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Using the budget constraint to monetarise impact assessment results

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ABSTRACT

Recent developments in Life Cycle Impact Assessment (LCIA) provide a basis for reducing the uncertainty in monetarisation of environmental impacts. The LCIA method "Ecoindicator99" provides impact pathways ending in a physical score for each of the three safeguard subjects humans, ecosystems, and resources. We redefine these damage categories so that they can be measured in terms of Quality Adjusted Life Years (QALYs) for impacts on human well-being, Biodiversity Adjusted Hectare Years (BAHYs) for impacts on ecosystems, and monetary units for impacts on resource productivity.

The monetary value of a QALY can be derived from the budget constraint, i.e. the fact that the average annual income is the maximum that an average person can pay for an additional life year. Since a QALY by definition is a life-year lived at full well-being, the budget constraint can be determined as the potential annual economic production per capita at full well-being. We determine this to be 74,000 EUR with an uncertainty estimate of 62,000 to 84,000 EUR. This corresponds well to the 74,627 EUR willingness-to-pay estimate of the ExternE project. Differences to other estimates can be explained by inherent biases in the valuation approaches used to derive these estimates.

The value of ecosystems can be expressed in monetary terms or in terms of QALYs, as the share of our well-being that we are willing to sacrifice to protect the ecosystems. While this trade-off should preferably be done by choice modelling, only one such study was found at the level of abstraction that allows us to relate BAHYs to QALYs or monetary units. Stressing the necessity for such studies, we resort to suggest a temporary proxy value of 1400 EUR/BAHY (or 52 BAHY/QALY), with an uncertainty range of 350 to 3500 EUR/BAHY.

The practical consequences of the above-described monetarisation values has been investigated by combining them with the midpoint impact categories of two recent LCIA methods, thus providing a new LCIA method with the option of expressing results in both midpoints and an optional choice between QALY and monetary units as endpoint. From our application of the new method to different case studies, it is noteworthy that resource impacts obtain less emphasis than in previous LCIA methods, while impacts on ecosystems obtain more importance. This shows the significance of being able to express impacts on resources and ecosystems in the same units as impacts on human well-being.

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1. Introduction

The applicability of cost-benefit assessments (CBA) is affected by the high uncertainty in relation to monetarisation of environmental impacts (see e.g. Turner et al., 2004). CBA has also been criticised for incompleteness (see e.g. Bos and Vleugel, 2005). Recent developments in Life Cycle Impact Assessment (LCIA) offer a basis for reducing both the uncertainty in monetarisation and the completeness problem.

The UNEP/SETAC framework for LCIA (Jolliet et al., 2004) operates with three overall safeguard subjects (humans, ecosystems, resources), fundamentally parallel to the "People, Planet, Profit" distinction for sustainability made popular by WBCSD (World Business Council for Sustainable Development). Since the three safeguard subjects are logically exhaustive (any item must be either human or non-human, biotic or abiotic, intrinsic or instrumental), they provide a complete framework for all imaginable values for protection.

The LCIA method "Ecoindicator99" (Goedkoop and Spriensma, 2001) was the first to provide impact pathways that ended at a physical score for each of the three safeguard subjects humans, ecosystems, and resources. In the following, we shall elaborate a novel procedure for monetarising these physical scores. The procedure is aimed at reducing some of the previously encountered uncertainty and incompleteness in monetarising environmental impacts.

2. Defining the damage categories

For each of the three safeguard subjects (humans, ecosystems, resources) we specify a common measurement unit. Our measurement units are slightly adjusted compared to the units for impact or damage applied in the "Ecoindicator99" (Goedkoop and Spriensma, 2001).

Within the safeguard subject "humans" we define the damage category as "Human well-being" with the measurement unit Quality Adjusted Life Year (QALY). This measurement unit is identical to the Disability Adjusted Life Year (DALY) used by Goedkoop and Spriensma (2001), except for a reversal of signs (QALY measures a positive state, while DALY measures damage, i.e. 1 QALY = −1 DALY) and that while the disability adjustment is limited to health issues, the quality adjustment may also apply to social aspects, such as infringements on autonomy and equal opportunities (Weidema, 2006). The reversal of sign is of little consequence and is mainly made to ensure consistency with the traditional definitions and usage of EUR and QALYs in previous work in the field of CBA and health economics. The most critical value choice in the DALY and QALY concepts is that all individuals are given equal weight irrespective of socio-economic status.

Within the safeguard subject "ecosystems", we define the damage category as "Biodiversity" with the measurement unit Biodiversity Adjusted Hectare Year (BAHY). This measurement unit is identical to the PDF m^2 years used by Goedkoop and Spriensma (2001), where PDF is an abbreviation of Potentially Disappeared Fraction of species, except for the more convenient size of the unit (1 ha = 10,000 m^2), a reversal of signs (BAHY measures a positive state, while PDF m^2 years measure damage, i.e. 1 BAHY = −10,000 PDF m^2 years), and that we specify the damage relative to the number of endemic species under natural conditions. It would be possible to define the damage category wider, e.g. in terms of Quality Adjusted Hectare Years, to capture also other aspects of ecosystems quality than just biodiversity. However, in practice, the currently available operational measures of ecosystems quality are all related to biodiversity, so a more encompassing name would be presumptuous. The most critical value choice in the PDF m^2 years and BAHY concepts is that all species are given equal weight.

In giving equal weight to all individuals or species, the QALY and BAHY concepts have a level of abstraction that may complicate their application for valuation in e.g. choice modelling, but at the same time gives them the level of neutrality required to reduce arbitrariness and uncertainty from specific contexts.

For the safeguard subject "resources" we define the damage category as "resource productivity" measured as the future economic output in monetary units. In practice, we use "EUR_{2003}", i.e. the currency unit Euro at its average value in year 2003. The conversion factor to USD is close to 1 for this year. To measure the impact of mineral resource use on future generations, Goedkoop and Spriensma (2001) used "MJ" additional energy required for future extraction as a result of current dissipation. However, dissipation of mineral resources is only a small part of the non-internalised impacts on resources caused by current human activities. Examples of much more important impacts are the lost production due to health impacts on the labour resource, and the lost agricultural output resulting from photochemical ozone impacts; see Table 3, the notes to Table 4, and Weidema et al. (submitted for publication). Since all losses of resource productivity, including the additional efforts needed for future extraction of mineral resources, can be measured directly as the economic production value foregone, it appears reasonable to use a monetary rather than a physical unit as the common unit of measurement.

3. Using the budget constraint to obtain the monetary value of a QALY

In this section, the monetary value of a QALY is derived from the overall budget constraint, and the resulting value compared to and discussed in the context of the results of other methods to derive the monetary value of a QALY.

The budget constraint, i.e. the fact that the average annual income is the maximum that an average person can pay for an additional life year, provides an upper limit for the monetary value of a QALY. Since a QALY by definition is a life-year lived at full well-being, the budget constraint can be determined as the potential average annual income at full well-being, which is equal to the potential annual economic production per capita.

Since a QALY conceptually covers all aspects of human well-being that one would be willing to pay for, all income will on average be spent on total production to maintain full well-being, providing that there is no long-term change in capital stock. Therefore, the potential average annual income at full