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Economic valuation of environmental benefits from wastewater treatment processes: An empirical approach for Spain

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ABSTRACT

Economic research into the design and implementation of policies for the efficient management of water resources has been emphasized by the European Water Framework Directive (Directive 2000/60/EC). The efficient implementation of policies to prevent the degradation and depletion of water resources requires determining their value in social and economic terms and incorporating this information into the decision-making process. A process of wastewater treatment has many associated environmental benefits. However, these benefits are often not calculated because they are not set by the market, due to inadequate property rights, the presence of externalities, and the lack of perfect information. Nevertheless, the valuation of these benefits is necessary to justify a suitable investment policy and a limited number of studies exist on the subject of the economic valuation of environmental benefits. In this paper, we propose a methodology based on the estimation of shadow prices for the pollutants removed in a treatment process. This value represents the environmental benefit (avoided cost) associated with undischarged pollution. This is a pioneering approach to the economic valuation of wastewater treatment. The comparison of these benefits with the internal costs of the treatment process will provide a useful indicator for the feasibility of wastewater treatment projects.

1. Introduction

Many countries, especially in the Mediterranean area, are facing important challenges in the field of water management. The task of satisfying an increasing demand for water resources while avoiding the degradation of ecosystems requires viable answers from the economic and environmental point of view. This is necessary to guarantee the sustainability and quality of life in the present and future.

The need to meet a growing demand for water resources, while preventing further degradation of ecosystems and natural processes, poses a challenge that must be addressed from a realistic multidisciplinary perspective. In this sense, economic studies regarding the design and implementation of policies for the efficient management of water resources are a necessity that is increasingly recognized — as set out for example in the Water Framework Directive (Directive 2000/60/EC) (Birol et al., 2006). Moreover, the use of market instruments to solve environmental problems is becoming increasingly useful and successful (Gayer and Horowitz, 2006).

Undoubtedly, the over-exploitation of resources and inefficient allocation is a result of the absence of a market that can adjust supply and demand through price; as well as the very limited success of authorities in attempting to manage by regulation. We must not forget that the implementation of efficient economic, social, and environmental policies which can prevent the degradation and depletion of water resources means that the total value of these resources must be measured and incorporated into the decision-making process.

A number of methodologies can be used as support instruments when implementing policies and selecting measurements, with cost–benefit analysis (CBA) being the most accepted and used. This analysis is performed to compare the economic viability of different proposals. The benefits of each proposal are compared with their costs by using a common analytical methodology. In the context of the WFD, a CBA is made to identify cases where the adoption of measures for achieving a good water quality in lakes and rivers involves a disproportionate cost. In this sense, performing an analysis of disproportionate costs – and therefore the raising the possibility of temporarily failing to meet one of the quality objectives required by the WFD – means that a CBA should be performed beforehand to compare the costs of the measures with the benefits of improved water quality. These benefits and costs are usually measured in different physical units, whereas comparison should be made in common monetary units. The net profit of each option is the result of the difference between benefits and costs. Proposals are economically viable only when they generate net profit. The best option offers the highest net profit (Turner et al., 2004).

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Making a cost–benefit analysis of actions with environmental impacts is complex because many environmental resources (including most water resources) are public property, and so do not have a market that sets price. Both surface water and groundwater are public resources that economic agents can use and so price does not reflect scarcity, and frequently only the costs of private extraction are paid (Koundouri, 2000).

Inadequate property rights or the absence of such rights, the presence of externalities, and the lack of perfect information are major obstacles in evaluating projects with environmental effects. Property rights are particularly important in the context of water management because, for example, a polluter would then have a legal obligation to compensate water users downstream, and so setting the 'optimum' level of pollution (Birol et al., 2006).

Externalities refer to any consequence (positive or negative, intentional, or random) that derives from a project. The quantification of these consequences is necessary before adopting any measure or action that could have environmental effects. For example, a project to reuse treated water could be considered to have the following positive externalities: an increase in water availability, a potential savings in the use of agricultural fertilizers, a reduced over-exploitation of aquifers, among others. Negative externalities such as chemical or biological risks may also appear.

There is a growing interest in this concept — although the calculation of these externalities is currently unusual in economic feasibility studies or activities with environmental effects. An example of this growing interest is the new role of economic analysis in the WFD. This Directive represents a new approach to water resource planning and among the new concepts introduced is the principle of cost recovery of water-related services. This principle implies that the measures applied to achieve water quality in lakes and rivers should not only consider the financial costs, but also the environmental costs and related resources, and all in accordance with a detailed and rigorous economic analysis.

In this context and from the pioneering work by Färe et al. (1989), and within the framework of studies into efficiency, a stream of research has been produced that aims to provide a valuation methodology for those undesirable outputs that have no market. Using the concept of the *distance function*, a *shadow price* is calculated for those goods arising from human and productive activities (solid waste, pollutants, wastewater, etc.) which have no market value and have substantial environmental impacts. A series of studies (Färe et al., 1993, 1996; Yaisawarng and Klein, 1994; among others) have been developing a valuation methodology for such undesirable goods that is fully supported by the literature.

Some of the applications of this empirical method based on distance functions can be found in Coggin and Swinton (1996), and Swinton (1998), where shadow prices are calculated for sulphur dioxide emissions resulting from the manufacture of electrical appliances. It is worth noting that their price estimates are in line with the actual prices paid for the emission permits. McClelland and Horowitz (1999) estimate the marginal cost of water pollution abatement for pulp and paper plants. Reig et al. (2000) use a methodology based on distance functions for estimating the shadow prices of waste generated by the ceramic industry in Spain. The economic value obtained for these undesirable outputs is used to calculate a productivity index that takes into account not only the market value of the production, but also the waste produced by the production process. More recently, Ha et al. (2008), made use of distance functions to estimate shadow prices for three undesirable outputs with a clear environmental impact and resulting from the process of recycling paper in Vietnam.

The calculated shadow prices represent the value of externalities that could produce environmental damage if inadequately managed. In this sense, we consider water treatment as a productive process in which a desirable output (clean water) is obtained together with a series of undesirable outputs (suspended solids, nitrogen, phosphorus, etc.). Pollutants extracted from wastewater are considered an undesirable output because if these untreated materials are dumped in an uncontrolled manner they would generate a negative environmental impact. A shadow price for these undesirable elements would be the equivalent of the environmental damage avoided. If we assume that the current pollution levels are optimal, then marginal cost equals marginal benefit, and therefore the shadow prices of the undesirable outputs can be interpreted as an estimation of the environmental benefits gained from the treatment process. This article aims to calculate shadow prices associated with undesirable outputs produced by wastewater treatment. It is important to emphasize that this paper uses the methodology of shadow prices to estimate the avoided costs resulting from the removal of pollutants during the process of wastewater treatment. For this reason, avoided costs represent an estimation of the economic value of the environmental benefits obtained from the cleaning process. These benefits are at least as high as the costs required to prevent or compensate for environmental damage. The estimated environmental benefit does not reflect the full economic value; nor the willingness to pay for environmental enhancements resulting from cleaned wastewater — and these avoided costs represent a minimum of the real value of the benefits. This quantification of environmental benefits through avoided cost is an approach widely used because it is relatively easy to calculate and integrates well with some of the tools of economic analysis (for example, CBA) contained in the WFD.

Despite these advantages it must also be acknowledged that this approach has limitations. Avoided costs do not measure the total economic value and so underestimate the value of water resources. That is why the use of avoided costs as estimation for the global benefits does not provide all the information needed to perform an analysis of disproportionate costs as proposed for the implementation of the WFD.

The methodological approach proposed by Färe et al. (1989) is used below for a sample of wastewater treatment plants located in the Valencia region (on the Mediterranean coast of Spain).

2. Methodology

Distance functions were developed by Färe et al. (1993). Conceptually, a distance function generalizes the concept of conventional production functions and measures the difference between the outputs produced in the process under study and the outputs of the more efficient process. This function provides the distance of a vector of outputs from the frontier of maximum output and starting from a vector of constant inputs. Assuming that the production process uses a vector of N inputs $x \in R_+^N$ to produce a vector of M outputs $u \in R_+^M$, the distance function is defined as:

$$D_0(x,u) = \{\theta : (^u/_\theta) \in P(x)\}$$

where $P(x)$ is a vector of outputs that are technically viable and use the vector of x inputs, while θ is a ratio between zero and one, that is, $D_0(x,u) \in [0,1]$. Large values indicate a good approximation to the production frontier, and therefore a high level of efficiency. The distance function has the following properties (Coelli, 1998):

(i) $D_0(x,u)$ is a lower semi-continuous function
(ii) $D_0(x,u)$ is non-decreasing in u and non-increasing in x;
(iii) $D_0(x,u)$ is homogeneous of degree 1 in u;
(iv) $D_0(x,u) \geq 0$ and $D_0(x,0) = 0$
(v) $U \in P(x)$ if and only if $D_0(x,u) <= 1$; and
(vi) $D_0(x,u) = 1$ if u belongs to the production 'frontier' of the production possibility set.

The relationship of duality between the distance function of output and the revenue function (Shephard, 1970) creates the link between relative and absolute output shadow prices (Färe et al., 1993). The