of ecosystems. However the operation of the polluter-pays principle based upon a system of charges, would involve a better resource allocation. Initially it could induce a decline in output but it would lastly encourage the diffusion of environmental - saving innovations and the use of more efficient practices.

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ANNEX - ESTIMATION OF THE COBB-DOUGLAS STOCHASTIC PRODUCTION FRONTIER

The functional form is

$$\ln Q_i = b_0 + \sum_{k=1}^K b_k \ln X_{ki} + \varepsilon_i \quad (i = 1 \dots n)$$

where Q_i is the output of the i th farm, X_{ki} is the k th element of a vector of K inputs of the i th farm, b_0 and b_k are parameters and ε_i is a farm-specific error term. The error term is composed of two independent elements :

$$\varepsilon_i = v_i - u_i$$

The symmetric component v_i permits random variation in output due to factors outside the control of the farmer, it is assumed to be independently and identically distributed as $N(0, \sigma^2_v)$. A one-side component ($u_i > 0$) reflects the technical efficiency relative to the stochastic frontier, it is assumed to be identically and independently distributed as $|N(0, \sigma^2_u)|$. Now define :

$$\sigma^2 = \sigma^2_u + \sigma^2_v$$

and consider σ^2_u / σ^2 as the total variation in output from the frontier which is attributable to technical inefficiency.

Jondrow et al (1982) have demonstrated that individual measures of technical efficiency can be calculated from the error terms ε_i since :

$$E(u_i / \varepsilon_i) = \frac{\sigma_u \sigma_v}{\sigma} \left| \frac{f(\varepsilon_i \alpha / \sigma)}{1 - F(\varepsilon_i \alpha / \sigma)} - \frac{\varepsilon_i \alpha}{\alpha \sigma} \right|$$

where $\alpha = \sigma_u / \sigma_v$, $f(\cdot)$ and $F(\cdot)$ are the standard normal density function and the standard normal distribution function evaluated at $(\varepsilon_i \alpha / \sigma)$. Measures of technical efficiency can be calculated as.

$$TE_i = \exp [-E(u_i / \varepsilon_i)]$$

so that $0 < TE_i < 1$. Model estimation is based on the corrected ordinary least squares (Aignes et al. 1977).

