What is the benefit of a good environment?

Some empirical examples

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Cost-benefit analysis is a method whereby the advantages and disadvantages of public projects are compared by measuring all effects in money terms. It turns out, however, that the interests of some groups are given greater emphasis in the analysis when individual utility changes are measured in monetary units and then aggregated than would have been the case if another numéraire had been chosen for aggregation. On the basis of the data from seven contingent valuation studies, we have estimated the value of social benefits of some environmental projects, and studied whether these values change if we measure individual utility changes in units of the environmental good instead of money. The result is some considerable changes in social benefit estimates .

Public projects and conflicts of interest

Public projects in order to improve the environment will normally entail economic costs, which in some way or another must be distributed. In general, it is virtually impossible to ensure that the costs are distributed in such a way that those who derive the greatest benefit from an environmental measure are also those who pay the most for it. There will therefore often be conflicts of interest associated with public projects of this type. A rich, asthmatic environmentalist can, for example, derive considerable benefit from a measure to improve air quality even after having paid her share of the costs, while a healthy, poor person who is not particularly interested in the environment may find that the costs she has to pay are far from compensated by the environmental improvement.

Cost-benefit analysis is a method used to compare the advantages and disadvantages of public projects (see NOU 1997:27 and NOU 1998:16). In order to be able to compare the different effects, attempts are made to measure the importance of each effect in a common unit, in practice money. These amounts are then used to estimate to what extent the total social benefits of a project are greater than the costs. The principles used in the valuation naturally have a bearing on the conclusions reached. In order to place a value on effects that do not have a market price, for example changes in the environment, a sample of the population is often asked the maximum that they would be willing to pay in order to achieve (or avoid) the change. Willingness to pay is interpreted as a measure of the individual's utility of the environmental change, and the sum of all individuals' willingness to pay is interpreted as a measure of social welfare. If total benefits exceed total costs, it is often said that the project is socially efficient, or socially desirable. For such a project, those who have a net benefit can theoretically provide financial compensation to all those are worse off than previously, and still have a net benefit. In practice, however, it is very difficult to carry out this compensation. As a rule, socially desirable projects will also therefore involve conflicts of interest. Some will have a net benefit when the project is implemented, while others will view it as a disadvantage. In textbooks on cost-benefit analysis it has traditionally been maintained that the choice of money as the numéraire in cost-benefit analysis does not matter; all the effects could just as well have been measured in decibels or in grams of sulphur per cubic metre. The use of money as the numéraire has been based on practical considerations, but it has been thought that other units of measurement would have yielded exactly the same conclusion in terms of social desirability. Research in Statistics Norway, however, has shown that if there are conflicts of interest associated with a project, this is not always true. In an article published in the highly respected Journal of Public Economics in 1997, Kjell Arne Brekke showed that the choice of numéraire does indeed matter in cost-benefit analyses because the numéraire plays a role in determining the interests that are given more emphasis when individual welfare effects are aggregated.[1] The article was primarily theoretical, but also contained an empirical example based on a willingness to pay study for

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1 If financial compensation to those do not benefit from a project is actually carried out, a positive aggregate net willingness to pay will mean that everyone is better off than before. In that case there is no conflict of interest and the problem discussed here will be eliminated. Because such compensation is seldom implemented, we will disregard this possibility in the following.

cleaner air carried out by Strand (1985). In the example, Brekke found that the social value of a 50 per cent improvement in the quality of Oslo air was 22 times higher when money was used as the numéraire than if air quality had been used as the numéraire when aggregating individual utility, but then converting the total welfare effect to monetary units.

Compared with the traditional alternative, that of using money as the numéraire, the use of environmental units as the numéraire involves a different weighting of interests. Using money as the numéraire favours environmentalists who value money the least; using environmental units favours those who, in relative terms, value money the most, either because they are materialistic or because they are poor. If everybody is the equale, and are in agreement about most things, the difference is eliminated. The numéraire problem is essentially linked to the fact that when we are different, and have different interests, it is not easy to find a “neutral” basis for evaluating which interests are most important. A seemingly “technical” problem therefore turns out in this case to have politically interesting implications.

Brekke’s article spurred a debate in economic circles (see Drèze 1998, Johansson 1998), but the discussion was primarily focused on the interpretation of the analysis. So far the validity of the main theoretical result has not been questioned: Aggregating individual net utility measured in money terms can result in a total sum with a different sign than would have been obtained by aggregating individual utility measured in (e.g.) units of an environmental good, ceteris paribus. Despite this, we are not yet aware of any published articles in which attempts are made to determine the empirical importance of the result: How important is this really? Is Brekke’s example typical or will the problem normally be of only marginal importance?

In this article we present empirical calculations which show that in practice the problem can be considerable. The analysis below is based on Medin, Nyborg and Bateman (1998) and Medin (1999). We refer to these publications for a more detailed description of the assumptions and methods. We have used individual willingness to pay data from seven different contingent valuation studies as a basis for our analysis. The social benefit of the environmental change in each project (without deducting costs) is calculated on the basis of two main methods: either by using money or by using units of the environmental good as the numéraire when aggregating individual utility changes, but then converting the total figures to NOK in order to be able to compare the results. For some of the projects we have also calculated their social desirability after costs have been deducted, and in several alternatives a change in the numéraire means that the estimated social desirability of the entire project changes sign.

Comparison of utility: Measurement and measurability

In this section we will briefly explain the main features of the theory concerning the importance of the numéraire. Readers who are interested in a mathematical presentation are referred to the appendix, while more details may be found in Brekke (1997), Medin, Nyborg and Bateman (1998) and Medin (1999).

Individual willingness to pay is depicted in economic literature as a method of measuring individual utility changes. If Hansen is willing to pay NOK 100 for 50 per cent cleaner air, but only NOK 20 for preserving the river of Sauda, it must be because the first is more important to him. However, there is no basis for comparing this utility measure between individuals. Even though Hansen is willing to pay NOK 100 for cleaner air, while Jensen is only willing to pay NOK 50 for the same, it is not certain that Hansen has a greater benefit from cleaner air than Jensen. It may be the case, for example, that Jensen is so poor that he cannot afford more than NOK 50, while Hansen is so rich that money matters very little to him. If, for example, they both have to pay NOK 70 to have the measure implemented, Hansen will have a positive net willingness to pay of NOK 30, while Jensen will have a net loss corresponding to NOK 20. But if money is not as important to both of them, it is still conceivable that Jensen’s utility loss is greater than Hansen’s utility benefit – if it is to be at all meaningful to compare utility in this way.

If cost-benefit analysis is to be used to weigh someone’s loss against another’s benefit, however, interpersonal comparison of utility changes is unavoidable. This problem is usually solved by simply assuming that everybody has the same marginal utility of income.[2] Willingness to pay is then a comparable measure of utility changes, and those with the highest willingness to pay also have the highest welfare effect. The net social benefit of an environmental measure, i.e. the social welfare effect of a better environment minus costs, may then be calculated simply by aggregating net willingness to pay (individual willingness to pay for the environmental improvement minus the individual’s share of the costs) for all individuals. (We obtain exactly the same result when we instead aggregate individual willingness to pay for the environmental improvement and then deduct total costs.)

In practice, it is extremely difficult to estimate the willingness to pay for environmental goods. The replies given are often largely influenced by details in the formulation of questions, it may be difficult to know how the respondents

2 Strictly speaking, it must be assumed that the social welfare effect is the same when any individual is given an additional unit of income. In this analysis we assume that those making decisions in society place the same emphasis on marginal utility changes for each individual (utilitarianism). Applying this assumption, there is no distinction between equal individual and social utility of income. The assumption concerning utilitarianism simplifies the analysis, but is not necessary for the reasoning.

have interpreted the willingness to pay question, and strategic responses may also appear. In this article we entirely disregard these problems, and assume that both willingness to pay for the environmental improvement and the total costs are known. In the following we will assume, for the sake of simplicity, that costs are shared equally among everyone.[3]

The simple procedure above, where utility changes are measured in money terns, is the one most commonly used in cost-benefit analysis. In order to allow the sum of net willingness to pay to be interpreted as a measure of the change in total social benefits, however, everyone must have the same marginal utility of income. But what if this does not hold true? If small changes in income actually matter very little to Hansen, but a great deal to Jensen, we will unintentionally place too great an emphasis on Hansen's interests by merely aggregating willingness to pay. An example may explain this: Assume, as in the example above, that a project for improving air quality will result in a higher tax of NOK 70 for both, and that Hansen's and Jensens's willingness to pay for cleaner air is, respectively, NOK 100 and NOK 50, so that their net willingness to pay is, respecively, 30 and minus NOK 20. Assume further that an extra krone will give Hansen and Jensen 1 and 2 utility units, respectively. This implies that the project will yield a net benefit of 30 utility units for Hansen, who is not particularly concerned about money. Money, however, means twice as much to Jensen, so for him a loss of NOK 20 corresponds to a utility loss of 40 utility units. The total net benefit is thus negative. If, however, we (incorrectly) assume that both have the same marginal utility of income, and use the sum of net willingness to pay as a measure of social welfare, we will conclude that the project is socially desirable because the sum of the willingness to pay was positive.

There is no generally accepted method for comparing the utility effect of increases in marginal income empirically, and it is therefore difficult to confirm or reject the assumption of equal marginal utility of income. We can, however, examine how sensitive the estimate for total net benefits is to changes in this assumption. We could, for example, replace this with a seemingly very similar assumption, i.e. that everybody has the same marginal utility of the environmental good. Under this assumption, different willingness to pay will be solely due to the fact that money is valued highly by some, but is of less importance to others. With equal marginal utility of income, on the other hand, all differences in willingness to pay must be ascribed to differing marginal utility of the environmental good. The assumption that everybody has the same marginal utility of the environmental good is as difficult to test as the assumption of equal marginal utility of income, but it might be interesting to see whether this influences the conclusions.

Let us now define a project as socially desirable measured in environmental units if the sum of individual net benefits, measured in environmental units, is positive. Assume that the project from the example above will result in an improvement in air quality of 50 per cent. We could now have asked Hansen and Jensen: "How much cleaner air must you have before you would be willing to pay NOK 70?" Call the answer to this question the individual's public good requirement, in this case an environmental good. Hansen, who recorded a positive benefit from the project, reports a public good requirement of 35 per cent. We can call the difference between the actual environmental improvement (50 per cent) and the public good requirement (35 per cent) his net environmental benefit, and here this will be 15 per cent.[4] This figure can be interpreted as a measure of his net benefit. Jensen, who does not think the improvement in air quality justifies the cost of NOK 70 reports a public good requirement of as much as 70 per cent, and thus records a negative net environmental benefit, i.e. minus 20 per cent. If both actually have the same marginal utility of an environmental good, we can find the total net social benefit simply by aggregating net environmental benefits. This will then be 15+(-20) = -5. When we measure individual utility in environmental units, we then obtain the result that the project is not socially desirable.

If everybody actually has the same marginal utility of income, individual utility changes shall be measured in money terms, and aggregation in monetary units will provide the correct answer. If everybody actually has same marginal utility of an environmental good, the environment good shall be used as the numéraire when measuring individual utility, and aggregation of net environmental benefits will provide the correct answer. However, if we assume that everybody has the same marginal utility of income, but this does not hold true, those with a high willingness to pay for environmental goods will be given too high a weight in the analysis. If we assume that everybody has the same marginal utility of the environmental good, but this is actually not the case, those with a low willingness to pay will be given too high a weight in the analysis. The truth is probably somewhere in between, but where we do not know. It is obvious, however, that the choice of method has implications for which group interests are given the greatest emphasis in the analysis. In general, we will primarily favour the interests of a person when the numéraire is of relatively little value to that person (see Brekke 1997).

The two measures above do not provide directly comparable measures of total utility changes since they are measured in different units. However, we can compare them by examining the maximum per person cost that would make the project socially desirable.[5] The choice of numéraire will in this context correspond to the choice of assumption

3 Other ways of distributing costs may change the results. See Medin (1999) and Brekke (1993).
4 Net environmental benefit can be deducted from individual willingness to pay, so in practice it is not necessayr to ask new questions if such data already exist.
5 See the appendix for a formal presentation.

of marginal utility, i.e. whether we assume that the marginal utility of income or the marginal utility of the environmental good is the same for everybody. If a project is to result in exactly zero net benefits with money as the numéraire (i.e. if everybody has the same marginal utility of income), the per person cost must be equal to average willingness to pay for the environmental improvement. Call this per person cost C*. Let us further denote C** as the per person cost that results in exactly zero net benefits when the environmental good is used as numéraire, i.e. when it is assumed that everybody has the same marginal utility of the environmental good.[6]

In order to compare the importance of this choice in practice, we shall in the next section study the size of C* in relation to C**. Both C* and C** are measured in monetary units, and both can be interpreted as a measure of the aggregate net welfare effect, but under different assumptions of individuals' marginal utility . We will call the ratio C*/C** the MAC ratio (for Maximum Acceptable Cost). If the MAC ratio is equal to 1, the choice of numéraire does not matter. If it is greater than 1, we will be able to accept higher per person costs if we use money as the numéraire than if we had measured utility changes in environmental units. When the MAC ratio is higher than 1, a given project, with given per person costs, will thus emerge as more desirable if we measure in monetary units than if we measure in environmental units.

Generally, the MAC ratio will always be higher or equal to 1 when costs are shared equally between individuals. If costs are distributed in other ways, there may be other groups that are better off or worse off as a result of the project, and we have other conflicts of interest. Because the importance of the numéraire is linked to different weighting of interests, this may result in different MAC ratios. See Brekke (1993) and Medin (1999) for further details concerning this.

Data and method

The studies used

We have used willingness to pay (WTP) data from seven contingent valuation studies with a total of 18 subsamples: Bateman et al. (1995), Bateman and Langford (1997), Bateman et al. (1997), Loomis (1987), Magnussen et al. (1997), Navrud (1993) and Strand and Wahl (1997).[7] In these studies, the social benefits of various environmental projects were estimated by asking a sample of the population about their willingness to pay for the projects and then aggregating individual willingness to pay. We have converted individual willingness to pay to individual public good requirements and then calculated the MAC ratio for each sample.[8]

Bateman et al. (1995) studied annual WTP to prevent flooding of a wetland area in East Anglia in Britain (Norfolk Broads). This is the largest of the studies used, with two subsamples of 846 and 2 051 completed interviews, respectively. Bateman and Langford (1997) studied WTP for conservation of the recreational facilities at Lynford Stag, a woodland site within the Thetford Forest in East Anglia. Bateman et al. (1997) estimated WTP for a beach protecting scheme at Caister, a coastal village in East Anglia.

Loomis (1987) is based on a study carried out in 1985. The study measured WTP for a reduction in the diversion rate of Mono Lake, one of California's largest lakes.

We have also used data from several Norwegian studies. Magnussen et al. (1997) examined annual WTP for increased environmental quality of two polluted watercourses: Gaustadvannet/Ånøyavassdraget in Melhus municipality (subsamples M1 and M2) and Langenvassdraget in Ski municipality (subsamples S1 and S2). Navrud (1993) measured WTP for maintaining the fish stock in the municipalities of Lindesnes and Adnedal in Vest-Agder county, while Strand and Wahl (1997) measured WTP for preventing a reduction in Oslo's municipal parks.

Interpretation of zero-bids

In calculations of aggregate willingness to pay (in money), just a few respondents with an unusually high willingness to pay may have a very considerable influence on the results. It is often assumed that such responses do not reflect the respondent's actual willingness to pay, but is e.g. an indication of strategic behaviour or a protest reaction to the willingness to pay question. A common approach in traditional cost-benefit analysis is therefore to omit them from the data set.

When the MAC ratios and thereby public good requirements are to be calculated, a similar problem arises for those respondents who report zero as their maximum willingness to pay (zero-bid). This respondent is not willing to pay anything for seeing the project implemented. Any minimal cost we force her to pay will therefore mean that she is worse off after the project has been implemented than before. If we interpret the zero-bid literally, i.e. that each environmental unit is worth nothing in money terms to this person, the reverse must also be true, i.e. each krone must be worth an infinite number of environmental units. The social welfare loss measured in environmental units caused by forcing this person to pay part of the costs of a project will therefore be infinite.

The change in net social welfare measured in environmental units will therefore also be an infinite and large negative figure, and no acceptable per person cost will exist. If

6 It can be shown (see appendix) that C** is equal to the inverse of the average of inverse willingness to pay.
7 See Medin, Nyborg and Bateman (1998) for a description of the various subsamples and discussion of possible methodological problems in using data from these studies.
8 See appendix.

Tabele 1. MAC ratios under different assumptions on zero-bids. Costs shared equally

Survey	N	Zero-bids in per cent of N	MAC ratio Version 1	Version 2	Version 3
Bateman et al. (1995)					
Subsample 1	846	15	20 202	1 036	38
Subsample 2	2 051	15	22 434	1 129	11
Bateman og Langford (1997)					
Subsample 1	93	37	8 647	459	70
Subsample 2	90	63	378	20	6,7
Subsample 3	88	6,8	93	9,0	5,2
Subsample 4	80	16	5 894	350	83
Bateman et al. (1997)					
Subsample 1	143	18	11 598	687	169
Subsample 2	126	10	18 003	1 135	307
Loomis (1987)	78	17	82	6,3	3,2
Magnussen et al. (1997)					
Subsample M1	143	60	101	5,9	3,1
Subsample M2	139	59	34	2,4	2,1
Subsample S 1	139	47	97	5,9	2,9
Subsample S2	132	49	87	5,2	2,3
Navrud (1993)	161	32	806	42	4,2
Strand og Wahl (1997)					
Subsample 1	140	14	23	2,5	1,8
Subsample 2	140	13	30	2,8	1,8
Subsample 3	138	28	60	4,0	1,8
Subsample 4	145	21	69	4,9	2,3

N = Number of respondents
MAC ratio = Maximum acceptable per person cost that makes the project socially desirable when individual utility is measured in monetary units divided by maximum acceptable per person cost that makes the project desirable when individual utility is measured in units of the environmental good.
Version 1 = Zero-bids are set equal to 5 per cent of the lowest strictly positive bid in the survey.
Zero-bids are set equal to the lowest strictly positive bid in the survey.
Zero-bids are removed from the data set.

a valuation study contains at least one zero-bid, the project will never be socially desirable when environmental units are used as the numéraire for individual utility (!), given that the project results in a positive cost, and the MAC ratio is then not defined. If at least one respondent's willingness to pay approaches zero, the MAC ratio will go to infinity. The choice of numéraire is therefore extremely important.

However, one possible interpretation is that zero-bidders have a positive but very small willingness to pay. We have therefore calculated the MAC ratio using three different (somewhat arbitrarily selected) assumptions concerning zero-bids. Versions 1 and 2 are calculated on the assumption that zero-bidders actually have a low, but positive WTP, i.e. 5 per cent (version 1) and 100 per cent (version 2), respectively, of the lowest strictly positive bid reported. In version 3, all zero-bids are omitted from the data set, which is equivalent to assuming that zero-bids actually should have been distributed in the same way as WTP in the rest of the sample. As noted above, the MAC ratio goes to infinity when at least one bid approaches zero. Version 3 is therefore the most conservative one in our study as we have omitted all of the lowest bids from the data.[9]

Empirical results

The empirical results of our study are shown in table 1. The first column shows the number of observations in each study (after removing "don't know" bids, but before zero-bids are eliminated). The second column shows the percentage of zero-bids in the sample. The third to fifth columns show versions 1, 2 and 3, respectively, of the MAC ratio in the various surveys.

9 Those who do not reply to the WTP question or say they don't know are often omitted from the data set in valuation studies or it is assumed that their WTP is equal to zero. The latter method is often used in order to avoid overestimating average WTP (see e.g. Navrud 1993, p. 22). Since WTP close to zero has a considerable effect on the problem that is being studied here, we have removed "don't know" responses from the data set when possible. This is equivalent to assuming that actual WTP for these respondents is distributed in the same way as the rest of the sample.

Tabell 2. Estimated average costs and gross benefit estimates from different valuation studies. All figures in NOK, except for results from Loomis (1987), which are shown in USD

	Costs	Gross benefit estimates (Costs not deducted)			
	C	Average willingness to pay	C** Version 1	C** Version 2	C** Version 3
Loomis (1987)	0.16	4.8	0.06	0.77	1.8
Magnussen m.fl. (1997), subsample S1	341 - 455	870	11	183	668
Magnussen m.fl. (1997), subsample S2	341 - 455	1 030	10	179	759
Navrud (1993), calculation A	116	670	1	17	252
Navrud (1993), calculation B	201	2 186	3	57	824
Strand og Wahl (1997), subsample 1	0.18 - 0,36	0.63	0.03	0.26	0.41
Strand og Wahl (1997), subsample 2	0.18 - 0,36	0.81	0.03	0.31	0.55
Strand og Wahl (1997), subsample 3	0.18 - 0,36	0.44	0.01	0.11	0.33
Strand og Wahl (1997), subsample 4	0.18 - 0,36	0.66	0.01	0.13	0.35

C = monthly (Loomis), annual (Magnussen et al., Strand and Wahl) or present value of (Navrud) per household costs (per person in Navrud's data).
Average willingness to pay = monthly (Loomis), annual (Magnussen et al., Strand and Wahl) or present value (Navrud) of average per household willingness to pay (per person in Navrud's data).
C** versions 1, 2 and 3 = maximum acceptable per household cost (Navrud: per person) calculated on the assumption of equal marginal utility of the environmental good; monthly (Loomis), annual (Magnussen et al., Strand and Wahl) or present value (Navrud). See footnote under table 1.

Version 3 of the MAC ratio, in which all zero-bids are omitted from the data, shows values varying between approximately 2 [all subsamples in Strand and Wahl (1997) and subsample S2 in Magnussen et al. (1997)] and 307 [subsample 2 in Bateman et al. (1997)]. Even the smallest MAC ratios thus indicate that the choice of numéraire is of considerable importance. A MAC ratio of 2 indicates that using environmental units as the numéraire instead of money halves the maximum acceptable cost which leaves the project socially desirable. In the study with the highest MAC ratio, the maximum acceptable per person cost varies with a factor of up to 307 if we assume equal marginal utility of the environmental good or equal marginal utility of income.

Versions 1 and 2 of the MAC ratio show ratios that are considerably higher than version 3. In version 2, the MAC ratio varies between 1 135 [subsample 2 in Batemal et al. (1997)] and 2.5 [subsample 1 in Strand and Wahl (1997)], while in version 2 it varies between 22 434 [subsample 2 in Bateman et al. (1995)] and 23 [subsample 1 in Strand and Wahl (1997)]. The results confirm that the MAC ratio is very sensitive to how we interpret zero-bids.

The second column shows that zero-bids account for a relatively high percentage of the samples. One reason for high MAC ratios may be considerable differences between reported WTP replies. The MAC ratios in Bateman et al. (1995), Bateman et al. (1997) and subsamples 1 and 4 in Bateman and Langford (1997) are considerably higher than those of the other surveys. In all of the three abovementioned surveys, the lowest strictly positive WTP bid is very low in relation to the highest bid. In subsample 2 in Bateman et al. (1995), for example, the highest bid reported was £2 500, while the lowest strictly positive bid was £0.01 (a pence). With such data the net benefit of the person with the highest WTP is actually weighted 250.000 times more than the net benefit of the person with the lowest WTP when money is used as the numéraire, compared with the procedure of using environmental units as the numéraire. In subsample 1 in Strand and Wahl (1997), which is one of the samples with the lowest MAC ratios, the ratio between the highest and lowest bid is only 50. A considerable difference between the highest and lowest bid is a good indication of high MAC ratios even though the relationship is not clear-cut.

We have also made calculations where all zero-bids are removed, and where we also eliminate one very extreme (high or low) bid. Generally, the MAC ratio changes more if we remove the lowest strictly positive bid than if we omit the highest bid. In subsample 2 in Bateman et al. (1995), the MAC ratio was actually almost halved by removing a very low bid despite a sample size of nearly 2000 observations. One reason that some very low bids can have such a large influence on the results is that discussed in the section above: When a bid approaches zero, C** also approaches zero, and the MAC ratio goes to infinity.

Social desirability

In order to be able to calculate the social desirability of an environmental project, it is also necessary to know the costs in addition to willingness to pay. If we assume that everybody must actually pay the same cost C, the criterion for social desirability will be C* when we measure individual utility in money terms, and C** when individual utility is measured in environmental units.

Four of the studies we have examined contain cost estimates: Loomis (1987), subsamples S1 and S2 in Magnussen et al. (1997), Navrud (1993) and Strand and Wahl (1997). Let us therefore investigate whether the conclusions concerning social desirability change if we change the numéraire. When calculating C**, we need information not only about total costs, but also about the distribution of costs. In order to simplify the calculations we assume that the costs of the project would have been shared equally so that everybody pays the same amount.[10] In the same way as for the MAC ratio we have calculated three different versions of C**, the maximum per person cost that leaves the project socially desirable when we use environmental units.[11]

When using the traditional method for calculating the change in net social benefits as a result of the project, i.e. by assuming that everybody has the same marginal utility of income, all projects were found to be socially desirable. In most cases the conclusions did not change by using the most conservative version of C** (version 3, i.e. the version where all zero-bids are removed). On the other hand, when the most extreme version is used (version 1), the conclusion changes in all the studies. For version 2, the results vary from sample to sample. Table 2 below shows the estimated per household or per person costs, the estimate for average WTP, and the three versions of the alternative benefit estimate C** from each of the four CV studies.

For the data presented in Loomis (1997), the alternative benefit estimates are greater than per household costs in all cases except when we use version 1 of C**. The conclusion concerning this project's social desirability is thus changed only when we apply our most extreme treatment of zero-bids.

The costs of the project studied by Magnussen et al. (1997) were uncertain, but were estimated at between NOK 341 and 445 per household. When we measure individual utility in environmental units, the project remains desirable when we use version 3 of C**, i.e. when all zero-bids are removed from the data. However, when we use versions 1 and 2 of C**, the conclusion concerning social desirability changes in both subsamples.

In Navrud (1993), the present value of the change in social welfare as a result of the project is calculated using different assumptions concerning social discount rates, the time horizon, and estimates of the increase in the relative value of the environmental good. Altogether 12 cost-benefit calculations were made. All methods of calculation concluded that the project was socially desirable. In the table, we show per person costs, average WTP, and versions 1, 2 and 3 of C** calculated at present values. Calculation A corresponds to the method used by Navrud (1993) which gave the lowest social present value of the project, with a time horizon of 10 years, an annual discount rate of 7 per cent, and no increase in the relative value of the environmental good. Calculation B corresponds to Navrud's alternative that gave the highest net present value, with a discount rate of 5 per cent, a time horizon of 30 years and an annual 2 per cent increase in the relative value of the environmental good. The conclusion concerning the project's social desirability does not change either in A or B when version 3 of C** is used. However, when using versions 1 or 2 of C**, the present value of per person costs is greater than the present value of the welfare estimates in both A and B, and the project can therefore no longer be considered socially desirable.

In Strand and Wahl (1987), the estimate of actual costs (C) depends on whether a discount rate of 7 per cent (C=0.35) or 3.5 per cent (C=0.18) is used. The conclusion concerning the project's social desirability changes for all subsamples and both discount rates when we use version 1 of C**. When using version 2 of C**, the conclusion changes for subsamples 3 and 4, while the conclusion will depend on the discount rate for the other two samples. For version 3 of C**, the project is socially desirable for subsamples 1 and 2. For subsamples 3 and 4, the project is desirable if, when calculating the costs, a discount rate of 3.5 per cent is used, but not if the discount rate is set at 7 per cent.

Conclusions

In order to weight the advantages of public projects against the disadvantages we must be able to compare different individuals' utility changes. Economic theory provides little guidance on this subject. In cost-benefit analysis, however, it is common to assume equal marginal utility of income. If this assumption is correct, we can use the sum of all individuals' net willingness to pay, i.e. the sum of changes in individual utility measured in money terms as a measure of the effect of the environmental change on social welfare.

In this article we have studied the consequences of replacing the assumption above with another, seemingly similar assumption, notably equal marginal utility of an environmental good. Using this assumption we can measure social welfare as the sum of all individuals' utility, measured in units of environmental goods. These two alternative assumptions will entail a systematically different emphasis on the interests of some groups (Brekke, 1997): Those who have a high willingness to pay for the environmental good will be relatively best off with the first assumption, which corresponds to common practice in cost-benefit analysis.

Our analysis shows that the estimates of the net social welfare effect of an environmental project can be very sensitive to the assumption chosen. The results, however, are highly dependent on how one treats respondents who report that they are not willing to pay anything at all to achieve an environmental change. In contingent valuation studies there are as a rule many such respondents, and if these replies are interpreted literally this has an extreme impact on the results when equal marginal utility of the environmental good is assumed.

The assumptions of equal marginal utility of income and equal marginal utility of the environmental good are probably both unreasonable. Nor has the point of this study been to argue that one assumption or the other is the correct one.

10 Distributing costs differently might have resulted in different conclusions concerning the projects' desirability.

11 In C** versions 1 and 2, all zero-bids are assumed to correspond to 5 and 100 per cent, respectively, of the lowest strictly positive bid in the sample, while C** version 3 is estimated by removing all zero-bids from the data set.

Our purpose has rather been to point out that a comparison of interpersonal utility, as this is done in cost-benefit analysis, is far from being a trivial matter. The choice of method may have decisive consequences for which interest groups are given the greatest emphasis, and thereby unintentionally favouring some groups instead of others.

In applied cost-benefit analysis it is individual willingness to pay that is aggregated. Against the background of the analysis above, it is important to be aware that aggregate willingness to pay is not the same as aggregate utility. We simply do not know whether total net willingness to pay is a reasonable measure of total utility or not. At this time economic research is not able to give us a complete answer to this question, and a solid portion of sound judgement will therefore still be necessary in order to be able to interpret the results of a cost-benefit analysis.

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Appendix

Mathematical presentation of the importance of the numéraire in the valuation of environmental goods

Assume a consumer i with the following utility function, where E is an environmental good and Y_i is the consumer's income:

$$U_i = u_i(E, Y_i) \tag{A1}$$

The increase in E as a result of the project is marginal and equal to dE. (See Medin et al., 1998, for a discussion of the case with non-marginal projects). The cost person i must pay as a result of the project, C, is the same for everybody. The individual's utility change as a result of the project will then yield

$$dU_i = u_{iE}dE - u_{iY}C \tag{A2}$$

where u_{iE} and u_{iY} are, respectively, the marginal utility of the environmental good and income. We divide by the marginal utility of income and find that the utility change is proportional to net willingness to pay:

(A3) $dU_i / u_{iY} = (u_{iE} / u_{iY})dE - C$

where the expression in brackets is i's marginal willingness to pay for the environmental good. (A3) can be interpreted as a monetary measure of the consumer's utility change.

Alternatively, we can divide dU_i by the marginal utility of the environmental good, and then find that the utility change is proportional to net environmental benefits, i.e. the environmental improvement actually experienced by the consumer (dE) less the cost she must pay (C) weighted by the consumer's valuation of income in relation to the environment (u_{iY}/u_{iE}), the inverse of the consumer's marginal willingness to pay:

(A4) $dU_i / u_{iE} = dE - (u_{iY} / u_{iE})C$

This can be considered a measure of the individual's net benefit, measured in environmental units. We see that if we know the individual's willingness to pay for a marginal unit of the environmental good (u_{iY}/u_{iE}), as well as dE and C, we can calculate both utility measures.

Assume for the sake of simplicity that we want to give the same weight to everybody's interests, i.e. we have a utilitarian welfare function:

(A5) $$W = \sum_{i=1}^{n} U_i$$

where W is social welfare. We shall now calculate the change in social welfare as a result of the project:

(A6) $$dW = \sum_{i=1}^{n} dU_i = \sum_{i=1}^{n} (u_{iE}dE - u_{iY}C)$$

However, we have no information about u_{iY} or u_{iE}. But if we assume that everybody has the same marginal utility of income, i.e. $u_{iY}=u_Y$, we can divide both sides of the equal sign by this, and then have

(A7) $$\frac{dW}{u_Y} = \sum_{i=1}^{n} [(u_{iE}/u_Y)\, dE - C]$$

This is aggregate net willingness to pay, which traditionally has been used as a welfare measure in cost-benefit analysis, i.e. the measure of changes in social welfare we obtain by aggregating individual willingness to pay measured in money terms. As we see, this welfare measure presupposes that everybody has the same marginal utility of income.

Alternatively, we can assume that everybody has the same marginal utility of the environmental good, i.e. $u_{iE}=u_E$, and divide both sides of (A6) by this. We then have

(A8) $$\frac{dW}{u_E} = \sum_{i=1}^{n} [dE - (u_{iY}/u_E)C]$$

This is the sum of individual net environmental benefits, and corresponds to what we obtain when we aggregate individuals' valuation of the project measured in environmental units. This procedure thus presupposes that everybody has the same marginal utility of the environmental good.

The two welfare measures we have derived are not directly comparable because they are measured in different units. We can, however, compare them indirectly by using for each welfare measure the highest acceptable per person cost, given that the project shall be socially desirable (Brekke 1997; Medin, Nyborg and Bateman 1998). The per person cost (C) that gives exactly $dW/u_Y=0$ we can call C*. From equation (A7) we then have

(A9) $$C^* = \frac{1}{n} \left(\sum_{i=1}^{n} \frac{u_{iE}}{u_{iY}}\right) dE$$

We see that C* is equal to average willingness to pay. If the per person cost is greater than the average willingness to pay, the project will then not be desirable when we measure individual utility in monetary units.

The per person cost that gives exactly $dW/u_E=0$ we will call C**. We then have from equation (A8) that

(A10) $$C^{**} = \frac{n}{\left(\sum_{i=1}^{n} \frac{u_{iY}}{u_{iE}}\right)} dE$$

As we see, C** is equal to the inverse of the average inverse willingness to pay. If the per person cost is higher than this, the project will not be desirable when we measure individual utility in environmental units.

The importance of choice of numéraire can be analyzed with the help of the ratio of C* to C**. Call this ratio the MAC ratio (Maximum Acceptable Cost):

(A11) MAC-brøken = $$\frac{C^*}{C^{**}} = \frac{1}{n^2} \left(\sum_{i=1}^{n} \frac{u_{iE}}{u_{iY}}\right) \cdot \left(\sum_{i=1}^{n} \frac{u_{iY}}{u_{iE}}\right)$$

If C*>C**, the MAC ratio will be greater than 1. Then, we can accept higher per person costs when we measure individual utility in monetary units than when we use environmental units as the aggregation unit.