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Do Cost-Benefit Analyses favour Environmentalists?

by

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Abstract

Money and environmental quality units are considered as unit for aggregating willingness to pay. For those with a high willingness to pay for environmental quality, the choice of money as aggregation unit is most favourable. Arguments for either choice of aggregation unit are discussed, and I argue that none of them is convincing, and that both choices are equally natural. Thus in the choice between two equally natural procedures, the conventional choice favours a particular group. On the other hand, with no "correct" choice we cannot conclude that the conventional method is "biased".

1 Introduction

Valuation of public goods is an important tool in environmental economics, and the computed value is an essential component in the determination of optimal environmental quality. Contingent valuations studies may even be accepted as court evidence in cases involving environmental damages. In these applications it is crucial that the valuation method is not biased in the favour of particular groups.

Economic welfare theory, and especially valuation studies, has been based upon a welfaristic and mostly utilitarian moral philosophy. This foundation is controversial. The problem of restricting the informational basis to utility information has been pointed out in Sen (1979)[1], and much moral philosophy, like Rawls (1972) seminal work, is not based on utilities at all. However, the implications of this criticism is not necessary that calculations based on utilities are irrelevant, they may just be incomplete. An example is Kelman (1981) who is very critical to the philosophical foundations of cost benefit analysis, but still concludes that "*some efforts* to measure costs and benefits may be justified." (Italics added.)

The problem of how to measure cost and benefits remains. Since Arrow's seminal impossibility theorem, it has been known that ordinal utility information is narrow basis for a meaningful aggregation of utility. The impossibility theorem has shown to be surprisingly robust, and many authors have pointed out that the information basis for aggregation has to be extended to include cardinal and interpersonally comparable utility. (For a discussion see Arrow (1963), Sen (1970, 1979, 1986) and Kelsey (1987).) This insight has led to several attempts of measuring cardinal utility. A survey of this literature is given in Tinbergen (1991). Furthermore, the modern theory of Cost – Benefit analysis, as presented in Drèze and Stern (1987), Mäler (1985) and Starret (1988), is based upon aggregation of cardinal utility.

The traditional approach to valuing public goods is to add individual willingness to pay. Implicitly this procedure takes the utilitarian approach of adding utilities,

[1] See also the discussion between Ng (1981) and Sen (1981).

where it is assumed that an additional dollar corresponds to the same amount of cardinal utility independent of wealth, income or other characteristics of the person who receives the dollar. However, there are no reasons to assume that an additional monetary unit corresponds to the same amount of cardinal utility units to every person. This is reflected in the theoretical conclusion that individual willingness to pay has to be weighted.

Drèze and Stern (1987) points out that the welfare weights "have a straigthforward interpretation". But a straightforward interpretation does not imply that it is straightforward to quantify. The purpose of this paper is to add some intuition to the quantification of weights, or rather to challenge the conventional wisdom on the reasonable sizes of welfare weights. Besides, it will be shown that the choice of weights is a choice of which group to favour.

The conventional wisdom on welfare weights seems to be that the relative differences between individual should be small. Few empirical studies uses weights at all. This is not too surprising, since the theory gives few advises to choosing weights. We will discuss Drèze and Stern's (1987) proposal to set weights by inverse optimization. With few theoretical advises, the choice of nonequal weights will to some extent be arbitrary, and controversial. But equal weights are as arbitrary. We will demonstrate that the choice of different units of measurement in the aggregation of preferences, will correspond to a shift in weights. This shifts may be considerable, a shift in weights of a factor of 6000 is found in an empirical example.

2 Should we put environmental prices on money? An example

Consider two persons, a 'materialist' and an 'environmentalist'. Their preferences are defined over private money Y, that can be used to buy commodities at given prices, and environment E: Their utility functions are given as:

$$U_1(Y_1, E) = 100Y_1 + E \quad (1)$$

for the materialist, and

$$U_2(Y_2, E) = Y_2 + 100E \quad (2)$$

for the environmentalist.

Their initial income is $Y_i = 1000$ and the state of the environment is $E = 1000$ (according to some measurement rule.) Consider the project $\Delta Y_j = -1$ for $j = 1, 2$ and $\Delta E = 1$. The welfare change for person j of the project can be expressed in money terms as a willingness to pay $WTP_{j,Y}$ satisfying

$$U_j(Y_j + WTP_{j,Y}, E) = U_j(Y_j + \Delta Y_j, E + \Delta E). \quad (3)$$

Similarly the willingness to pay may be expressed in environmental quality terms as WTP_{Ej}, satisfying

$$U_j(Y_j, E + WTP_{j,E}) = U_j(Y_j + \Delta Y_j, E + \Delta E), \quad (4)$$

e.g., the willingness to pay in environmental units, for person 1 above, will be $WTP_{1,E} = -99$, as is easily verified by inspection.

Individual and average willingness to pay in this example is reported in table 1.

	1	2	Average
Enironment-units	-99	+0.99	-49
Income units	-0.99	+99	+49

Table 1: Willingness to pay in different units

We see from the table that the average WTP is negative in environment units, and the project looks bad. This will be the case even in a society with 99% environmentalists (utility U_2). At the same time WTP is positive if it is computed in money terms. The average WTP will be positive even if only 1% in the society are environmentalists. The choice of scale thus may be extremely important. The crucial question then becomes: Is there any reason to prefer one choice to the other?

Note that if the average willingness to pay is reported only in money term, there is no way the decision maker can recover the fact that the average willingness to pay is negative when average is computed in environmental quality units. To see this, note that the average willingness to pay is also consistent with the case $U_1 = U_2 = Y_j + 50E$. In this case the average willingness to pay in money units is positive also when computed in environmental units. A decision maker who find environmental quality units to be the appropriate unit of aggregation will be unable to detect that the project is bad according to his judgments.

In the remainder of this paper we will demonstrate that the choice of unit is equally important in a more general framework, and that the choice of money rather than environmental units as aggregation unit will favour those with high willingness to pay for environmental quality. Also we will discuss the arguments for using a particular aggregation unit.

3 The Theory of Cost Benefit Analysis

More generally we consider a society of I individual. Assume that there are n market goods, and m public goods, denoted by the vector $E \in \mathbf{R}^m_+$. Individual i's consumption of market goods is denoted $x_i \in \mathbf{R}^n_+$. We assume moreover that $U_i : \mathbf{R}^{n+m}_+ \mapsto \mathbf{R}$ is a cardinal utility function of individual i, and that these utility functions are interpersonally comparable. Furthermore, assume that the social preferences can be represented by a Samuelson-Bergson welfare function, i.e.,

$$W(X) = V(U_1(x_1, E), \ldots, U_I(x_I, E)) \tag{5}$$

where $X = (x_1, \ldots, x_I, E)$ is the social state.

For later reference we note that the bundle of market goods can be aggregated to a composite good, by the following procedure. For a given E, i's preferences over bundles of market goods, can be represented as an indirect utility function $v_i(y,p)$ where y is income and p is the price vector. For a given set of prices, the utility is thus only a function of income, and environmental quality. Thus

$$W(X) = \tilde{V}(v_1(y_1, E), \ldots, v_I(y_I, E)) \tag{6}$$

Now return to (5), and consider the effect of a marginal change ΔX, in the social state. ΔX also will be referred to as a project. The effects of this marginal change on the welfare function may be written

$$\Delta W \approx \sum_{i=1}^{I} \left[\frac{\partial W}{\partial U_i} \Delta U_i \right] \tag{7}$$

where[2] $\Delta U_i \approx \nabla_x U_i \cdot \Delta x_i + \nabla_E U_i \cdot \Delta E$, is the change in i's utility. This may be rewritten, using willingness to pay, and welfare weights.

$$\Delta W = \sum_{i=1}^{I} \beta_i \left[\frac{\Delta U_i}{\lambda_i} \right] \tag{8}$$

where $\lambda_i = \frac{\partial U_i}{\partial x_{1,i}}$ is the marginal utility of a numeraire (here component 1 of x_i) unit to individual i. β_i are welfare weights defined as

$$\beta_i = \lambda_i \frac{\partial V}{\partial U_i}. \tag{9}$$

The term in brackets in (8) can be interpreted as the willingness to pay for the total project. Since an extra unit of the numeraire good will add λ_i to i's utility, it takes approximately $\frac{\Delta U_i}{\lambda_i}$ units of the numeraire good to achieve the utility change ΔU_i. Thus the total change in social welfare is a weighted sum of individual willingness to pay in units of the numeraire good.

This approach to Cost-Benefit analysis is standard by now, see Atkinson and Stiglitz (1980, Lecture 15), Drèze and Stern (1987), Starret (1988), and Mäler (1985).

[2] $\nabla_x U$ is the gradient of U with respect to the x-vector, similar with $\nabla_E U$.

The problem to which there is no standard solution, is how to determine the welfare weights. Welfare weights have a straightforward interpretation as the product of the marginal utility of an extra dollar to i times the marginal contribution of social welfare from a utility unit extra to i. But these are two unobservable quantities. An alternative view on the weight is that to maintain social welfare, j must be compensated with β_i units of the numeraire if i looses β_j.

Note that interpersonal comparable utilities do not only depend upon i's preferences, but also on how other people judge this person's well-being compared to other persons. Thus there is no theoretical reason why people should agree on these interpersonal comparable utilities, and there is no empirical evidence of such a consensus. Thus we should expect that disagreement on the size of welfare weights, see Brekke et. al. (1993).

Below we will demonstrate that different choices of numeraire, will have huge effects on the welfare weights. Moreover, with equal weights, $\beta_i = \beta_j$ for all i and j, different choice of numeraire will favour different groups.

3.1 Does equal weight Cost-Benefit analysis in general favour environmentalists?

The importance of the choice of numeraire that was demonstrated in the example in section 2 can now be formulated more generally. For simplicity, we will consider the case with an aggregate private market good Y_i, and one public good called environmental quality E. Consider an improvement of environmental quality, i.e., $\Delta E > 0$, while $\Delta Y_i < 0$ for all i. We want to study the difference between average willingness to pay in environmental units and in money terms. To simplify the notation we introduce $\xi_i = \frac{\partial U_i}{\partial E} / \frac{\partial U_i}{\partial Y_i}$. It is easily verified from a local linearization of the utility function, that ξ_i is individual i's willingness to pay in monetary terms for an additional unit of environmental quality.

Let $\hat{u}_i(\Delta Y_i, \Delta E)$ denote individual i's willingness to pay for the *total* project in monetary terms. Formally $\hat{u}_i$ is defined implicitly as:

$$U_i(Y_i + \hat{u}_i(\Delta Y_i, \Delta E), E) = U_i(Y_i + \Delta Y_i, E + \Delta E). \tag{10}$$

Similarly let $\tilde{u}_i(\Delta Y_i, \Delta E)$ denote individual i's willingness to pay for the *total* project in environmental units. Formally $\tilde{u}_i$ is defined implicitly as:

$$U_i(Y_i, E + \tilde{u}_i(\Delta Y_i, \Delta E)) = U_i(Y_i + \Delta Y_i, E + \Delta E). \tag{11}$$

Both $\tilde{u}_i$ and $\hat{u}_i$ are numerical representations of i's preferences.

From the previous section we know that locally, i.e., for ΔY_i, $i = 1, ..., I$, and ΔE sufficiently small

$$\hat{u}_i(\Delta Y_i, \Delta E) = \Delta Y_i + \xi_i \Delta E, \tag{12}$$

and in environmental units:

$$\tilde{u}_i(\Delta Y_i, \Delta E) = (\Delta E + \Delta Y_i/\xi_i). \tag{13}$$

Thus a first order approximation of the total willingness to pay for the project is in environmental units is:

$$WTP_E = \sum_{i=1}^{I} \tilde{u}_i(\Delta Y_i, \Delta E) = \sum_{i=1}^{I} \left[\frac{\Delta Y_i}{\xi_i} + \Delta E\right] \tag{14}$$

while in money terms it will be

$$WTP_Y = \sum_{i=1}^{I} \hat{u}_i(\Delta Y_i, \Delta E) = \sum_{i=1}^{I} [\Delta Y_i + \xi_i \Delta E] \tag{15}$$

Since both $\hat{u}_i$ and $\tilde{u}_i$ are numerical representations of i's preferences, WTP_E and WTP_Y may be given a utilitarian interpretation as the sum of individual utilities, where either $\hat{u}_i$ or $\tilde{u}_i$ for $i = 1, ..., I$ is interpreted as *interpersonal comparable cardinal utility functions.*

Note that for all i, $\hat{u}_i = \xi_i \tilde{u}_i$, and hence,

$$\sum_{i=1}^{I} \hat{u}_i = \sum_{i=1}^{I} \xi_i \tilde{u}_i. \tag{16}$$

Hence, compared to aggregating in environmental units, aggregation in monetary units is equivalent to multiplying the weight of i's willingness to pay in environmental units with the factor ξ_i. Of the two alternatives, the choice of money as aggregation unit is favourable to those with high marginal willingness to pay in monetary units.

Since WTP_Y and WTP_E are in different units, they cannot be compared directly. And unless there is a correct price of environmental quality, there will be no obvious way to transform WTP_E into money units. On the other hand, if WTP_E defines social ordinal preferences, only the sign is important. To compare the signs it turns out to be convenient to use average willingness to pay $\bar{\xi} = \frac{1}{I}\sum_{i=1}^{I} \xi_i$.

What is the difference between $WTP_E\bar{\xi}$ and WTP_Y? For notational simplicity, we consider the cost shares as a probability distribution with probabilities $p_i = \Delta Y_i/\Delta Y$ where $\Delta Y = \sum_{i=1}^{I} \Delta Y_i$. The corresponding expectation operator is denoted $E[\cdot]$. Straightforward calculations shows that:

$$WTP_Y - (WTP_E \cdot \bar{\xi}) = \Delta Y \left[1 - \bar{\xi} E[\frac{1}{\xi}]\right]. \tag{17}$$

To proceed, we introduce some extra structure by assuming that the costs are distributed proportional to ξ_i^{α} for some $\alpha > 0$. The following Lemma is useful

Lemma 1 *Suppose that cost are distributed proportional to ξ_i^{α} for $\alpha > 0$, i.e.,*

$$\Delta Y_i = \Delta Y \frac{\xi_i^{\alpha}}{\sum_{i=1}^{I} \xi_i^{\alpha}}. \tag{18}$$

Then $\bar{\xi}E[\frac{1}{\xi}] < 1$ if and only if $\alpha > 1$.

Proof: Note first that in this case $p_i = \xi_i^{\alpha}/(\sum_{i=1}^{I} \xi_i^{\alpha})$, and

$$\bar{\xi}E[\frac{1}{\xi}] = \sum_{i=1}^{I} \frac{\xi_i^{\alpha}}{\sum_{i=1}^{I} \xi_i^{\alpha}} \frac{\bar{\xi}}{\xi_i} = \frac{\bar{\xi}\sum_{i=1}^{I} \xi_i^{\alpha-1}}{\sum_{i=1}^{I} \xi_i^{\alpha}} \tag{19}$$

Furthermore

$$\sum_i \xi_i^{\alpha} - \bar{\xi}\sum_i \xi_i^{\alpha-1} = \sum_i \xi_i^{\alpha-1}(\xi_i - \bar{\xi}) = \sum_i (\xi_i^{\alpha-1} - \bar{\xi}^{\alpha-1})(\xi_i - \bar{\xi}). \tag{20}$$

Since the function $x^{\alpha-1}$ is increasing for $\alpha > 1$ and decreasing for $\alpha < 1$, we conclude that $(x^{\alpha-1} - \bar{x}^{\alpha-1})(x - \bar{x}) > 0$ for any $x, \bar{x} > 0$, $x \neq \bar{x}$, if and only if $\alpha > 1$. Thus $\sum_i(\xi_i^{\alpha-1} - \bar{\xi}^{\alpha-1})(\xi_i - \bar{\xi})$ is positive for $\alpha > 1$ and negative for $\alpha < 1$. Combining this conclusion with (19) the claim follows immediately. □

Note that the sharing rule considered in the lemma, the cost share of i is more than proportional to ξ_i if $\alpha > 1$, and less than proportional to ξ_i for $\alpha < 1$, This observation and the lemma motivate the following definition

Definition 1 *The costs are* overproportionally distributed *if* $\bar{\xi}E[\frac{1}{\xi}] < 1$, *and* underproportionally distributed *if* $\bar{\xi}E[\frac{1}{\xi}] > 1$

We are now ready to compare the signs of WTP_E and WTP_Y. Since $\bar{\xi} > 0$, the following theorem is an obvious consequence of the previous definition and of equation (17).

Theorem 1 *If costs are underproportionally distributed, then*

$$[WTP_Y < 0] \Rightarrow [WTP_E < 0]\,, \tag{21}$$

while if costs are overproportionally distributed then

$$[WTP_E < 0] \Rightarrow [WTP_Y < 0]\,. \tag{22}$$

The theorem reinforces the previous conclusion that the environmentalists, i.e. those with high marginal willingness to pay for improvements in environmental quality, will always gain on the choice of money as aggregation unit, compared to choosing environmental quality as unit. When costs are underproportionally distributed, the proponents of the project will be the environmentalists, and the choice of money scale serves the project. When costs are overproportionally distributed, however, the opponents of the project, if any, will be the environmentalists, since the materialists will share a very small fraction of the costs. In this case the choice of money as unit will be to the project's disadvantage. The rising movement among environmental organization demanding pricing of environmental quality, e.g. green GNP, is thus strategically wise.

4 How important is the choice of numeraire?

In the previous section we used average willingness to pay to transform WTP_E into monetary units. This was convenient to prove the theorem, but the quantity is hard to interpret. Now suppose that the cost of the project is uniformly distributed to all individuals, i.e. $\Delta Y_i = \frac{1}{I}\Delta Y = \Delta Y_1$. Then we can find the per capita cost that makes the project socially indifferent to status quo, when aggregated in environmental units. That is, ΔY_1 is chosen so that $WTP_E = 0$. It is easy to see that this requires

$$\Delta Y_1 = \left(\frac{1}{I} \sum_{i=1}^{I} (\xi_i)^{-1} \right)^{-1} \Delta E \tag{23}$$

In Strand (1985) average willingness to pay for lowering emission to air from automobiles was estimated. The analysis is based on a survey of 2059 individuals. Of these 1852 responded, which is about 90%. The project under analysis was lowering emissions to air from automobiles with 50%. The respondent's willingness to pay varied from zero (277 respondents) to over 1200 kroner (five respondents). ΔY_1 in (23) will become zero if $\xi_i = 0$ for at least one i. On the other hand it seems reasonable to assume that $\xi_i = 0$ is reported when ξ_i is in fact positive but small. The lowest interval of positive willingness to pay was 10 to 90 kroner.

To aggregate in environmental units, the distribution aspects of the project have to be known. An analysis of the income distribution effect of a carbon tax in Alfsen et. al. (1992) shows that it is reasonable in this case to assume that the cost is evenly distributed. Thus the procedure above seems justified in this case. With these assumption I found ΔY_1= 31 kroner. This can be compared to the average willingness to pay in money terms of 685 kroner.

Thus with per capita cost of 31 kroner, the average environmental quality improvement demanded is equal to ΔE. While given the specified environmental quality improvement, the average willingness to pay is 685 kroner.

The conclusion this far is that money as aggregation unit is more favourable to environmentalist than environmental quality. But this is OK if money is in some sense the "correct" aggregation unit. In the next two section we will consider arguments in favour of either money or environmental quality as aggregation unit. Is any of them the correct one?

5 Arguments for aggregating in money terms

The Hicks-Kaldor (Kaldor (1939), Hicks (1939)) criterion for project evaluation claims that the project is preferable if the winners *potentially* can compensate the loosers. No compensation has to be paid. The problems with this criterion are widely recognized. Scitovsky (1941) demonstrated that the criterion may give rise to inconsistent social preferences. Possible solutions to this problem are discussed in Sen (1970, Ch 2*). But most important, the principle is not morally attractive. As pointed out in Drèze and Stern (1986) "An important and obvious ambiguity with the proposed criterion is that it remains vague on wether Pareto improvements will be actually implemented. If no such guarantee exists, then the criterion is certainly unacceptable." From example with zero transaction costs, a transfer of income from the very poor to the very rich, will pass this criterion, since the winners obviously can compensate the loosers. This violates Dalton's (1920) widely accepted *principle of transfers.*

Still, as pointed out by Tisdell (1991), "the criterion of a *potential* Pareto improvement underlies much of social cost–benefit analysis." This use of the Hicks–Kaldor criterion requires a justification. Three common justifications listed in Mitchell and Carson (1989, p. 22).

The first argument is that efficiency and distribution should be distinguished. They claim that "The most common ... is the argument that projects should be decided on a basis of strict economic efficiency, since political authorities can, if necessary, use lump-sum transfers to address any distributional consequences." Note that "strict economic efficiency" in this quote refers not to Pareto–efficiency, but to potential Pareto–efficiency. We will point at two problems with this argument. First, is it really easy to design the compensation transfers? And secondly, will such a transfer actually be implemented?

To the first problem note that actually to design a real Pareto improvement, the distribution of costs must depend upon marginal willingness to pay. Formally, ΔY_i, should depend upon i's ξ_i. But ξ_i is private information. There is a huge literature on how to design game forms that will implement a particular cost sharing rule such that the individuals will have incentives correctly to reveal their willingness to pay. For a recent proposal see Jackson and Moulin (1992). Common to all these game forms is that the project is decided on the basis of the *same information* that is collected for the decision of cost distribution. Had the project already been decided upon, the problem of designing a mechanism to reveal the private information would become much worse.

Secondly, even in a case where it is easy to design a compensations scheme, there is no guarantee that the lump sum transfers will actually be implemented. So why should a *potential* Pareto improvement be accepted when it is easy to design a *real* Pareto improvement? Why go for a bad solution when a good one is at hand? A claim that lump sum transfers are easy to design is actually an argument for only accepting project that has positive total willingness to pay *independent of choice of numeraire*, that is independent of the choice of welfare weights. If this requirement is used, only real Pareto improvements will be implemented.

In the proposed distinction between efficiency and distribution, distribution is usually specified to 'income distribution'. The problem of aggregating preferences can re reformulated as a problem of income distribution using an extended income concept, where $Y_i + \hat{u}_i$ is considered as income. Could indicators like the Gini-index may be applied to the distribution of extended income? Unfortunately this procedure is very sensitive to the choice of reference point. Note that indicators of income distribution are developed to handle distribution of a one-dimentional quantity (income). In the example of section two, the two consumers are identical in all respects both in the status quo position, and after the project is implemented. Especially is their income equal. The only difference is their preferences. If we judge their conditions to be equal in one of the two position, the extended income will be unequally distributed in the other position. Without any guidance to the choice of reference point, the procedure will be arbitrary. The question is one of redistribution between individual with *different taste*, not redistribution between individual with *different income.*

A second argument is that "the potential Pareto criterion is one piece of evidence available to the policymakers, who are free to reject any policy changes with adverse distributional consequences if they wish." But the total willingness to pay, aggregated in environmental units is another piece of information that can be made available for the policy makers. The total willingness to pay with other arbitrary welfare weights is a third piece of evidence that can be made available to the policy. There is no end to the list and the policy maker is free to disregard any particular piece of information made available.

A third argument is that if the government undertake a large number of projects and "if every of these projects meets the potential Pareto-improvement criterion, it is likely that everyone, or at least almost everyone, will be better off if they are all implemented." No empirical evidence for this proposition is presented. Moreover, if aggreagtion in monetary units, favours environmentalists, the total effect of all projects is likely to favour environmetalists as well. Most important, the argument applies equally well irrespective of the choice of welfare weights.

Consider the society of two individual from section 2. If the costs of any public projects are equally distributed, any project can be represented as a point in $\mathbf{R}^2$, as in figure 1. The status quo point is A, and we assume that two project adds up to the total project represented by the shift from A to B. The indifference curves through A for the two individuals are dotted, and since B is above both, the projects add up to a real pareto improvement. The social indifference curves with both choices

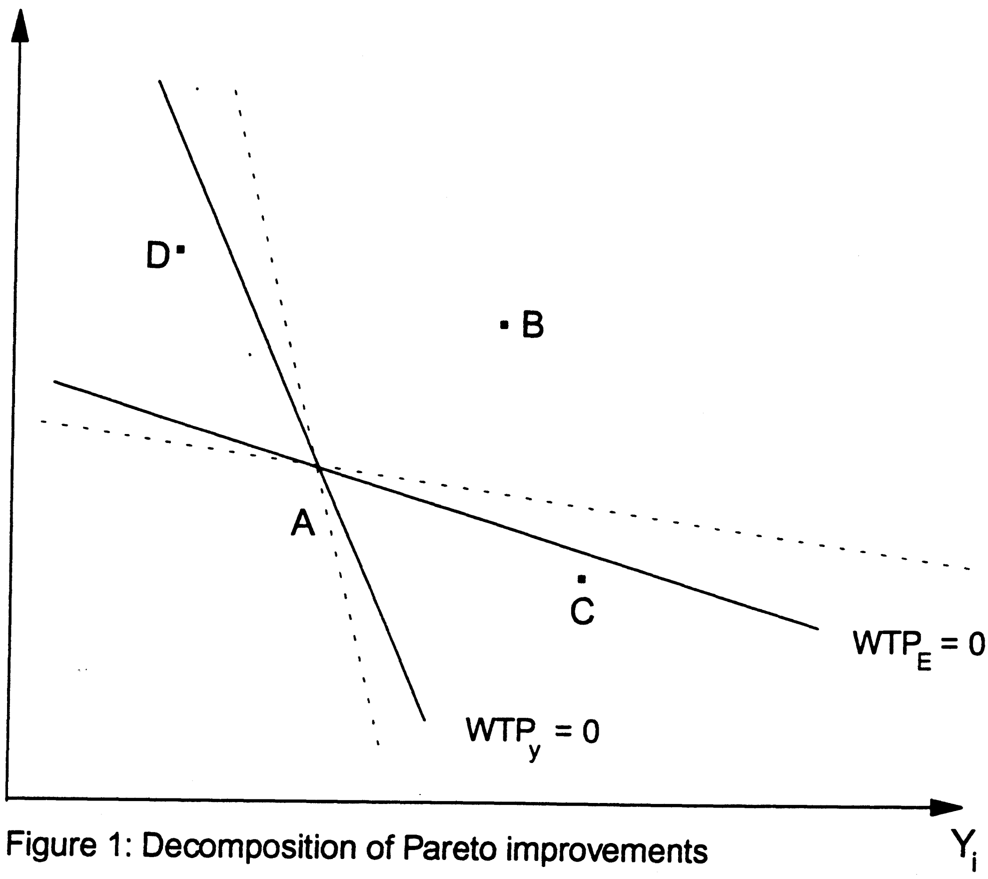

Figure 1: Decomposition of Pareto improvements

of numeraire are drawn with solid lines[3]. Indifference curves through other points will be parallel to the ones drawn in the figure.

This far nothing has been said of the smaller project, and any decomposition of the project from A to B is consistent with the analysis this far. We will consider two alternatives, the first is that A to B consists of the projects A to C and C to B, and the second is that A to b consist of the projects A to D and D to B. Note that none of the smaller projects are real Pareto improvements.

If this change is decomposed as the projects from A to C and from C to B, the change would be implemented if aggregation is done in money units, but with environmental units only the project A to C (which is no Pareto improvement) would be implemented. On the other hand, if the project is decomposed as A to D and D to B, then the situation is opposite. Only aggregation in environmental units will

[3]It can easily be demonstrated that $WTP_E = 0$ is the horisontal average of the individual indifference curves, while $WTP_Y = 0$ is the vertical average.

implement the Pareto improvement from A to B. The argument that many small projects with positive total WTP makes up a real Pareto improvement is, if correct, no argument in favour of any particular choice of welfare weights.

6 Arguments for aggregating in environmental units

This far we have focused extensively on distribution between individuals of different taste, but most studies of distribution focuses on income distribution. It would be interesting to consider the appropriate choice of numeraire in the case where differences in income is the only reason for redistribution. Thus we assume that there are no reasons for redistribution between individuals with the same income. Thus differences in taste are ruled out, and so are differences in the cardinal utility function. If we add the assumption of plain utilitarian, environmental quality units turns out to be the appropriate aggregation unit, as demonstrated in the following theorem.

Theorem 2 *Suppose that the cardinal interpersonal comparable utilities of all individuals are given as*

$$U_i(Y_i, E) = f_1(Y_i) + f_2(E) \tag{24}$$

where f_1 and f_2 are increasing and concave. Assume furthermore that the welfare function is utilitarian,

$$W = \sum_{i=1}^{I}(f_1(Y_i) + f_2(E)) \tag{25}$$

Then, as a first order approximation,

$$\Delta W = \beta \sum_{i=1}^{I} \tilde{u}_i \tag{26}$$

Hence in this case, aggregation in environment units is the correct welfare measure.

Proof: Choosing E as numeraire, the welfare weights according to (9) is

$$\beta_i = \frac{\partial U_i}{\partial E} \cdot \frac{\partial V}{\partial U_i} = \frac{\partial U_i}{\partial E} = f_2'(E), \tag{27}$$

which is independent of i. Hence (26) is a direct consequence of (8). □

Remark: Note that unless there are i and j such that $Y_j \neq Y_i$, the choice of numeraire will not matter.

The intuition behind this theorem is straightforward. WTP_E only depends upon total cost, ΔY, and not how the cost is distributed. If the distribution of cost is the only important distribution matter, we should expect a criterion that uses this information to be superior.

Unfortunately the assumptions of this theorem are to strong to be generally applicable. Environmental quality is a public good, in the sense that it is impossible to change the consumption of environmental quality for one individual without changing the consumption of all others. On the other hand, environmental quality is not equally available to all. There are obvious differences between individuals living in rural and urban areas, and individuals with different life style. In the case where income is more evenly distributed than access to environmental quality, the argument may be reversed, by assuming that $Y_i = Y$ for all i while accessible environment $e_i = \alpha_i E$, where $\alpha_i \neq \alpha_i$ for at least one pair i and i. In this case money would be the correct aggregation unit.

A second argument for aggregation in environmental quality units was presented in the previous section. We know that except in the (presumably rare) cases where project costs are overproportionally distributed, $WTP_E \geq 0$ is stricter requirement than $WTP_Y \geq 0$. If it is easy to design real Pareto improvements from potential ones, a good criterion should rule out projects with poor cost distribution design. Since any real Pareto improvement gives $WTP_E \geq 0$, this requirement is preferable. On the other hand, the huge literature on implementation of social choice rules indicates that the design of real Pareto improvements is very difficult.

7 Cost–Benefit analysis with welfare weights

As we noted above,

$$\tilde{u}_i = \frac{\hat{u}_i}{\xi_i}. \tag{28}$$

Hence, the use of environmental quality as aggregation unit is equivalent to choosing welfare weights $\beta_i = \frac{1}{\xi_i}$. Thus Cost–Benefit analysis with welfare weights is more general than choosing either money or environmental quality as aggregation unit. Moreover, the use of welfare weights seems to be widely accepted in the theoretical literature. Drèze and Stern conclude the discussion about " 'Avoiding' value judgements" by pointing out: "It is noteworthy that whilst some non-economists, e.g. the lawyer Lord Roskill in chairing the enquiry into London's proposed third airport, refuse weighting [see Roskill Commission (1971)], it has come to be accepted by some of those economists who had been its strongest opponents – see, for example, Harberger (1978) and Nwaneri (1970) and Layard, Squire and Harberger (1980)."

Drèze and Stern go on to propose several ways to quantify the weights. Their main proposal is to solve the "inverse optimum" problem to identify the weights implicit in previous project decisions. There are as the authors point out several problems with this approach. "First, the calculated welfare weights may be sensitive to the model of the economy and to which tools are assumed optimally chosen. Secondly, the assumption that the government has optimized must be examined critically. One way of doing this would be to ask directly whether the calculated welfare weights correspond to plausible value judgments. One could go further and use inverse optimum calculations as part of a dialogue with the government concerning both its values and wether the current policies are optimum. Interpreted this way, rather than as a mechanical device for deriving welfare weights, the inverse optimum exercise can be instructive."

An additional problem not touched upon is that there are no reasons to stick to measurements of costs and benefits as the sole information on which to base project decision. If decisions are based upon non-utility information too, the inverse optimum approach would require a non-welfarist model that allows a more general moral philosophy. The problem of how to organize project information a way that enhance an open and rational public discussion about the social preferability, is the subject of a separate paper. See Brekke et. al. (1993).

8 Conclusion

In this note I have studied the importance of the aggregation numeraire in cost benefit analysis. It has been demonstrated that the value of environmental quality will depend crucially on the choice of welfare weight, and that different choices favours different groups. Furthermore we have argued that there is no generally applicable reason to prefer money as aggregation unit.

On the other hand, the theory of cost benefit analysis allows for welfare weights, and any choice of numeraire corresponds to a set of weights, with money as aggregation unit. Thus the arbitrariness of the choice of numerair demonstrated in this note is just a special case of the observation that welfare weight cannot be determined a priori from theory.

In spite of the widespread acceptance of welfare weights in the theory of cost benefit analysis, there is few empirical studies using welfare weights. Many resent works on valuation of environmental goods goes into details about measuring aggregate willingness to pay (aggregated in monetary units) without mentioning welfare weights at all, see e.g. Mitchell and Carson (1989), Tisdell (1991), Navrud (1992). Why are weights so absent in empirical work? I can think of several reasons. But since I have not succeeded in finding any evidence that these are view that are held by anybody, I am in danger of arguing against straw men.

Unweighted aggregation may be seen as the canonical approach. The introduction of weights will introduce some arbitrariness. In this note I have demonstrated that the choice of money as aggregation unit is as arbitrary. There are no generally applicable argument to favour money to environmental quality units as aggregation unit. And if unweighted aggregating seems less arbitrary, does that not make it more correct.

Another possible explanation of the absence of weighting is that the weighting may be seen as a small adjustment. Given the uncertainty of the data, it may not be worth undertaking. The empirical evidence presented in this note shows that such a view is not justified. The social cost of reduced emission from automobiles was reduced from 685 kroner to 31 kroner by a change in aggregation units. Moreover, I have demonstrated that the choice has huge influence on the relative strength of different interest groups.

A third explanation is acceptance of the view that distributional consequences should be undertaken with other instruments, especially taxes. Even though efficiency and distribution cannot be separated in theory, if may be thought that is it wise for practical purposes to keep them apart. In this note I have pointed out that distributional problems remain even if all had the same income. Individuals with different taste will prefer different social states, and one particular choice of valuation principle will favour groups with particular types of preferences.

Finally remember that the theory of cost benefit analysis, even *with* welfare weights, depends upon welfarism and interpersonal comparable utility. For policy-makers who subscribes to a rights-based moral philosophy, calculations based upon a welfaristic fundation will anyhow be of limited importance. Furthermore, even the possibly of interpersonal comparison of utilities may be questioned, see Pollak (1991). Given the problems with such welfaristic based calculations, perhaps the debate about the environmental consequences of different policies would be better served with other indicators instead of "values" or "prices"?

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