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METHODS

Valuing environmental factors in cost–benefit analysis using data envelopment analysis

Timo Kuosmanen[a,*], *Mika Kortelainen*[b,1]

[a]*Economic Research Unit, MTT Agrifood Research Finland, Luutnantintie 13, 00410 Helsinki, Finland*
[b]*Department of Economics and Business Administration, University of Joensuu, P.O. Box 111, 80101 Joensuu, Finland*

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ABSTRACT

Environmental cost–benefit analysis (ECBA) is used for the social evaluation of investment projects and policies that involve significant environmental impacts. Economic valuation of environmental impacts forms one of the critical steps of ECBA. We develop a new method for this purpose, which does not require price estimation for environmental impacts using stated or revealed preference methods. Our approach is based on data envelopment analysis (DEA), which is modified to ECBA by using absolute shadow prices instead of relative prices. We also discuss how the method can be used for sensitive analysis in ECBA. We illustrate the method by means of a hypothetical numerical example.

1. Introduction

The absence of markets for environmental goods and services such as clean air and water resources is one of the prime examples of the market failure. It is well known that the lack of economic value for environmental goods generally leads to over-exploitation and degradation of these resources. Therefore, economic valuation of the environment and its services is one of the most fundamental topics in ecological and environmental economics (e.g. Cropper and Oates, 1992; Bingham et al., 1995; Costanza et al., 1997).

Standard valuation methods can be classified into two main categories: the *stated preference* (SP) methods and the *revealed preference* (RP) methods (e.g. Freeman, 2003; Perman et al., 2003). The SP methods include techniques such as contingent valuation method (CVM) that inquire people about their willingness to pay for environmental goods or willingness to accept compensation for reduction in environmental quality. While there are many different strategies to encourage the respondents to state their preferences, the SP approaches generally rely on respondents' direct valuation of the environmental issue at hand or indirect valuation based on their choices in different hypothetical scenarios (see e.g. Louviere et al., 2000; Holmes and Adamowicz, 2003; Kanninen, 2007, for different stated preferences methods). By contrast, the RP methods try to infer individuals' willingness to pay based on their observed behavior. Examples of these approaches include the travel cost method and the hedonic pricing method. While the RP techniques stand on a more objective ground, their scope for environmental valuation is

* *Corresponding author*. Tel.: +358 9 5608 6309; fax: +358 9 5608 6264.
E-mail addresses: timo.kuosmanen@mtt.fi (T. Kuosmanen), mika.kortelainen@joensuu.fi (M. Kortelainen).
[1] Tel.: +358 13 251 4241; fax: +358 13 251 4299.

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more limited. The RP approaches can be applied in situations where people already pay for an environmental good or service in one way or another, and this payment can be directly observed and associated with the use of that particular good or service.

Environmental cost–benefit analysis (ECBA) is one important area where the valuation techniques have been used. ECBA refers to social evaluation of investment projects and policies that involve significant environmental impacts. ECBA is widely applied by national environmental protection agencies and in many countries the legislation requires ECBA to be implemented for all public projects and policies that have significant environmental impacts.[2] Yet, many economists and ecologists have pointed out numerous problems, challenges and concerns associated with ECBA (see e.g. Dorfman, 1996; Ackerman and Heinzerling, 2002, 2004).

The economic valuation of the environmental impacts is clearly one of the most heavily debated stages of ECBA due to the deficiencies and problems in the conventional valuation techniques.[3] First of all, as the RP techniques are based on observed data from the past behavior and cannot be employed for evaluating non-use (or existence) values, their applicability for ECBA is limited. Indeed, the SP methods have been more typically used for environmental valuation in ECBA. On the other hand, the SP methods have been heavily criticized because of their hypothetical character. According to many critics, the price estimates given by these methods are just hypothetical and do not represent actual willingness to pay (see e.g. Kahneman and Knetsch, 1992; Rosenthal and Nelson, 1995; Hausman, 1993; Diamond and Hausman, 1994; Cummings et al., 1995). Many critics reject CVM as a valuation method because in their view the results of CVM studies are inconsistent with the economic theory and do not measure individual's underlying preferences (see e.g. Hausman, 1993). Despite this heavy critique presented by renowned economists, ecologists as well as other social scientists, in practice CVM and other SP methods are extensively used in ECBA, because in many applications there are no alternative methods (see Whitehead and Blomquist, 2006).

This paper proposes a new alternative approach for environmental valuation within ECBA framework that is based on data envelopment analysis (DEA: Farrell, 1957; Charnes et al., 1978). In addition to its traditional confinements in productivity and efficiency analysis, DEA is frequently applied in many other areas of applied economic sciences, including agricultural economics, development economics, financial economics, public economics, and macroeconomic policy, among others. In the fields of ecological and environmental economics, DEA has been earlier used for eco-efficiency analysis (e.g. Kuosmanen and Kortelainen, 2005; Kortelainen and Kuosmanen, in press), environmental performance measurement (e.g. Färe et al., 1996), environmentally sensitive productivity analysis (e.g. Yaisawarng and Klein, 1994; Weber and Domazlicky, 2001) as well as the estimation of shadow prices for emissions (Lee et al., 2002). Färe and Primont (1995) and Womer et al. (2006) have earlier suggested using DEA for cost–benefit analysis (CBA). However, these studies focused on the other aspects of CBA and did not pay particular attention on the valuation of environmental impacts, which forms the main topic of this paper. This paper intends to show that DEA can also be a very useful tool for environmental valuation in the context of ECBA.

In its purest form, the unique valuation principle of DEA does not depend either on stated or revealed preferences. Rather, it turns the valuation problem the other way around, and asks what kind of prices would favor this or that particular project or policy alternative. In some situations, DEA can provide a clear-cut solution for the ECBA valuation problem without a need to invest in costly RP or SP studies. Even if such clear-cut solution does not arise, a preliminary DEA assessment can help to structure the problem and to identify the critical parameters that need to be estimated by other methods, which can save a considerable amount of time and money when the more demanding RP or SP evaluation studies are implemented.

Relying on the implicit preferences of the project proponents revealed by the observed environmental profiles of the projects, DEA shares some common intellectual roots with the revealed preference approaches. Thus, the basic DEA approach is likely to appeal to those who generally prefer RP to SP methods. However, in contrast to the traditional RP techniques, the DEA approach proposed in the paper does not require historical, observed data, but can be used for evaluating future projects, policies or investments as well. Moreover, the DEA analysis is not limited to the use values of environmental factors, but can also account for possible non-use values of environmental resources. On the other hand, DEA has structural similarities with multi-criteria analysis (MCA), which is often mentioned as a "softer" alternative for the more traditional economic techniques. Like MCA, DEA views the valuation problem from a multi-dimensional perspective, and it can be applied in combination with MCA or other techniques that involve subjective judgments and stated preference information. Thus, DEA offers a flexible and general framework that can easily be adapted to the specific features and purposes of the ECBA study.

The practical application of DEA in the ECBA framework presents two major challenges. First, the purposes of the traditional DEA and ECBA are very different. The traditional DEA is geared towards *ex post* comparative performance assessment of comparable production units performing similar tasks or functions. By contrast, ECBA is typically geared towards *ex ante* analysis where the purpose is to identify one socially optimal project (or a basket of projects) to be implemented from a set of available alternatives. Second, the concept of price is different in DEA and ECBA. The traditional DEA applies shadow price multipliers that have only a meaning as a relative price, and thus cannot be anchored in some currency unit (such as dollar or euro). By contrast, the absolute prices expressed in a given currency are necessary for ECBA in order to determine whether any of the alternative projects is profitable enough to be implemented.

The main contribution of this paper is to show that these two rather fundamental differences can be reconciled by proper adjustments to DEA. Further, because sensitivity analysis is also an important part of ECBA, we describe how

[2] E.g., in the USA, ECBA is mandated by the US Executive Order 13258.

[3] See e.g. the lively debate by Ackermann et al. (2004).