ECOLOGICAL ECONOMICS 68 (2009) 1633–1642

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Environmental cost–benefit analysis of alternative timing strategies in greenhouse gas abatement: A data envelopment analysis approach

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ARTICLE DATA

Article history:
Received 31 January 2007
Received in revised form 9 May 2008
Accepted 20 July 2008
Available online 21 August 2008

Keywords:
Ancillary benefits
Applied general equilibrium modeling
Climate change
Eco-efficiency
Environmental performance

ABSTRACT

Assessing the benefits of climate policies is complicated due to ancillary benefits: abatement of greenhouse gases also reduces local air pollution. The timing of the abatement measures influences both the economic costs and ancillary benefits. This paper conducts efficiency analysis of ten alternative timing strategies, taking into account the ancillary benefits. We apply the approach by Kuosmanen and Kortelainen [Valuing Environmental Factors in Cost-Benefit Analysis Using Data Envelopment Analysis, *Ecological Economics* 62 (2007), 56–65], which does not require prior valuation of the environmental impacts. The assessment is based on synthetic data from a dynamic applied general equilibrium model calibrated to The Netherlands. Our assessment shows that if one is only interested in GHG abatement at the lowest economic cost, then equal reduction of GHGs over time is preferred. If society is willing to pay a premium for higher ancillary benefits, an early mid-intensive reduction strategy is optimal.

1. Introduction

Climate change presents a major environmental policy challenge both at present and in the future. Through a large scale incineration of fossil fuels, human activities have released a still growing stream of CO_2 and other greenhouse gases (GHGs) into the atmosphere. GHGs occur naturally in the atmosphere and are not detrimental for the environment as such. However, the emissions of GHGs contribute to the global warming through a process known as the greenhouse effect.

Since GHGs are uniformly mixing in the atmosphere, climate policy requires international cooperation. In the United Nations framework convention on climate change (UNFCCC) and its famous Kyoto protocol, ratified by 180 countries [as of May 2008], participants have committed to reducing the GHG emissions by 5% from the 1990 emission levels during the period of 2008–2012.[1] The Kyoto protocol and the Marrakech Accords prescribe a number of mechanisms for the GHG abatement. Some of these mechanisms allow for international trade in abatement/emissions among the participating countries. Industrialized (Annex I)[2] countries are also obligated to take substantial domestic measures to cut down their GHG emissions.

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[1] For further details, see the official UNFCCC homepage: http://unfccc.int/.

[2] The term Annex I refers to the Kyoto Protocol and lists countries with a binding reduction target; see UNFCCC (op.cit.)

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doi:10.1016/j.ecolecon.2008.07.012

Given the multitude of abatement measures, it is not clear which policy measures achieve the abatement targets with the lowest costs. Moreover, the timing of the abatement measures can influence the costs. The assessment of alternative policy measures is further complicated by a multitude of ancillary benefits due to GHG abatement. The emission of CO_2, the most important GHG, is directly connected to energy use. Most climate policy measures entail restructuring of energy use, with shifts in the use of different fuel types and qualities and the decrease in the total use of fossil fuels. Since the use of fossil fuels is also a major cause of air pollution, the climate policy measures can provide significant ancillary benefits in the form of reduced acidification, eutrophication, smog formation, and particle emissions. The European Environment Agency (EEA, 2006) has estimated that the climate policy that meets the EU objective of the Kyoto protocol would reduce the NO_X, SO_2, PM_{10} and $PM_{2.5}$ emissions by 10, 17, 10 and 8%, respectively, by year 2030. Ancillary benefits of such magnitude should be taken into account in the economic assessment of the climate policies.

Environmental cost-benefit analysis (ECBA) is the standard approach to the assessment of alternative environmental policies (e.g. Boardman et al., 2001). In many countries the legislation requires ECBA to be implemented for all public projects and policies that have significant environmental impacts.[3] However, ECBA is subject to many shortcomings, as a number of economists and ecologists have pointed out (see e.g. Dorfman, 1996; Ackerman and Heinzerling, 2002, 2004). The economic valuation of the environmental impacts is one of the most controversial and heavily debated phases in ECBA due to the deficiencies and problems in the conventional valuation techniques (including stated and revealed preference methods).[4] Valuation of the ancillary benefits presents a major challenge for ECBA assessment of the climate policy.

The recent paper by Kuosmanen and Kortelainen (2007) [henceforth KK] proposed a new approach to ECBA which does not require prior valuation of the environmental impacts. Their approach is based on shadow prices in similar vein to the data envelopment analysis (DEA: Farrell, 1957; Charnes et al., 1978).[5] The unique valuation principle of DEA does not depend either on stated or revealed preferences. Rather, the valuation problem is turned the other way around by asking what kind of prices would favor this or that particular project or policy alternative.

The key differences between the conventional ECBA and the DEA approach by KK are summarized by Table 1 that lists the steps involved in each approach. Both types of ECBA analyses start with problem definition, identification of environmental and social issues at stake, and the measurement of impacts (Steps 1 and 2). The pivotal idea of KK is to skip the economic valuation of impacts by stated or revealed preference methods (Step 3 of the conventional approach), and proceed directly to the discounting step. Instead of discounting cost or benefit flows, KK propose to discount the flows of physical impacts. Given the discounted impacts, KK optimize the values (or prices) of the environmental factors to maximize the *competitive advantage* of the evaluated project or policy (Step 4). The competitive advantage can be seen as a measure of eco-efficiency (compare with Kortelainen and Kuosmanen, 2007): a project is deemed efficient if its competitive advantage index is strictly positive, otherwise the project is inefficient. The thus obtained competitive advantage measure provides a means to assess the eco-efficiency of a project, policy, product or producer throughout the life-cycle of the unit without ex ante valuation of the various environmental impacts. Alternatives with a positive competitive advantage are possible optimal solutions to the choice problem underlying ECBA. The range of shadow prices supporting this or that project (or policy alternative) provides valuable information for the purposes of sensitivity analysis.

Table 1 – Steps involved in the conventional environmental cost benefit analysis (ECBA) and the data envelopment analysis (DEA) approach

Step	Conventional approach to ECBA	DEA approach to ECBA
1	Problem definition	Problem definition
2	Measurement of environmental impacts	Measurement of environmental impacts
3	Economic valuation of impacts	Discounting of impacts
4	Discounting of cost /benefit flows	Shadow pricing the discounted impacts by DEA method, maximizing competitive advantage
5	Ranking of projects/policies according to the net present value criterion	Ranking of projects/policies according to competitive advantage criterion
6	Sensitivity analysis	Sensitivity analysis

Bosetti and Buchner (2005) have conducted efficiency analysis of eleven alternative climate policy scenarios by making use of DEA and the competitive advantage measures of KK. The scenarios differ in terms of what will happen after the Kyoto protocol ends and new climate agreements are negotiated. An innovative feature of this study is its use of synthetic data from the FEEM-RICE model (Bosetti et al., 2004), which is a multi-region applied general equilibrium (AGE) model based on the RICE model by Nordhaus and Boyer (2000). Since a large proportion of the costs and benefits of the climate policy occur far in the future, relying on the synthetic model forecasts is often the only way to meet the necessary data requirements of the *ex ante* ECBA. On the other hand, while AGE models are well suited for forecasting the economic and social impacts of alternative climate policies, the choice of the optimal climate policy involves tradeoffs between multiple incommensurable criteria that cannot be resolved within those models. Therefore, using the forecasts from an AGE model as inputs to the DEA assessment can be a successful recipe for a powerful policy analysis.

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

[4] See e.g. the lively debate by Ackerman et al. (2004).

[5] 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, 2007), 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).