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Agricultural policy and environment in developed countries**

F. BONNIEUX and P. RAINELLI*

1. Introduction

The agricultural policies of wealthy countries were set up in a period of scarcity, therefore they aimed at self sufficiency or an export expansion. The productivity increase necessary to reach these goals was achieved at different times by different countries. In addition, these policies allowed the incomes of those farmers remaining in business to increase at a time when economic growth needed a greater force.

But this agricultural policy has been too successful and has resulted in expensive surpluses and environmental degradation. One might also question its effects on social welfare.

To take an appropriate view of the relationship between agricultural policy and environment we have to identify the main features of agricultural pollution and analyse them from an optimal point of view. The corrective measures which could be implemented are then first discussed in order to improve social efficiency.

1. Features of agricultural pollution and optimal allocation

1.1. Features of agricultural pollution

1.1.1. Agricultural intensification

The environmental problems associated with agriculture are supposed to be brought about by intensification. This comes from changes in factor costs, in particular the considerable increase in labour costs compared with capital and agro-chemical costs. As a result, per hectare output has become increasingly higher. Agricultural product price programs are generally seen as the main reason for this intensification, especially in the European Economic Community (Bowers and Cheshire, 1983).

** Thanks are due to Hervé Guyomard (INRA-Rennes) for helpful comments.
But nominal protection rates vary according to the commodities. For instance, during the period 1977-1983 the EC’s nominal protection rates were 1.32 for cereals, 1.30 for pork, and 1.17 for poultry. Using the effective protection rates, i.e., a rate of protection measured at the value-added stage, important differences for the same commodity among countries are found (Mahé and Courgeon, 1986). For instance, the effective rates for pork are 1.97 for Germany and 1.27 for Denmark.

Intensification and the increase of productivity which goes with it, leads to the economic and social marginalisation of many small farmers. In a period of overproduction these small farmers cannot compete and have to leave agriculture. This involves the impoverishment of the poorer farmers and the abandonment of less favoured areas and an alteration of some environmentally sensitive regions.

The best example demonstrating the relationship between intensification and pollution is the contamination of groundwater by nitrates, which implies a human hazard, mainly for infants (methaemoglobinemia). Even if there are other sources of nitrates, there is no denying that the responsibility of agriculture is important, especially in rural areas where cropland prevails. The case of La Petite Traconne, a spring located in Seine-et-Marne, a French intensive cereal region, is enlightening. The level of nitrates in the drinking water is associated with the increasing use of fertilizers, mainly nitrogen, particularly from the fifties (see Graph 1).

![Graph 1](image_url)


Graph 1. Sales of nitrogen in Seine-et-Marne and nitrate concentration in the drinking water (the example of the spring La Petite Traconne)
1.1.2. Irreversibility

The impacts of intensive farm practices can be analysed in relation to nature protection, and distinctions can be made among decisions and actions on the basis of whether their consequences are difficult or impossible to ameliorate. This introduces the key concept of irreversibility.

Some ecosystems are prized for their genetic uniqueness, their special scientific uniqueness, or their unusual biological combinations. The current high technology agricultural production system and the decreasing diversity of cropping and livestock patterns are leading to the extinction of wild species in fauna and flora. At present, only 20 plant species provide 90% of human calorific intake. Two thousand years ago mankind used 5000 species (OECD, 1985: 151). Loss of natural populations can adversely affect human welfare as the loss of genetic information may in the future be useful in some form of economic activity or medicine.

Programs of land consolidation aiming at the establishment of more efficient farm organisations and rural structure lead to the alteration of the landscape with the destruction of small woodlands, hedge-fringed fields and wetlands.

A second sort of damage includes the degradation of agricultural potential and increased human health hazards. The former damage deals with farm practices and their impacts on soil erosion and the consequences for productivity. The substitution of maize for grassland worsens the effect of run-off waters, so that off-farm costs of sediment damage are more important than on-farm costs of soil productivity loss (Crosson, 1987). Nevertheless, soil conservation programs avoid massive erosion.

Concerning risks to human health, the most important factors are contamination of groundwater by nitrates and pesticides, and bacterial contamination of marine shell fish by pathogenes.

The significance of irreversibility in economic processes can be widened to agricultural policy. This concept was developed to deal with the case of a hydro-electric site located on a free-flowing stream suitable for inclusion in a scenic area of unique interest. In this case, the destruction of the site was virtually impossible to reverse. So we need to take into account the loss of features which have special characteristics: uncertain demand, no close substitutes, not readily reproduced. So it's worth noting that a part of the benefit of a preserved natural environment arises from uncertainty of the future demand (Fisher et al., 1972; Henry, 1974). Since agricultural policy has irreversible impact on the environment it is possible to use a similar procedure.

In order to measure benefits from the preservation of the wilderness a two-period setting is assumed. The decision problem when traditional grazing marshes are converted into cropland, is: how much arable cultivation should be developed in each of the two periods. There are two main assumptions. First, development in any period is irreversible; second the benefits at the end of the first period are not known. At the beginning of the second period the decision-maker has to choose whether to continue or not. If new information is forthcoming, the risk
will be reduced. If the expected benefits deal with uncertainty, and if there are irreversible consequences, we have to choose the conservative option because the central postulate of welfare economics is that the reduction of options represents a welfare loss.

As things stand at present, from an environmental point of view, we are at the end of the first period concerning agricultural policy. The consequences of the policies implemented are known. Now we can see what type of structural changes are needed in agriculture to help reconcile the agricultural and environmental objectives in the perspective of social optimum.

1.1.3. Specific features of agricultural pollution
In comparison with other industries, agricultural pollution sources present a different and more complex problem. The reason lies in the fact that there are non-point sources. When flows of pollutants come from non-point sources, they cannot be monitored accurately or at a reasonable cost. In other words, non-point pollutions are inherently stochastic.

For instance, slurry spreading can have different consequences, through infiltration and run-off water, on the quality of the water or the disruption of ecosystems. It depends on the nature and the state of the soil, and the type of crop. Climatic conditions (rain, frost), the extent of which land is saturated, and the incline of the land, account for the extent of damage from run-off water pollution.

The situation with off-farm sediment damage is typical (Crosson, 1987). As regards the flow of pollutants from run-off there is a spatial discontinuity, between the place where the soil is removed and the place where, as sediment, it causes damage. But there are also temporal discontinuities. The time between soil removal and sediment damage can vary from a few hours, to years. Because of the spatial and temporal discontinuities between site of run-off and site of damage one cannot be sure that controlling run-off pollution will give proportional and timely reductions in water quality.

This highly tenuous relationship between run-off from farms and sediment damage downstream makes the application of the emission-based policy instruments, which have been the focus of economic inquiry, difficult. Models which estimate or predict non-point pollutant flows utilising information on farm management practices, weather, soil characteristics, etc., are available. But their efficiency is limited and they are used just as a tool for diminishing the uncertainty about non-point loading. Hence, the estimation of the damage function is not easy.

1.2. Socially efficient allocation
The agricultural industry uses the environment as a factor of production and generates social costs. These are not borne by agriculture, therefore the cheapest way out is to ignore polluting effects, with the result that market equilibrium
The basic issues of the taxation of production externalities can be captured in a simple model involving two economic agents, the polluter and the polluted. For the latter, let us take the example of a water treatment plant which, due to pollution, leads to extra costs. For the former we will consider two cases. The first one is intensive livestock production in which polluting emissions depend on the level of output. The second one is crop farming in which pollution is influenced by a specific input.

1.2.1. Intensive livestock example
To be more specific, consider the pig industry in a watershed. We adapt a classical model (Varian, 1984: 259-263) with only one input: labour.
Assume that pigs are produced with a production function \( Y_1 = Y_1 (N_1) \) meeting usual regularity conditions. Polluting emissions increase with the output:

\[
\frac{dY_1}{dN_1} > 0 \text{ and } \frac{d^2 Y_1}{dN_1^2} < 0
\]

and have a negative impact on the production of drinking water:

\[
Y_2 = Y_2 (N_2, E) \text{ with } \frac{\partial Y_2}{\partial N_2} > 0 \text{ and } \frac{\partial Y_2}{\partial E} < 0
\]

The farmers are price-takers and profit-maximisers, then the pig industry will employ labour until:

\[
p_1 \frac{dY_1}{dN_1} = w
\]

where \( p_1 \) is the price of pigs and \( w \) is the wage rate.

It is fairly clear that this situation is not an efficient allocation of resources. The output of the pig industry adversely affects the output of the water treatment plant, but this externality is ignored by farmers and so the number of pigs fed is too high. If there are externalities, price-taking profit maximisation behaviour will not necessarily lead to a social welfare optimum. To make it evident, consider what would happen if aggregate profits are maximised.

Total profit, including both industries, is:

\[
p_1 Y_1 (N_1) + p_2 Y_2 (N_2, E) - w_1 N_1 - w_2 N_2,
\]

with \( p_2 \) for the price of drinking water. The first order condition (1) is now replaced by:

\[
\left( p_1 + p_2 \frac{\partial Y_2}{\partial E} \frac{dE}{dY} \right) \frac{dY_1}{dN} = w
\]
where \( p^*_1 = p_1 + p_2 \frac{\partial Y_2}{\partial E} \frac{dE}{dY} < p_1 \).

Since \( dY_1/dN_1 \) decreases when \( N_1 \) increases, the optimal output of the pig industry will be less when the externality is taken into account than when the two industries operate independently.

The social price of pigs is \( p^*_1 \). In order to ensure efficient resource allocation we only need to ensure that the pig industry faces the social price rather than the private price. This could be done by taxing pigs by an amount \( p_1 - p^*_1 \). This discrepancy can be viewed as a shadow price for pollution, as it equals the change in manure emission. A market for externalities could be a solution to achieve an efficient allocation of resources. Both solutions are equivalent and lead to a Pareto-optimum allocation.

1.2.2. Crop farming example

Put more simply, the production function of the crop farming industry depends on two inputs, labour and fertilisers \( X \). This concave function is given by:

\[
Y_1 = Y_1 (N_1, X)
\]

Polluting emissions are due to fertilisers:

\[
E = E (X) \quad dE/dX > 0
\]

and the production function of the water treatment plant is the same as before.

First consider the situation where industries operate independently. Farmers will employ fertilisers until:

\[
p_1 \frac{\partial Y_1}{\partial X} = q
\]

where \( p_1 \) is the price of crops and \( q \) is the price of fertilisers. As a result, the crop farming industry will employ too much fertilizer because it does not take into account its adverse effects on the treatment plant.

We get an efficient allocation by maximising aggregate profits:

\[
p_1 Y_1 (N_1, X) + p_2 Y_2 (N_2, E) - wN_1 - wN_2 - qX
\]

where \( p_2 \) and \( w \) are always the price of drinking water and the wage rate.

Equation (2) is now replaced by:

\[
p_1 \frac{\partial Y_1}{\partial X} = q - p_2 \frac{\partial Y_2}{\partial E} \frac{dE}{dX} = q^* > q.
\]
The social price of fertilizers is $q^*$, which is higher than the market price $q$ because it takes into account adverse effects on the water treatment plant. A tax on fertilizers, equal to the difference between the social price and the market price, would imply a decrease in fertilizer demand. Taxation would produce a Pareto-optimum allocation as a market for pollution would do, once one has identified pollution as just another output of production.

1.2.3. Some practical difficulties

Tax is on pollution and it is designed to reduce the level of emissions, therefore the policy instruments are identical in both examples just reviewed. Their relative impact on agricultural output is different. Given current technology, the intended policy would imply an appreciable drop in the output of the intensive livestock industry. The shift would be smaller for crop farming for which large factor substitution possibilities exist.

Taxation of externalities is an important reason for government intervention. An environmental agency which has to maximise social welfare can support such a policy. If very restrictive hypotheses are not met (linearity of the damage function . . . ) taxation must be tailored to each polluter (Bohm and Russel, 1985: 406-411). To compose a full set of such taxes requires a lot of information and an intricate computation model. Otherwise the monitoring and the enforcement of this system would be difficult.

When there are externalities, threshold effects often occur and involve discontinuities in consumer and producer behaviour. This results in multiple equilibria (Fisher, 1981: 177) and the production set is no longer convex. Starret (1972) provides an interesting example of such a situation (Figure 1). The output $Y_2$ of the water treatment plant is plotted as a function of the output $Y_1$ of the pig industry, holding all inputs at fixed levels.

![Figure 1. Convexity hypothesis](image)

In case (1a), the convexity hypothesis holds: the water treatment plant undergoes marginal damage, increasing with pollution. The output of drinking water decreases up to the point when the plant quits, after which it is zero. In case (1b), the convexity hypothesis does not hold: marginal damage increases
up to a point and then decreases towards zero. This latter example becomes realistic when the concentration of pollution is very high. For instance, when a river is so polluted that it becomes a sewer, the benefits for the water treatment plant from marginal improvement may be negligible. It is the same for households, water-based recreation activities are impossible.

1.2.4. *The Coasian market solution*

Coase (1960) has stated a process in which both parties, the polluter and the polluted, negotiate a voluntary agreement in order to achieve an optimal resource allocation. To illustrate this process, consider the example of the water treatment plant and the pig industry. Figure 2 depicts the marginal benefit $AB$ of the pig industry and the marginal damage $OE$ suffered by the treatment plant, both as function of $Y_1$.

![Figure 2. The Coasian market solution](image)

Without considering externalities, the pig industry will produce $OB$ pigs. This amount maximises its profit which is equal to $OAB$. The area $OBE$ gives an assessment of damage suffered by the water treatment plant. The difference between these two quantities represents the aggregate profits.

Figure 2 is a market equilibrium diagram adapted to the specific pollution problem. Social welfare corresponds to the output $OD$ of the pig industry, this level of output equalises the marginal benefit and the marginal damage. Maximum aggregate profits are represented by $OAC$. The corresponding area is greater than the difference between areas $OAB$ and $OBE$.

It is possible to obtain an optimal level of pig output without government intervention. Given well-defined property rights, a negotiation between parties is a simple means to restore social efficiency. To make this point clear, consider two opposite rules. The first one is defined as the zero liability rule, there is no law against pollution. The second one is the full liability rule, it requires that externalities be limited to zero.

Under the zero liability rule, the pig industry can operate without taking pollution into account, and the level of output maximises private profit. The affected party is able to offer bribes as high as its marginal damage and the
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Polluter is willing to accept this compensation provided it is as high as its marginal benefit. A process of negotiation will start between parties, and an agreement will be reached in which the level of pig output is socially efficient. For its lost profit, the pig industry will receive an amount of money equal to the area $BCD$. This solution is favourable to the polluted party because it involves a decrease of its own damage equal to the area $BCE$.

Under the full liability rule, the water treatment plant enjoys a right to clean water, which means no environmental deterioration due to the pig industry. In order to operate, the polluting industry must offer bribes to the affected party. The negotiation process will result in benefits for social welfare. The polluted party receives a compensation that is exactly equal to the extra costs incurred — measured by the area $OCD$. The pig industry profit increases by an amount represented by the area $OAC$, and both parties are better off after this negotiation.

The final allocation is Pareto-optimal and independent of the initial distribution of property rights. This result is true, provided there are no transaction costs.

The ultimate distribution of income is influenced by the specification of property rights. Under the zero liability rule, the affected party pays bribes to the polluting party, while under the full liability rule, the polluting party pays compensation to the affected party. Consequently, if income effects cannot be neglected, the final allocation will depend on the initial distribution of the property rights.

Under the more realistic assumption, the efficient quantity of pollution abatement depends on the specification of property rights, but it is still true that a compromise is possible and gainful. The process of negotiation can be generalised to take into account many economic agents using the concept of Lindahl equilibrium (Måler, 1985: 29).

2. Policy instruments

2.1. Policy approaches and the ‘polluter pays’ principle

Using new developments in welfare economics it is possible to determine the conditions that characterise a Pareto optimal allocation of resources in the presence of pollution externalities. But there are theoretical, political and administrative constraints which lead to the consideration of second best optima. The optimal amount of pollution being unknown, the aim of the policies implemented becomes one of pollution control at minimum cost. The socially efficient allocation is not aimed at since the analysis of externalities proceeds in a partial-equilibrium framework.

2.1.1. An overview of the policies

Commonly suggested methods of controlling pollution are focused on economic
approaches (market incentives, public investments) or on direct controls. The suitability of each method must be taken into account regarding its efficiency, the farm income distribution and its feasibility (see Table 1). Market instruments, or market-line policy instruments are mainly used for reversible effects, whereas regulation deals with less reversible, or irreversible effects. The former assumes an administrative setting to manage the system, like the French ‘bassin’ agencies, or the German ‘bassin’ associations for water pollution control. The latter needs a national system with local adaptations.

2.1.2. The ‘polluter pays’ principle
If environmental values are regarded as community rights, then the ‘polluter pays’ principle may be considered as an extension of property rights. Besides, a tutelary right is sometimes given to organisations to manage public goods, e.g. inland fishing waters in some countries. This principle leads to the internalisation of negative externalities with good conditions of acceptability, feasibility and resource allocation.

The aim should be that the producer should use the environment as a production factor set up to the limit at which its marginal production equals the cost to society of the marginal unit of pollution. Therefore, the firm will set its output so that its contribution to collective well-being (its marginal product) is equal to what it costs society (marginal cost of pollution). The intersection between the marginal evaluation of environmental deterioration according to the activity of the enterprise (curve $C_{me}$) and the cost to society of controlling the pollution (curve $C_{mc}$) allows for an optimum distribution of resources (Figure 3). $OT$ is the charge, here at the optimum rate, levied upon the polluter, while $ON$ is the standard.

In this situation, the charge allows the cost of pollution-associated damages to be fully internalised. This is because the polluter bears the charge equal to $OTAB$, with $ANB$ as the equivalent to the cost of pollution control as such;
<table>
<thead>
<tr>
<th>Type of Instruments</th>
<th>Suitability regarding feasibility:</th>
<th>efficiency (performance)</th>
<th>farm income distribution</th>
<th>farmers' view</th>
<th>Governments' view</th>
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</thead>
<tbody>
<tr>
<td><strong>1. Economic instruments</strong></td>
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<tr>
<td>(a) Market incentives</td>
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<td>- taxation of environmental damage</td>
<td>Theoretically</td>
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<tr>
<td>- subsidy + per unit of reduction of effluents</td>
<td>these incentives</td>
<td>+</td>
<td></td>
<td>++</td>
<td>++</td>
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<td>+ cover for costs of damage-control equipment</td>
<td>achieve</td>
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<td>- tradeable permits (rights, licenses)</td>
<td>social welfare</td>
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<td>- refundable deposits</td>
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<td>- specification of property rights</td>
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<td>(b) Public investments</td>
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<td>- damage prevention and waste treatment facilities</td>
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<td>- extension and reduction services</td>
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<td>- research</td>
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<td><strong>2. Enforcement instruments</strong> (including monitoring and police)</td>
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<tr>
<td>- general regulation</td>
<td>These incentives</td>
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<td>- specific regulation</td>
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<td>- standards + of effluents</td>
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<td>individual cases</td>
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ANo being the cost of the residual damage of pollution ON. OTA can be analysed as a tax upon the environmental resource from which the polluter benefits since we suppose there is a community right to an unpolluted environment.

However, as one cannot know the damage function for certain, there is no equivalence between the pollution standard and the charge. It is easy to show that the charge, if properly set, is more effective than the standard; it is a better incentive (OCDE, 1980: 11).

2.2. Implementation for crop farming

The operation of the ‘polluter pays’ principle for crop farming relies on fertiliser taxation. It is efficient for arable farms, specially for the cereal-oriented type, but some authors disagree with this point. Such a policy instrument would cause a smaller loss in the profitability of agriculture than a decrease in the price of crops. Tax receipts could be allocated to the financing of public treatment plants. Therefore, the treatment of residual wastes would supplement the abatement of effluents.

2.2.1. The efficiency of fertiliser taxation

Several studies using similar methodologies (De Haen, 1984; England, 1986) question whether fertiliser taxation is an efficient means to reduce nitrogen pollution. Conclusions are drawn from the estimation of yield response curves to fertiliser applications for different crops. These authors also consider the changes in fertiliser demand and in gross margin with changes in fertiliser and crop prices. They use linear programming to aggregate the results for individual crops to farm level, taking into account the rotational constraint on the total area. As a conclusion, the own-price elasticity of fertiliser demand is low.²

Own-price elasticities obtained by De Haen range from -0.16 to -0.50; Ray (1982) obtains similar values for the United States (-0.32 to -0.49 for different years) as Boyle (1981) does for Ireland (-0.54 to -0.62 for different periods). Given these estimates, a significant impact on fertiliser demand would require a very high level of taxation. But all these estimations rely on the concept of Hicksian demand.

Own-price elasticities derived from the estimation of Marshallian demand take into account the various compensations through crop substitutions, and are higher. Shumway (1983) quotes a figure equal to -0.70 for Texas, Weaver (1983) obtains -1.38 for North Dakota and -2.16 for South Dakota. Finally Higgins (1986) obtains -1.38 from a random sample of Irish farms.

Estimations from French time series for the period 1959–84 confirm these results. Thus the fitting of a simple demand equation gives figures ranging from -0.39 to -0.55 according to different regions. In order to split these results into short-run and long-run effects, a more sophisticated modelling has been considered. It specifies expectations and adjustment lags in response to price
changes. Short-run, own-price elasticity is -0.33 and the long-run one reaches -1.10. A full adjustment needs a little more than two years.

Taxation is more efficient in reducing fertiliser demand on cereal-oriented farms, and on arable farms in general. Alternatively, it will induce a decrease of output if and only if fertiliser demand is output elastic (Silberberg, 1978: 211) for the crops concerned.

2.2.2. Effects of taxation
The effects of taxation on the profitability of agriculture have to be compared with the effects of a fall in crop prices which have a similar impact on fertiliser use. This can be done through a duality framework with value-added as a proxy variable for income. Let us compare two policies, a tax on the price $q$ of fertilisers, and a decrease in the price $p$ of cereals.

Value-added is defined in terms of $p$, $q$ and also the price-vector $r$ of other variable input and output prices and the vector $z$ of fixed inputs (Weaver, 1983).

$$VA = f(p, q, r, z)$$

The share of fertilizers in value-added is given by:

$$S_x = \frac{-\frac{\partial \log f}{\partial \log q}}{\partial f/\partial q} = \frac{qX}{VA}$$

where $X = - \frac{\partial f}{\partial q}$ is fertiliser demand.

The share of cereals equals:

$$S_c = \frac{\frac{\partial \log f}{\partial \log p}}{\partial f/\partial p} = \frac{pY}{VA}$$

where $Y = \frac{\partial f}{\partial p}$ is cereal supply.

A taxation of fertilisers and a fall in cereal price imply the same decrease in fertiliser demand if and only if:

$$\frac{\Delta p}{p} = \left(\frac{\epsilon_{XX}}{\epsilon_{XC}}\right) \left(\frac{\Delta q}{q}\right)$$

where $\epsilon_{XX}$ is the own-price elasticity and $\epsilon_{XC}$ is the cross-price elasticity of fertiliser demand. Therefore, decreases in the ratio of value-added, as implied by equivalent shifts of cereal and fertiliser prices, is equal to:

$$\left(\frac{\epsilon_{XX}}{\epsilon_{XC}}\right) \left(\frac{S_c}{S_x}\right)$$

and the policy using cereal price as an instrument is more costly for farmers than taxation if this ratio is greater than one.

Apart from the case where the share of cereals is very small, the ratio (2) is always higher than unity. On the other hand, the ratio (1) can be lower than unity in the very specific case of a single output agriculture, if inputs are gross
complements (Sakai, 1974). But for the normal case of an arable cereal-oriented agriculture the ratio (1) is higher than unity. Therefore the taxation policy is cheaper in terms of agricultural profitability. This result strengthens the idea that the best way is to act on the source of pollution.

The preceding argument can be illustrated with an example based on French data. Take the following values for the parameters:

\[ \varepsilon_{XX} = -0.42 \quad \varepsilon_{XC} = 0.73 \quad S_X = 0.10 \quad S_C = 0.36 \]

In the short run, a 10% tax on fertiliser price and a 5.8% decrease in cereal price are equivalent in terms of fertiliser demand, and the resulting reduction is 4.2%. The former policy induces a 1% drop of value-added, but the latter is two times more costly with -2.1%.

2.2.3. The design of a realistic policy

The implementation of fertiliser taxation can initiate a gradual process of pollution abatement. Even if its effectiveness is limited in the short run, it is a means to collect a lot of money that can be allocated to cover the costs of processing units, like water treatment plants, in order to get an extra abatement of pollution.

Figure 4 depicts marginal cost curves of pollution abatement \( Cm \) for the agricultural industry and \( Cmc \) for a public water treatment plant. Both curves are expressed as a function of fertiliser consumption, and \( Cmc \) is lower than \( Cm \). Faced with the emission tax rate \( OT \), the agricultural industry will use fertiliser up to \( ON_1 \). The operation of a treatment plant will allow more abatement – in terms of fertiliser it is equivalent to \( N_1 N_2 \). An emission standard equivalent to \( ON_2 \) would be more costly for the agricultural industry, and total welfare would decrease by the hatched area.

In the long run, there are two main approaches to reducing the levels of fertiliser applied. An improvement in the efficiency by which nitrogen is taken

![Figure 4. Social efficiency of public treatment plants](image-url)
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up by the crop could be achieved through agricultural training and extension services. Otherwise, nitrogen-fixing organisms could gradually be used as substitutes for nitrogenous fertilisers. Therefore social welfare purposes justify, to some extent, an allocation of taxation receipts to the agricultural education and research system.

The implementation of this policy to market gardening, which causes significant environmental stress, is questionable, because fertiliser demand is own-price inelastic in the short run. Anyway, it can supplement the operation of quality standards for vegetables.

2.3. Implementation for intensive livestock industry

The major stress on the environment results from the pig industry. Polluting emissions, animal waste, 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.

Figure 5 depicts the equilibrium positions of a representative competitive pig farm and the corresponding equilibriums of the industry (Baumol and Oates, 1975: 176-184). At the farm level, emissions equal by, and are strictly proportionate to output y. If there is no environmental program, the farm is faced with the market price \( p_0 \); its equilibrium position is \( A_0 \) (intersection point of the marginal cost curve \( Cm \) and the average cost curve \( CM \)). With a unit tax \( t \) on pollution emissions, the marginal and average cost curves shift upward by a vertical distance \( tb \), the corresponding equilibrium is \( A_1 \). The equilibrium output of the representative farm is exactly the same with and without taxation, and the shift of price corresponds to the cost of taxation by unit of output.

Figure 5. The 'polluter pays' principle applied to an intensive livestock industry
The market supply curve shifts from $S_0$ up to $S_1$, the ultimate equilibrium position is $B_1$ instead of $B_0$. Therefore, there is a decrease of total output and consequently of animal wastes. Consequently, less profitable pig farms leave the industry.

The result that all remaining farms produce the same amount arises from the assumption that the marginal cost curve shifts uniformly. If it does not, for instance because the economies of scale have been affected, the farm will not produce the same output.

Instead of having a taxation policy, let us consider a program of subsidies to induce a decrease in pollution emissions. A subsidy proportionate to animal waste decrease would have adverse impacts on total pollution. The output of the representative farm would decrease, but new firms would enter the industry, so a backward shift of the market supply curve would occur implying a decrease of price and an increase of total output.

Non-point pollution and the geographic distribution of agriculture are two reasons why it is not advisable to issue a single charge. The implementation of an individually tailored tax system is difficult, so transferable emission permits could be an option (Laffont, 1982: 21). Given total pollution, at the equilibrium of the market for effluent permits, the optimal allocation of emission levels is achieved and the long-run equilibrium of the industry is optimal (Spulber, 1985).

The extent and the spatial pattern of the damages depend on the locations of the sources of pollution and the locations of the receptor points (for instance the sources of water supply). The implementation of a program of tradeable permits involves one market for each receptor point. Montgomery (1982) has proved that such a program achieves a predetermined quality objective, at minimal cost, and that the ultimate allocation of permits is independent of the initial distribution. This system is rather cumbersome for polluters because they must have a portfolio of licences for each market, but its flexibility can be improved and it is possible to design a politically feasible as well as efficient program.

3. Concluding remarks

Environmental stress created by the farm sector in developed countries is partly due to agricultural policy, but the prevailing factor has been the tremendous growth of the economy. Therefore an adjustment of agricultural policy with a downward shift of prices, will not modify the trend of environment deterioration drastically. In order to achieve social welfare it needs the implementation of specific environmental programs.

Under irreversibility, the consequences of deterioration are difficult or impossible to ameliorate, therefore a policy using regulation as an instrument must be preferred. While, on the contrary, for reversible impacts, economic incentives especially in the form of prices are socially efficient. The specific study of the
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The relationship between intensive farming practices and water quality made this point clear with the operation of the 'polluter pays' principle.

Fertilizer taxation, as far as crop farming is concerned, would cause a smaller loss in the profitability than a decrease in the price of crops, so such a program is feasible, otherwise it is efficient at least for arable- and cereal-oriented farming. The operation of the 'polluter pays' principle would encourage a decrease in the level of output and a price increase for intensive livestock production, for which effluents closely depend on output.

In some regions, it is interesting to note that organic and synthetic nitrogen fertilizers are both applied. As quoted by Andersson, (1986: 196) rates of application tend to be very high, raising technical inefficiencies. A taxation of synthetic nitrogen would modify the ratio between its own price and the shadow price of organic nitrogen. It would be an incentive to move to organic substitutes and to promote manure banks. Otherwise, manure treatment plants could be considered as a means for reducing pollution.

The agricultural sector is now faced with surpluses, but also income problems, so the farm lobby is likely to argue against the operation of the 'polluter pays' principle. Nevertheless, the present situation is very similar to that of other sectors two or three decades ago, when the first environmental programs were designed. These programs have been less costly than predicted and had few effects on the rate and direction of technical progress (Christainsen and Tietenberg, 1985: 356-358). Environmental deterioration is a challenge which needs the enforcement of a suitable policy in the form of regulation and price incentives. It would also encourage the adoption of environmental-saving technology.

NOTES

1. For more details, see Amigues (1987).
2. There are discrepancies between the De Haen and England results concerning fertilizer response with respect to changes in output price.

REFERENCES


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