Journal of Cleaner Production 86 (2015) 170–179

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Review

Monetary valuation in Life Cycle Assessment: a review

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ARTICLE INFO

Article history:
Received 5 November 2013
Received in revised form
1 August 2014
Accepted 2 August 2014
Available online 19 August 2014

Keywords:
Monetary valuation
Externality
Life cycle assessment
Weighting

ABSTRACT

Monetary valuation is the practice of converting measures of social and biophysical impacts into monetary units and is used to determine the economic value of non-market goods, i.e. goods for which no market exists. It is applied in cost benefit analysis to enable the cross-comparison between different impacts and/or with other economic costs and benefits. For this reason, monetary valuation has a great potential to be applied also in Life Cycle Assessment (LCA), especially in the weighting phase. However, several challenges limit its diffusion in the field, which resulted in only a few applications so far. The authors have performed a review of different monetary valuation methods for use in LCA. Firstly, monetary valuation approaches, methods, and LCA applications were identified. Secondly, key features and the strengths and weaknesses of each monetary valuation method were determined. Finally, monetary valuation methods and LCA applications were evaluated according to a comprehensive set of criteria, ranging from scientific foundation to uncertainty and complexity. It was found that observed- and revealed-preference methods and the abatement cost method have limited applicability in LCA, whereas the choice experiment method and the budget constraint method are the best options for monetary valuation in LCA.

1. Introduction

Monetary valuation is the practice of converting measures of social and biophysical impacts into monetary units. This study focuses on the use of monetary valuation to determine the economic value of non-market goods, i.e. goods for which no market exists. Clean air or water, natural fish stocks, or rainforests are straightforward examples of non-market goods: it is relatively easy to identify, quantify, or measure them directly in physical units. Instead, non-market goods like human wellbeing or biodiversity do not have a direct physical counterpart and are therefore more "complicated" examples, in the sense that they are more "*difficult to disentangle and measure*" (Nunes and van den Bergh, 2001).

The Total Economic Value (TEV) of a non-market good is defined as the sum of its use and non-use values (Turner et al., 1994). The former is instrumental and includes both direct and indirect use values; the latter is intrinsic and includes both existence and bequest values. Natural resources (e.g. biomass, water) typically provide a direct instrumental utility to society, whereas ecosystem functions (e.g. carbon storage, flood control) provide an indirect one. Individuals may also value the pure existence of a non-market good without using it, its value for future generations, or for others (altruism). An "option" value can also be identified (either instrumental or intrinsic), an example being the value of genetic biodiversity for future medical purposes (Bachmann, 2011).

Monetary valuation is strictly related to the concept of externalities in welfare economics. Externalities are the unaccounted costs and benefits arising from economic activities of one agent, that impact on another (Pearce and Barbier, 2000). According to this definition, externalities can be divided into positive (benefits) and negative (costs, or external costs) when they constitute, respectively, a gain or loss of welfare. Externalities are typical examples of market failures. To correct market failures, and achieve what in economic terms is defined as the "optimal" resource allocation, externalities must be internalized, i.e. accounted for in the economic system (and hence reflected in the price of goods and services) and associated decision making. A key issue here is the quantification of externalities, and this is where monetary valuation becomes relevant.

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http://dx.doi.org/10.1016/j.jclepro.2014.08.007
0959-6526/

Ethical objections to monetary valuation stem from a position – commonly found in strong sustainability approaches – that some values are non-tradable and from the misunderstanding that monetary valuation can attach a monetary value to e.g. human life or biodiversity in absolute terms. However, the scope of monetary valuation is limited to estimating the value of small (marginal) changes in the availability of non-market goods. Changes in availability concern both changes in the amount and in the quality of a good and the service that it provides to society. What is measured is the individuals' Willingness To Pay (WTP) for avoiding the change (or willingness to accept compensation to consent the change). For example, monetary valuation does not seek to provide a measure of the absolute value of human life, but rather the value that individuals are willing to pay for a small change in life expectancy or life quality. Individuals do value the changes in availability of non-market goods and monetary valuation models this value in economic terms, to render the value more explicit and meaningful. Apart from ethical aspects, monetary valuation is criticised for being excessively arbitrary in respect to value choices, limited by inherently-high uncertainties, and by methodological flaws (Ludwig, 2000). Typical examples of value choices are: giving more or less weight to future generations, by e.g. discounting future impacts; and assuming or not assuming equality between people, e.g. people living in developing and developed regions (Bachmann, 2011).

Monetary valuation can support decision-making and is a common practice in Cost Benefit Analysis (CBA) of public and private projects with economic, environmental and social impacts (Boardman et al., 2006). When monetary valuation is used to convert the social and biophysical impacts on non-market goods into monetary units, they can be compared against each other and against the costs and benefits already expressed in monetary units. Although being diffused in CBA, monetary valuation is not applied extensively in Life Cycle Assessment (LCA), another widespread decision-support tool.

Several authors have discussed the advantages of using monetary valuation in the weighting phase of LCA (Ahlroth, 2014; Ahlroth et al., 2011; Finnveden et al., 2009; Hellweg et al., 2003; Jeswani et al., 2010). The weighting phase aims at solving the trade-offs between (environmental) impacts that are measured in different (biophysical) units and are thus incomparable. Converting these impacts in the same unit by using monetary valuation allows for a direct comparison. This may be a preferred solution compared to alternative weighting methods, which are the so-called “panel” and “distance-to-target” methods. The former are based on the preferences of specific individuals (panels of experts or laymen, or politicians) rather than the general public as in monetary valuation. The latter type of methods weights impacts by the ratio of the current level of each impact and a target level: this weighting expresses a rule-based ethic opposed to the utilitarian ethics of monetary valuation.

A challenge for the application of monetary valuation in LCA is that impacts in LCA have a high level of abstraction. This means that impacts do not refer to specific situations bur are generalizable, for two reasons. Firstly, LCA accounts for “potential” rather than “actual” impacts. Emissions from different processes/activities, as well as their impacts, are aggregated over space and time. Thus, the monetary valuation of potential impacts should result in monetary values applicable broadly. Secondly, LCA considers both midpoint and endpoint impacts. The former (e.g. climate change, ozone depletion, and acidification) usually represent well-defined cause-effect relationships, whereas the latter (damage to human well-being, damage to ecosystem quality) represent complex processes affecting a specific target (Areas of Protection). Consequently, midpoint impact assessment is usually performed bottom-up, in the sense that focuses on the strong quantitative relation between an emission and its midpoint impact, and proceeds by aggregation of different impacts. Instead, a top-down approach emphasises the relation between an area of protection and its endpoints, and proceeds by disaggregation of endpoints. Applying the monetary valuation at midpoint or endpoint may require different and not necessarily interchangeable approaches allowing either to focus on the link between a specific emission and its impacts, or to embrace the complexity of an endpoint, by e.g. disaggregating it into different features or attributes. In summary, the application of monetary valuation within the context of LCA poses different challenges than its conventional application in CBA, and requires approaches allowing for the valuation of different potential impacts aggregated over a life cycle and at different points of the impact chain.

Several methods exist for monetary valuation. This study evaluates different methods for monetary valuation with respect to their relevance in LCA and provides practical guidance for their use in this domain. The specific objectives were: (i) to formulate a comprehensive set of criteria with which to assess the different monetary valuation methods in relation to LCA; (ii) to review systematically, analyse critically, and evaluate the existing monetary valuation methods, as well as existing LCA-applications of these methods for converting (LCA) results quantified in physical units into monetary units; and (iii) to make recommendations for the practical use of monetary valuation in the context of LCA.

This study focused only on established monetary valuation methods and their relevance for LCA, and did not intend to review all the existing scientific literature on monetary valuation. A detailed analysis or discussion of the technical and ethical limits of monetary valuation and of the use of market information in LCA was also outside of the scope of this study. Since the authors elaborated mostly on Life Cycle Impact Assessment (LCIA), accounting procedures for the inventory of costs and benefits over a life cycle, such as Life Cycle Costing, were not covered by this review.

The article builds on the report by Weidema et al. (2013), and is structured as follows: different monetary valuation methods are presented and defined; the methodology applied in the review is described; the results of the assessment are summarised and discussed; conclusions are made on the state-of-the-art of monetary valuation in LCA; and recommendations are given. The supplementary information provides: the assessment criteria, a short description of each of the identified LCA applications of monetary valuation methods, and the detailed assessment.

2. Material and methods

2.1. Approaches and methods for monetary valuation

The review performed by the authors covered the monetary valuation methods listed in Table 1, where a classification of different approaches and related methods is proposed. In this paper, a monetary valuation *approach* was defined as a class of monetary valuation methods based on a specific internally-consistent hypothesis and principles. Monetary valuation *methods* were defined as different versions of the same monetary valuation approach, based on the same principle but differing in the practical implementation or in technical aspects. Finally, an *LCA application* was defined as a version of a monetary-valuation method that is developed or adapted specifically for use in LCA. The classification proposed in Table 1 gives a precise and unequivocal definition for each approach and method.[2] This was considered important as the

[2] For example, in this study mitigation cost, avoidance cost, control cost, replacement cost, damage cost, and restoration cost were considered as specific methods of the abatement-cost approach. All of them were classified under the abatement cost approach, as each of these methods follows the same general principle and hypothesis.