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Using hydro-economic modeling to investigate trade-offs between ecological and economic water management objectives

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This study investigates the use of volumetric water pricing as a tool to achieve some of the ecological status objectives of the EU Water Framework Directive (WFD). It also estimates the opportunity costs of meeting these objectives. The study uses a hydro-economic modeling approach in which water availability is estimated using a hydrologic model and water demands are based on economic uses of water.

The WFD requires member states to introduce water pricing policies that provide incentives for efficient use and contribute to the environmental objectives of the Directive. In this study, a single volumetric water price is applied to all wholesale water users in a river basin. The same price is applied to surface water and groundwater. The price does not vary with time. The single volumetric price approach is compared to a second approach in which groundwater and surface water are priced differently.

Water users in the basin are assumed to respond to water price changes according to neo-classical economic theory. Water use is adjusted according to the principles of profit and utility maximization. Urban/domestic, irrigation, industry, livestock, and tourism water users are included in the study.

Two approaches for representing farmer responses to water price changes are compared. The first approach is the residual imputation method, which assumes that willingness to pay for water can be determined by subtracting all non-water input costs from revenues, with the difference equal to the value of water. The second approach is based on Positive Mathematical Programming. This approach assumes that observable allocations of land, water, and other inputs are the result of profit-maximizing behavior by farmers and uses this information to parameterize non-linear production and cost functions. In this second approach, willingness to pay for water is assumed to equal the marginal value of water in production. The approach based on Positive Mathematical Programming appears to be more useful because it offers a reasonable way to model deficit irrigation and changes in cropping patterns resulting from water price changes.

Water prices are increased until flow patterns in 90% of the reaches in the basin exhibit good ecological status. Ecological status is measured using metrics that compare distributions of monthly volumes observed during a 20-year simulation period to distributions of natural flows that would have occurred during the same 20-year period had anthropogenic water use not taken place.

An iterative optimization approach is used to identify a water price that meets the ecological objectives of the WFD. In the optimization, water price is the decision variable. During each iteration, average annual demands are estimated based on the water price, assuming profit/utility maximization. These demands are translated into daily demand patterns, which become boundary conditions for the hydrologic model of the river basin. The hydrological model runs for a 20-year period using timeseries inputs estimated using historical data. The 20-year period is intended to capture a reasonable range of conditions that may be expected in the future. Simulated river flows are compared to estimates of natural flows in order to assess ecological status. The optimization continues until a water price has been found that meets ecological status objectives while minimizing opportunity costs to other users. When surface water and groundwater are priced separately, both prices are decision variables.

The economic impacts of increasing the water price are concentrated in the agriculture sector because the lowest marginal value uses of water occur in this sector. The introduction of different prices for surface water and groundwater reduces the opportunity cost of achieving a more natural hydrologic regime by reducing the use of surface water for low marginal value applications.