On the Choice of Cost and Effectiveness Indicators

in the Context of the European Water Policy

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Abstract

The Water Framework Directive requires EU Member States to analyse economic impacts of the Directive's implementation. To reach a "good status", instruments have to be judged according to their cost-effectiveness. We evaluate costs and effects of measures to reduce nitrate emission of Austrian agriculture. Results are based on a model that integrates production decisions with stochastic environmental outcomes. The Directive's requirement to involve stakeholders may make it necessary to take a large number of indicators into consideration. We find that alternative calculations of the effectiveness criterion give different rankings of the most effective combination of measures.

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1. Introduction

The objective of the European Water Framework Directive (WFD 2000/60/EC) is to maintain or achieve "good status" of water bodies. In the first phase of its implementation, Member States have to analyse the economic consequences of the directive's implementation. Member States have (i) to carry out an analysis on the characteristics of river basins, (ii) to review the impact of economic activities on the status of surface water and ground waters, and (iii) to make economic analyses of water use.

In our analysis, we focus on two requirements of the directive. Firstly, decisions on measures to improve the status of water bodies must be based on economic criteria. Secondly, during the decision making process, not only experts, but also other stakeholders need to get involved.

Measuring the effects of policies aiming at emission reduction using many diverse indicators is usually difficult and requires substantial resources (see e.g. Brouwer, and Crabtree, 1998). In some cases, the specific effects of a policy cannot even be observed because exogenous factors combined with individual decision making conceal an anticipated outcomes (e.g. biased results due to non-typical weather events). In other cases, the effects cannot be measured altogether because in ecosystems rapid transitions may lead to very slow changes and therefore the time span between a change of management practice and evaluation is too short for long-term environmental effects to show up.

This paper shows an approach that can be used to overcome some of the difficulties associated with the measurement of environmental outcomes by (i) defining environmental and economic indicators that are both acceptable by interest groups with diverging interests and measurable by economists and natural scientists, and (ii) choosing a methodology that overcomes some of the problems (e.g. few observation, effects that lie in distant future). We use nitrate emission from agriculture for this case study.

Research studies on the effectiveness of EU initiatives to reduce agricultural emission in a cost-effectiveness and cost-benefit framework are relatively rare, because of the difficulties involved in measurement and valuation of environmental outcomes (an early survey is provided by Hanley, et al. 1999). To overcome these difficulties, studies frequently use environmental indicators derived from literature as a proxy for environmental costs or benefits (see e.g. Lankoski and Ollikainen, 1999 and 2004).

This paper contributes to this literature by using an approach that allows a detailed assessment of how well each of the program goals could be attained. The methodology finally chosen in co-operation with stakeholders allows the assessment of various variables of interest (i.e. farm incomes, agricultural output, and environmental outcome) simultaneously.

The paper presents details of the Austrian policy initiatives to mitigate groundwater pollution in the next chapter. Then, a short description of the methodology is given followed by some major results of an inter-disciplinary modelling effort. We discuss our findings and considerations in the context of stakeholder participation, which is a core element of the Water Framework Directive (WFD). Finally, we consider some of the difficulties to obtain an uncontroversial point of reference for valuations in a cost-effectiveness analysis.

2. Policies to improve water quality in Austria

The quality of large ground water bodies in Austria is negatively affected by nitrates and pesticide residues, partly due to agricultural activities (BMLFUW, 2002). Over the last two decades a set of legislative measures was implemented to control emissions from agriculture. Incentive based instruments have been gaining importance since 1995, when Austria became an EU member state.

After the EU-accession, agri-environmental programs were introduced, which provide environmental subsidies for voluntary participation in emission reduction measures (based on CR (EEC) 2078/92 and CR (EC) 1257/1999). The objectives of these programs are to:

- accompany the changes that are introduced under the market organization rules,
- contribute to the achievement of the Community's policy objectives regarding agriculture and the environment,
- provide an appropriate income for farmers (this was no longer an objective in the 1999 version of this policy).

In many EU Member States, programs consisting of dozens of measures like the promotion of organic farming, the seeding of winter cover-crops, or the maintenance of ecological valuable sites have been introduced (Whitby, 1996; Deblitz and Plankl, 1998). These programs are co-financed by the EU and Member States.

The Austrian agri-environmental program (ÖPUL) is among the most complex ones in the EU (Sinabell and Hofreither 2000). ÖPUL is designed to be accessible for almost all farmers in Austria. If a farmer wants to enter the program, he or she commits to adopt alternative management measures for at least five years. There are 32 environmentally friendly management measures from which farmers can choose. Some of them can be implemented on single fields, others have to be on the entire farm; some can be used solely, others need to be combined. Consequently, farmers create a management measure mix that fits best in their current farm plan.

3. Program effectiveness and stakeholder participation

The Austrian agri-environmental program identified eight very general goals like "promotion of an environmentally friendly, extensive crop production" or "provide an incentive for long term set-aside because of environmental reasons". In addition, the EU Nitrates Directive and national policies are limiting the usage of nitrogen fertilizer while the WFD is aiming at ambient quality. How, and to what extent different management measures are supposed to contribute to these goals is not easy to identify.

A committee responsible for the evaluation of cost-effectiveness of the agri-environmental program included several stakeholders, among them representatives of farmers and environmental groups. An interdisciplinary team of scientists was commissioned first to develop a proposal for an evaluation procedure and then to carry out the analysis. It soon became evident that any measure could at least contribute to two objectives "securing an adequate income for farmers", and "contribute to an ecological balance and to the realization of agri-environmental policy goals" and thus a successful program performance was guaranteed. However, this result was not accepted unanimously. The approach found to be adequate to meet the diverging interest of stakeholders had to:

a) evaluate all three objectives (environmental outcome, output effect and income effect) simultaneously;

b) choose indicators that can be communicated easily to non-scientists, are linked well to the imputed effective program goals, and are scientifically sound;

c) look at the aggregate effects of a region, to overcome the reservation against case-studies which were seen to be interesting but not representative.

An adequate indicator for evaluating the environmental outcome was identified to be nitrate concentration of groundwater below the root-zone in a region that is known to be environmentally sensitive. The regional producer surplus was chosen as an indicator of farm incomes, and the crop output was taken as an indicator for the quantity effects.

The committee could be convinced that only a combination of monitoring and survey data analyses interfacing with computer modelling was adequate to provide the required information, because several effects prevented that these indicators could be measured directly:

- farm incomes are a function of price fluctuations which are not due to the introduction of the program,
- weather events during the program period could be untypical and any improvement or deterioration could be the outcome of a random process, and
- given these conditions measuring directly the nitrate concentration in percolation water could give results that were not causally linked to the introduction of the agri-environmental program.

A 70,000 hectare watershed (Marchfeld) was chosen for this pilot holistic assessment. It is divided into statistically derived homogenous hydrological response units (HRU) with respect to weather, soils, crop mixes and rotations, management practices, and topographies based on county-level survey data. Clustering crops, crop mixes, and soil types combined with daily weather records for ten years provides spatial and temporal representations of the watershed. Two site-specific biophysical process models (among them EPIC - Environmental Policy Integrated Climate) were utilized to simulate nitrogen leaching coefficients under eight different management practices for all HRUs (see Figure 1).

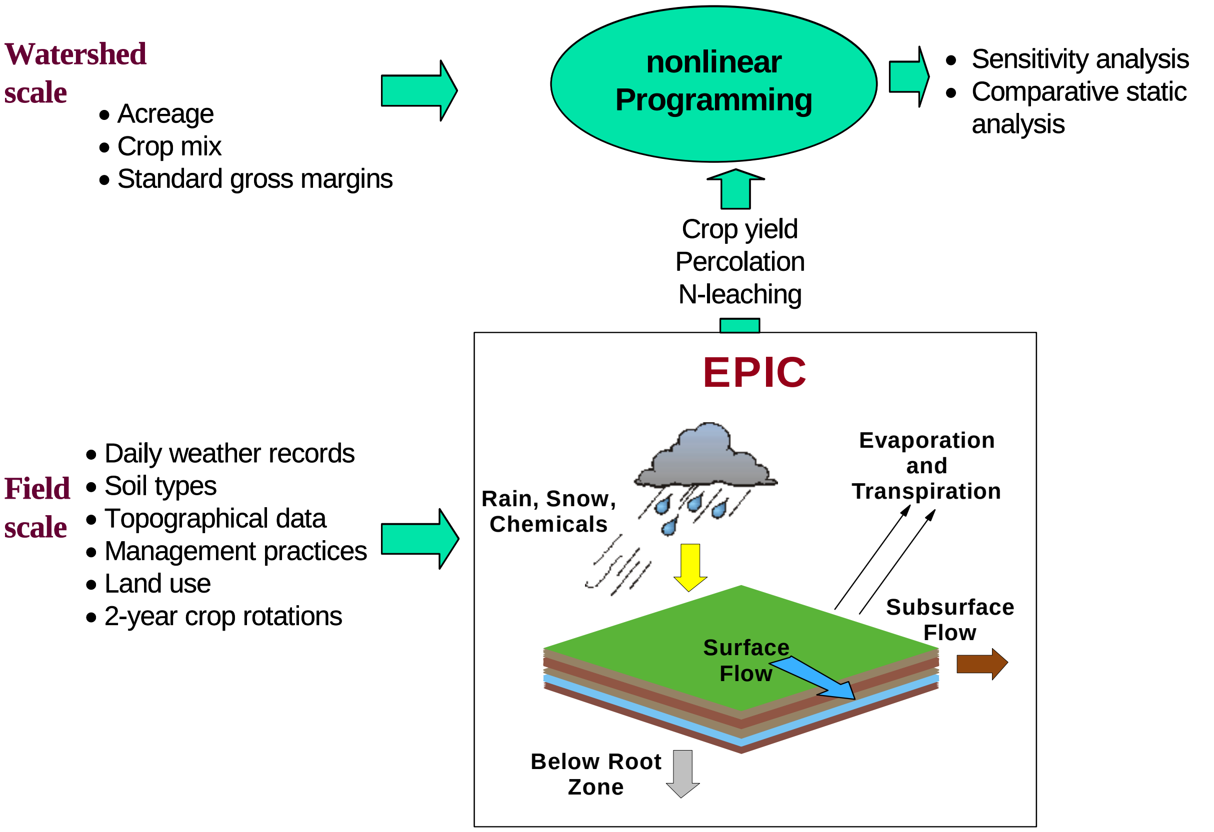

Figure 1: Modelling Framework of the Cost-Effectiveness Analysis

EPIC simulation coefficients of crop yield and nitrogen leaching are linked with a regional nonlinear mathematical programming model developed for purposes of aggregation and economic analyses. Annual crop budgets for each HRU, including simulated crop yields of ten years and compliance costs of management measures, are calculated and entered in the programming model. The aggregation process of 4,300 independent HRUs follows the approach of building convex combinations of historical crop mixes for each of the five crop mix clusters forming five sub-regions.

The objective function of expected producer surplus is maximized subject to land endowments and other technical and distributional resource constraints. Environmental effects and compliance costs of some management measures (e.g. introducing cover crops) cannot be assigned to either the main or preceding crop, therefore, all agronomic potential combinations of 2-year crop rotations were considered. In the model, a linear combination between main and preceding crops reflects farmer’s expectation on net return from a 2-year crop rotation.

For validation purposes and sensitivity analyses, coefficients of expectation and risk aversion are introduced in the model. The programming model is calibrated to average nitrate concentrations from 88 monitoring sites with 29 quarterly records in the watershed. Comparative static analyses reveal changes of alternative scenarios relative to a reference or base-run scenario. Site-specific crop yields, nitrogen loads, water, percolation water, and nitrate concentrations are compared with respect to representative soil types, crop rotations, and management practices at the field scale. In addition, the aggregation procedure obtained by the programming model allows comparisons of these indicators at the watershed scale.

4. Scenarios and results of the cost-effectiveness-analysis

In order to identify cost-effective policy options, comparisons among alternatives must be made. A comparison between the cost and effects of different strategies should allow a ranking. During the stakeholder process a set of measures were identified that met two criteria: (i) a wide adoption of a given management practice would entail less nutrient emission, and (ii) the measures needed to be acceptable by the farmers (they would effectively be compensated for carrying out a given practice).

The scenarios are described as follows:

- **Reference:** this scenario represents the situation "what would have happened if the agri-environmental program did not exist c.p." and is the counterpart in the evaluation process;
- **ÖPUL & cover crops:** this scenario captures the situation which existed in the region Marchfeld after the introduction of the agri-environmental program and the introduction of the Action Program of the Nitrates Directive; some extensive management measures and the seeding of cover crops are analysed;
- **ÖPUL & set aside:** this scenario analyses the effects of expanding set aside land from about 8 to 12 percent;
- **ÖPUL & organic farming:** this policy scenario analyses the effects of expanding organic farming land from about 2 to 10 percent (an objective defined by environmentally concerned stakeholders).

At the field scale, parameters of comparison (t-test, paired t-test, and F-test analyses) are introduced to reveal differences between indicators of management practices/measures under various states of nature. Differences of site-specific crop yield responses between conventional and extensive management practices can run from zero to -19 %. There is an ambiguous impact of management measures on crop yield variability depending on the actual situation of crop rotation and soil type. Differences of site-specific nitrogen leaching are vastly variable due to the randomness of weather events and spatial diversity resulting in discontinuous emission loads. This outcome emphasizes the importance of portraying the heterogeneity of watersheds in detail. In general, the analysed management measures show some significant potential in reducing both average and variability of nitrogen leaching.

Major simulation results reflecting the impact of measures, reducing agricultural emission, are summarized in Table 1. In general, the assessment reveals that agri-environmental measures have the intended effect on all three major indicators. The increase in farm income indicated by producer surplus is about 8 %. Farm income variability decreases due to the effect of more stabilized crop yield responses. The program objective of environmental improvements is attained by reduced average nitrate concentration in percolation water as an accompanying indicator.

Table 1: Cost and effectiveness indicators of measures to reduce nitrate emission in Marchfeld (Austria)

		Scenarios			
		reference (no ÖPUL)	ÖPUL & set aside	ÖPUL & organic farming	ÖPUL & cover crops
producer surplus	mil. €	59.16	63.08	69.25	64.11
total premiums	mil. €	0.73	7.81	10.04	7.81
	€/eligible ha	450		250	226
total compliance costs	mil. €	0.06	0.84	1.03	0.84
	€/eligible ha	37		26	24
eligible acreage	ha	1,622	34,558	40,200	34,558
nitrate concentration in percolation water	mg NO_3/l	68.5	59.9	58.7	60.4
std.dev.	mg NO_3/l	19.5	23.2	23.5	25.4
nitrogen emission	t in region	761,7	606,5	620,6	641,8
nitrogen emission	kg/ha	10.8	8.6	8.8	9.1
std.dev.	kg/ha	8.0	6.4	6.1	6.3
total percolation water	mm	69	64	69	67
total irrigation water	mm	43	41	42	45
total crop output	mil. t	1.16	1.11	1.11	1.14
total N application	kg/ha	108	98	99	101
		share of land with management measures and farming practices			
no management measure	%	97.7	51.0	43.3	51.0
organic farming practices	%	2.3	2.3	10.0	2.3
seeding of cover crops	%	0.0	13.3	13.3	13.3
extensive farming practices	%	0.0	16.2	16.2	16.2
combination of cover crops and extensive farming practices	%	0.0	17.2	17.2	17.2
		Δ program premiums / Δ emission indicator			
nitrate concentration	1000 €/mg NO_3/l		823.3	950.0	874.1
rank			1	3	2
nitrate emission	1000 €/t N		46.4	66.8	59.7
rank			1	3	2
effectiveness-indicator		Δ (producer surplus – program premiums) / Δ emission indicator			
nitrate concentration	1000 €/mg NO_3/l		367.4	-79.6	263.0
rank			3	1	2
nitrate emission	1000 €/t N		20.7	-5.6	18.0
rank			3	1	2

Source: Own results.

Regional producer surplus is considerable higher when organic farming is expanded. This effect is a result of higher crop market prices in addition to agri-environmental premiums. The assumption is made that more farmer can be motivated to voluntary participate in the organic farming scheme, which was judged to be realistic by a group among the stakeholders of this analysis.

The evaluation assessment reveals that agri-environmental measures provide some potential in meeting the objectives of the WFD. A program which offers such measures certainly provides generous compensation and incentives to farmers who react with a high program participation rate. In addition, the scenarios show that expanding organic farming would contribute to meeting the environmental objectives.

In an effectiveness context, the analysis does not provide unambiguous results. As shown in Table 1, the ranking of measures depends on the type of effectiveness-indicator chosen:

a) If the change of physical indicators is set in relation to the additional cost of the agri-environmental program, the "ÖPUL & set aside" combination of measures is most effective (largest environmental benefit per Euro invested in the program).

b) If the change of producer surplus minus program premiums is used in the numerator, "ÖPUL & organic farming" is the most effective combination of measures.[1]

Given both criteria, the ranking does not depend on the choice of the indicator of the environmental effect (reduction of concentration versus reduction of emission). However, such a situation could be conceivable if more combinations of measures were compared.

5. Conclusions

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[1] This combination would even give negative cost, effectively a net benefit. This result depends on the specific assumptions on prices of organic products versus conventional products and cost differences. If there is a net benefit we would expect that producers in the region would choose organic practices as a consequence of profit maximising behaviour. An effective measure – not specifically analysed – could therefore be to inform farmers about the economic benefits of producing food organically, a better environmental performance would be a secondary effect.

The objective of the European Water Framework Directive (WFD 2000/60/EC) is to maintain or achieve "good status" of water bodies. Throughout the EU, programs of cost-effective measures have to be implemented to reach the "good" status by using the same methodology.

As demonstrated in this case study, the identification of cost-effective programs is not a trivial task. Apart from the problem to identify effective measures and to quantify their cost and their environmental outcomes, ambiguous results may make the final decision difficult. The ambiguity is due to four major sources:

1) Stakeholders may turn a blind eye towards some effective measures and rule them out so that they are not considered in an analysis of alternative measures. Reasons can be special interests, certain policy preferences (e.g. the assumption that command and control instruments work better) or unforeseeable outcomes of group decision making. In addition stakeholders in one region may put a high weight on some management measures, which could get lower weight in other regions. Given that final programs must be compatible with the vision of the stakeholders, it is likely that their preferences will be important for the final choice.

2) The choice on the indicator which is used as a benchmark for the effectiveness may predetermine the final choice. It can make a difference whether "emission of kg nitrate per hectare" is used as effectiveness indicator or "concentration of nitrates in percolation water". Such outcomes can be expected if management measures are very different with respect to economic and environmental impacts.

3) The choice on the "most effective measure" is depending on the definition of cost. In this case study, two variants are compared: "program cost" and a better gauge of opportunity cost, "producer surplus minus program cost". The result of comparisons among

measures therefore depends on the scrutiny of the researcher and data available for an analysis.

4) The choice of the reference level of pollution is only vaguely defined in the WFD by referring to the 'polluter pays principle'. Given that property rights are defined differently across countries, we would not expect that cost-effective measures in Member State A are the same as in Member State B even if the same river basin is considered.

The European WFD is a rare piece of environmental legislation which explicitly makes a reference to economic criteria by requiring that goals need to be met at least cost. The implementation of this requirement by using the cost-effectiveness criterion will not be as easy as it looks at a first glance. In order to guarantee that the same basic decision criteria are used on all EU Member States, an agreement has to be reached on many details of the methodology of the cost-effectiveness analysis.

A handbook (see D'Eugenio. 2002 a and b) was drafted in order to establish standards for economic analyses in the context of the WFD. However, in its current state, the issues discussed in our paper are not yet addressed adequately in this guiding document. An approach which would be adequate to overcome major difficulties in decision making as outlined here, would be, to carry out cost-benefit analyses instead of cost-effectiveness analyses. However, the cost of carrying out the relevant analyses are an element of the total implementation cost. Therefore, there is obviously a trade-off between the scrutiny of the analyses and the reliability and relevance of the results.

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