Ecological Economics 150 (2018) 217–228

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Distributional Weights in Environmental Valuation and Cost-benefit Analysis: Theory and Practice

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ARTICLE INFO

Keywords:
Cost-benefit analysis
Environmental valuation
Distributional weighting
Willingness to pay

ABSTRACT

Cost-benefit analysis (CBA) is built on the Kaldor-Hicks efficiency criterion whereby projects that have aggregate positive net benefits are recommended even if those who lose are not compensated for their losses. Two kinds of problems can be identified with the use of the criterion. First, as income tends to affect monetary welfare changes positively, the preferences of those with higher wealth have a larger weight in societal decision-making. Second, monetary welfare changes can be thought of as changes in real income, which matter more for those with a lower initial wealth level. Both problems can be mitigated with distributional weighting. Despite their strong theoretical pedigree, distributional weights have been largely neglected in practical CBAs, one exception being analyses in climate change economics. We present the theory of distributional weighting and illustrate how weights can be applied empirically in an international environmental CBA that deals with marine water quality improvements. We show that different weighting schemes can result in different policy recommendations. We also show that taking the income distribution within countries into account can change a country's willingness to participate in the water quality improvement program and that the income elasticity of willingness to pay (WTP) is an important indication of the direction of change.

1. Introduction

Economic valuation of environmental goods and cost-benefit analysis (CBA) can form a valuable part of the information base for decision-making (Freeman et al., 2014; Bergstrom and Randall, 2016). The CBA is built on the Kaldor-Hicks efficiency criterion (e.g. Boadway, 2006; Coleman, 1980; Adler and Posner, 1999), which allows a favorable project to have both winners and losers but with the winners compensating the losers and still being better off. If such compensation is paid, the project turns out to be a Pareto Improvement, but no actual compensation is required for Kaldor-Hicks efficiency (Coleman, 1980).

To determine Kaldor-Hicks efficiency in a CBA, the total benefits and costs are typically measured in money, making income the numeraire (Dreze, 1998). The two relevant welfare measures, compensating variation (CV) and equivalent variation (EV), measure the monetary equivalent of the effect that change in the environmental good would have on the individuals' welfare. When either CV or EV is aggregated over individuals, a positive number indicates that the project should be recommended, as the monetary gains are higher than the monetary costs. It is this “aggregate benefit criterion” (ABC) that forms the principal basis for cost-benefit analysis and modern welfare economics (Dreze, 1998; Freeman et al., 2014).

Both theoretical (e.g. Boadway, 1974; Scitovsky, 1941; Blackorby and Donaldson, 1990) and ethical problems (e.g. Mishan, 1982; Sen, 2000; Dreze, 1998; Nyborg, 2014) have been identified in using the ABC as a decision rule. We concentrate on the problem of using income as a numeraire without adjusting it to account for differences in the *social marginal utility of money*. From their first introductory course, economists are taught the law of diminishing marginal utility as a golden rule, only to see it forgotten later when applying the ABC. Without adjusting or “weighting” monetary welfare changes to take into account the social marginal utility of money, CBA is systematically favorable to those who value money the least relative to alternative numeraires (Brekke, 1997; Dreze, 1998; Boadway, 2006). The reason for this is that, due to the diminishing marginal utility of money, the rich are usually willing to give up more of their income for a given (equally desirable) change and thus their opinion matters more in the social decision-making. In more technical terms, CBA is not symmetric among agents, as it is not irrelevant how a given vector of preferences is distributed among individuals: For example, if we change preferences

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https://doi.org/10.1016/j.ecolecon.2018.04.021
Received 15 December 2017; Received in revised form 12 April 2018; Accepted 14 April 2018
0921-8009/ © 2018 Published by Elsevier B.V.

such that a wealthy individual who initially preferred a golf course to a public park now prefers a public park to a golf course, and a poor individual reverses his or her preferences from a park to a golf course, it may very well be that the ranking of alternatives based on the ABC also changes.

As Dreze (1998) points out, in economic theory the need for adjustments or weights for individual welfare changes is well known but largely forgotten in practice. Many modern textbooks in environmental valuation (e.g. Freeman et al., 2014) focus very little on the use of distributional weights, while some (e.g. Boardman et al., 2006) discuss them briefly but nevertheless base most of the theory on the ABC. Organizations such as the World Bank abandoned the use of weights decades ago, but environmental policy analysts have recently shown renewed interest in them, with Hallegatte et al. (2016) applying them in a report on the poverty induced by disaster risks. On a national level, the UK government officially recommends using distributional weights in CBA (HM Treasury, 2003). It is also rare to find distributional weights included in the analyses in practical valuation studies (Adler, 2013; Nyborg, 2014). An exception is climate change economics (e.g. Nordhaus and Boyer, 2000; Fankhauser et al., 1997; Tol, 2005; Shiell, 2003; Anthoff et al., 2009; Dennig et al., 2016; Anthoff and Emmerling, 2016), where weights have been used to account for the different income levels between countries, mainly developed and developing countries. The results have shown that the order of magnitude of climate change damages can change by two if equity weights are used, making CBA results extremely sensitive to weighting (Anthoff et al., 2009). It is our hypothesis that similar results could be obtained in CBAs of other environmental goods.

This paper contributes to the limited empirical literature on the effect of using distributional weights in environmental valuation studies and CBA. We 1) provide a connection between the income effect and distributional issues, 2) compare different weighting schemes both theoretically and empirically, 3) show how the weights could be incorporated in a valuation study in practice, and 4) demonstrate that the results are sensitive not only to whether the weights are applied or not, but also to the choice of weighting rule and spatial resolution. In the empirical application, we use data from a contingent valuation study conducted in nine countries on people's willingness to pay for improved water quality and employ a range of weights to study the effects on the results of the CBA, much as a sensitivity analysis would. This approach has been advocated by at least Hanley (2001), Johansson-Stenman (2005) and Boardman et al. (2006) and applied in practice with regional weights for the costs of climate change damages by Fankhauser et al. (1997), Tol (2005) and Anthoff et al. (Anthoff et al., 2009 & Anthoff and Emmerling, 2016), and for natural disasters by Hallegatte et al. (2016).

The paper is organized as follows. Section 2 gives a theoretical overview of how income affects measured monetary welfare changes and the benefit incidence of a project. In Section 3 we then go on to discuss how these changes can be adjusted to take into account the social marginal utility of money and what the theoretical arguments for or against using weights are. In Section 4, we describe the data, and in Section 5 we test how the different adjustment mechanisms, or weightings, affect estimated environmental values and the results of a CBA. Section 6 provides a discussion of the results and Section 7 our conclusions.

2. The Effect of Income on Welfare Changes

In this section, we introduce the relevant welfare measures and review the theory of how these are affected by income. We also show that the benefit incidence ("who gets the benefits") is crucially dependent on the income elasticity of the welfare measures, for it measures how unevenly the benefits are distributed among different income groups. Last, we present empirical estimates for the income elasticity of welfare measures. Income elasticity is connected to the distributional weights and their impacts on CBA results in Section 3 and to the empirical results in Section 5.

The two relevant concepts for the Kaldor-Hicks efficiency test are compensating variation (CV) and equivalent variation (EV). For a gain in environmental quality/quantity (from q_0 to q_1), CV measures the willingness to pay (WTP) to obtain the change, and EV the willingness to accept compensation (WTA) to forego the change. CV and EV are defined with the expenditure function $e(q,u)$, where u_0 stands for the initial utility before the environmental quality/quantity change and u_1 stands for the utility after the change:

$$CV = e(q_{0,}u_0) - e(q_1, u_0) \tag{1}$$

$$EV = e(q_{0,}u_1) - e(q_1, u_1) \tag{2}$$

How the outcome of a CBA is affected by individuals' income differences is thus crucially dependent on how income affects CV and EV, as the more sensitive the welfare measures are to changes in income, the more the CBA gives weight to the preferences of wealthier people. Accordingly, we need to have a measure for the magnitude of the income effect, relate it to the benefit incidence, and find ways to correct the results to account for these effects.

2.1. Benefit Incidence

Benefit incidence can be linked to the concepts in Eqs. (1) and (2) as follows (Ebert, 2003; Lamber, 2001):

If the benefit b, defined as the welfare change (either CV or EV) divided by income y $b(\boldsymbol{p},q,y) = B(\boldsymbol{p},q,y)/y$, increases (decreases) with income ($\boldsymbol{p}$ is the price vector of all commodities) such that $\frac{\partial b(p,q,y)}{\partial y} > 0$ (< 0), then the benefits are distributed progressively (regressively). From direct partial differentiation of $B(\boldsymbol{p},q,y)/y$ with respect to income y, and using WTP as the measure of benefits ($B = WTP$), we obtain the main result presented in Ebert (2003):

$$\frac{\partial WTP(\boldsymbol{p},q,y)/y}{\partial y} = \frac{\partial WTP}{\partial y}\frac{1}{y} - \frac{WTP}{y^2} = \frac{WTP}{y^2}(\eta(WTP,y) - 1) \tag{3}$$

where $\eta(WTP,y)$ is the income elasticity of WTP.

The income elasticity of WTP ($\eta(WTP,y)$ can then be used in defining the benefit incidence as follows:

$$if\ \eta(WTP,y) > 1, \text{then } \frac{\frac{\partial WTP(\boldsymbol{p},q,y)}{y}}{\partial y} > 0; \text{the benefits are distributed progressively.} \tag{4}$$

$$if\ \eta(WTP,y) < 1, \text{then } \frac{\partial WTP(\boldsymbol{p},q,y)/y}{\partial y} < 0; \text{the benefits are distributed regressively.} \tag{5}$$

$$if\ \eta(WTP,y) = 1, \text{then } \frac{\partial WTP(\boldsymbol{p},q,y)/y}{\partial y} = 0; \text{the benefits are distributed proportionally.} \tag{6}$$

The income effect and its measure, the income elasticity of WTP, are the crucial factors determining 1) who has standing in a CBA and 2) who obtains the benefits. Let us take an example where the income elasticity of WTP for a given project is very close to 0 and the benefits are regressively distributed. Clearly, in such a case the good is mainly enjoyed by lower-income groups, who have a limited budget to express their preferences, and the use of distributional weights should increase the aggregate benefits relative to a project with a higher income elasticity of WTP.

2.2. Income Elasticity of WTP

The two main results related to the income elasticity of WTP, obtained by Haneman (1991) and Flores and Carson (1997), respectively,

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