Are diverse ecosystems more valuable? A conceptual framework of the economic value of biodiversity

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Abstract

Biodiversity is often believed to be economically valuable, but it is unclear where its value stems from. To date, a number of economic valuation studies targeted biodiversity in highly diverse ways, yet there exists no consistent framework for valuing it. In this paper, a conceptual framework for the economic valuation of biodiversity is presented. By drawing insights from both ecology and economics, the ways through which biodiversity influences human well-being are identified. It is argued that biodiversity's economic value has four sources: biodiversity contributes to ecosystem functioning (insurance value), is the carrier of future options (option value), provides 'efficient' support for migrating species (spill-over value) and influences the aesthetic appreciation of ecosystems (aesthetic value). Being only a property of ecosystems, it does not have value *per se*, but only contributes to the overall value of an ecosystem. The paper also includes a discussion of the conceptual framework's fit within the conventional TEV framework, from which the need is derived to expand TEV to better account for biodiversity; a possible extension is offered.

Keywords biodiversity, economic valuation, ecosystem functioning, insurance value, option value, TEV

JEL code Q51, Q57

1 Introduction

Biodiversity is scarce and declining both locally and globally (Barnosky et al., 2011). Also, it is often believed to contribute to human well-being. Thus, it fulfils the prerequisites for being considered an economic good—albeit a rather abstract one (Meinard and Grill, 2011). As such, it has received considerable attention from environmental economists, including those working on the theory and practice of economic valuation, who have identified it as a potential valuation object. And yet, it has been repeatedly found that 'there is certainly not yet an established framework for valuing biological variety' (Nijkamp et al., 2008, p. 218; see also Christie et al., 2004). The role of biodiversity within the common frameworks used as basis for economic valuation, *viz*., the ecosystem services (ESS) and the total economic value (TEV) frameworks, is also at least unclear (Atkinson et al., 2012; Jax and Heink, 2015; Mace et al., 2012; Pascual et al., 2015). A recent literature review identified significant deficiencies and inconsistencies in the practice of economic valuation of biodiversity (Bartkowski et al., 2015).

Is a particularly biodiverse ecosystem more valuable compared with a less biodiverse version of it? Where does this value stem from? How can economics draw upon insights from ecology and conservation biology in the quest for establishing a coherent 'framework for valuing biological variety?' These are questions the following contribution will offer an answer to.

The structure of the paper is as follows: section 2 provides an overview about the ecological perspective(s) on biodiversity, particularly on the issue of defining it and on its relationship with ecosystem functioning. Section 3 presents a conceptual framework that identifies the sources of economic value of biodiversity and their place within the total economic value (TEV) framework. Section 4 concludes.

2 Biodiversity from an ecological perspective

2.1 Definition(s)

Biodiversity is, first and foremost, a form of *diversity*. What is diversity in general terms? It has been argued that it is a combination of three properties of systems: variety (number of items in a category; the more items, the higher diversity, *ceteris paribus*), balance (distribution of elements in a category; the more even the distribution, the higher diversity, *ceteris paribus*) and disparity (degree of difference between items in a category; the less similar the items, the higher diversity, *ceteris paribus*). All three properties are relevant and constitutive of diversity (Stirling, 2007).

Due to the term's origins (cf. Takacs, 1996), biodiversity has been called an 'epistemic-moral hybrid' (Potthast, 2014), as it is often used in emotional, advocative sense. Whatever the exact motivation behind the coinage of the term, a widely recognized problem with biodiversity is that it has not a single, clear, agreed upon definition (Jax and Heink, 2015; Koricheva and Siipi, 2004).

This paper is based on the flexible yet encompassing definition of biodiversity provided by Maier (2012): According to him, biodiversity is the *multiplicity of kinds in one or more biotic or biota-encompassing categories*. Biodiversity consists of a multiplicity of categories, including genes, genomes, species and other taxonomic groups, functions etc. (see also CBD, 1992; Lyashevska and Farnsworth, 2012). This definition is also consistent with Stirling's (2007) above-mentioned definition, as dissimilarity stems from nothing else than additional dimensions that are taken into account above, e.g., taxonomic categories.

Importantly, biodiversity is not an *entity* but a *property* or *quality* of ecosystems. As such, it is not equivalent to 'life on Earth' and must not be used as a synonym of 'nature.' The concept of biodiversity is inherently egalitarian, in that it does not pay any attention to the identity of the kinds in biotic or biota-encompassing categories; rather, it is solely concerned with their dissimilar multiplicity.

> It is important to be clear about what is meant here by 'diversity.' People frequently cite conservation of diversity as a reason for mounting extraordinary efforts to preserve, say, the whooping crane. What they often really mean is that the whooping crane should be preserved because it is beautiful, or majestic, or inspiring, or because its presence confers some other direct benefit. I would say that these qualities, while important, do not really concern the value of 'diversity' per se. (Weitzman, 1993, p. 159)

2.2 Biodiversity and ecosystem functioning

There exists a vast and long-standing literature on the relationships between biodiversity and ecosystem functioning (BEF). It cannot be attempted here to summarise all the different strands of this controversial debate. The influence of biodiversity on ecosystem productivity, stability, resilience *etc.* has been investigated in a large number of both conceptual and experimental studies. There is agreement among most researchers in the field that, while details may be controversial and there remain knowledge gaps, the general picture provided by experimental studies seems to support the initially posed hypothesis that high levels of biodiversity and ecosystem functioning coincide (Balvanera et al., 2006; Cardinale et al., 2012; Isbell et al., 2015), even though the magnitude of the respective effects depends on which measure of ecosystem functioning is in focus (Pimm, 1984; Schmid et al., 2002).

The central mechanism behind biodiversity's positive influence on ecosystem functioning is *functional redundancy*: the existence of species '[w]ithin the same functional effect type' that, however, exhibit 'different requirements and tolerances (i.e. belong[…] to different functional response types)' (Díaz and Cabido, 2001, p. 653). *Functional response types* are groups of species that exhibit similar responses to the biotic and abiotic environment. *Functional effect types* are groups of species that influence ecosystem processes in similar ways. The notion of functional redundancy is closely related to the *insurance hypothesis* (Folke et al., 1996). This hypothesis amounts to the 'idea that increasing biodiversity insures ecosystems against declines in their functioning caused by environmental fluctuations' (Yachi and Loreau, 1999, p. 1463). As will be argued in section 3.1.1, this ecological hypothesis can be extended by including human preferences and risk-aversion so as to arrive at the concept of the *insurance value* of biodiversity.

An important point to note at this place is that, most likely, biodiversity as such does not have meaningful influence on ecosystem functioning. It is concrete species or groups of species and the interactions between various elements of ecosystems that determine ecosystem functioning (cf. Grime, 1997; Haines-Young and Potschin, 2010). However, as our knowledge of these processes, dynamics and interactions is inherently limited, we are forced to recur to the 'crude' notion of biodiversity, which is a useful proxy concept that allows to approximate the effects of species assemblages on ecosystem functioning. In this sense, the concept of biodiversity is only useful as a second-best solution, where the first-best solution (understanding the exact roles of the various components of an ecosystem for its proper functioning) is not available.

3 Biodiversity's contribution to the economic value of ecosystems

There are a number of economic valuation studies, in which biodiversity was valued. However, most of the approaches advanced in the studies are problematic (Bartkowski et al., 2015) and Nijkamp et al.'s (2008) conclusion that 'there is not yet an established framework for valuing biological variety' still applies. In what follows, a conceptual framework of biodiversity's economic value will be presented (see Figure 1). Three value categories of which biodiversity is the main carrier will be distinguished: insurance value, option value and spill-over value. In addition, the aesthetic appreciation of an ecosystem is also influenced by biodiversity.

It is important to note that biodiversity does not contribute to human well-being directly—rather, one should say that it is valuable insofar as it 'promotes useful properties' (Brock and Xepapadeas, 2003). Indeed, it may well be argued that at the core of biodiversity's contribution to the economic value of ecosystems lie uncertainty and knowledge limitations. The two main sources of biodiversity value presented below can be directly linked to uncertainty about future states of the natural world (insurance value) and about the preferences and needs of future generations (option value).[1] Thus, what is valuable is actually not biodiversity as such, but rather the properties of ecosystems which we approximate by the concept of biodiversity out of lack of better understanding of the complexities of ecosystems.

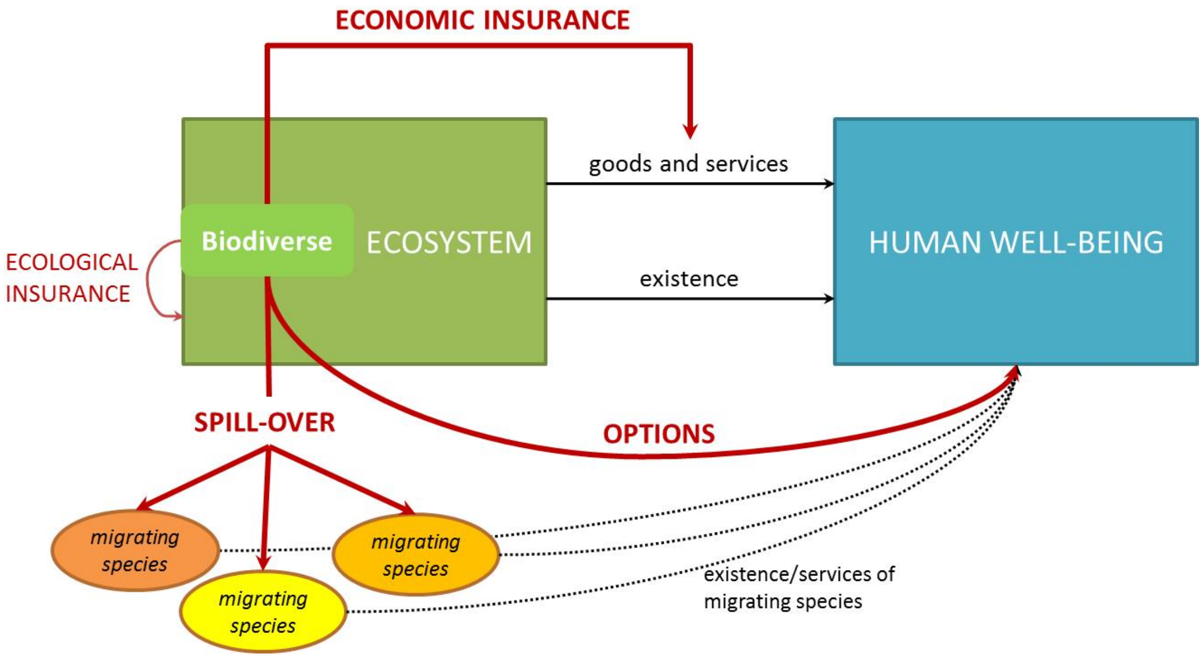

Figure 1 A conceptual framework of biodiversity's economic value

3.1 Biodiversity values

3.1.1 Insurance value

As suggested by the discussion of the BEF literature in section 2.2, biodiversity is positively correlated with ecosystem stability. This means that there exist important complementarities among biodiversity components (e.g., species) and between them and their habitat, which enhance the functioning of the ecosystem. This *insurance value* reflects the contribution of biodiversity to the temporal and spatial stability[2] of these complex systems. Of

[1] In fact, a similar intuition can be found in earlier publications as, e.g., Dasgupta et al. (2000).

[2] Stability is meant here in the sense of fulfilling (ecological) functions and providing ecosystem services, not in the sense of a stable, non-changing 'state.'

course, behind this reasoning lurks the assumption that stability has value in and of itself, i.e., that people prefer the supply of some goods and services when they deem it stable to the same supply deemed unstable. There is an obvious analogy here to insurances, which people are willing to pay due to risk-aversion, effectively purchasing security or predictability (Baumgärtner, 2007).

Baumgärtner (2007, p. 90) argues that insurance value is 'a value component in addition to the usual value arguments (such as direct or indirect use or non-use values, or existence values) which hold in a world of certainty.' He defines insurance value as the change in the risk premium of the 'lottery' (i.e., future state of the world) due to a change in biodiversity, and points out that it is biodiversity's influence on the variance of the yield of ecosystem services that is essential for its insurance value. The insurance function of biodiversity is close to the notions of self-protection and self-insurance (Ehrlich and Becker, 1972), as societies can 'insure' against future declines in the provision of ecosystem services by deliberately maintaining and increasing biodiversity in ecosystems (cf. Baumgärtner and Strunz, 2014; Pascual et al., 2015).

Much in the same spirit, Figge (2004) compared biodiversity to a financial portfolio ('bio-folio'). Maintenance of the bio-folio can be viewed as a risk-spreading strategy. Obviously, the analogy between biodiversity and a financial portfolio is rather metaphorical, as a financial portfolio consists of individual assets all of which have positive expected values. Otherwise, they wouldn't be bought and held. Contrary to that, biodiversity includes 'assets' whose (expected) value is not positive—e.g., pathogens or pests. Still, the portfolio metaphor appears useful, as it highlights how the diversity of biological assets in an ecosystem can contribute to the latter's stability. From the ecological perspective, this occurs mainly *via* functional redundancy (see section 2.2). The insurance premium for keeping redundant members of functional groups alive is the economic value of the resulting biodiversity. More specifically, it can be said that 'the insurance value of biodiversity is the marginal value of biodiversity in its function to reduce the risk premium of the ecosystem manager's income risk from using ecosystem services under uncertainty' (Baumgärtner, 2007, pp. 103–4).

Two specific interpretations of biodiversity's insurance value are available: first, biodiversity can be argued to promote *acute stability*[3] in the sense of resistance of the biodiverse ecosystem to exogenous shocks, e.g., storms (Thompson et al., 2009) or climatic events such as droughts (Isbell et al., 2015). This is insurance value in the most obvious sense.

[3] As used here, this term is closely related to the concepts of resistance and resilience.

Second, when biodiversity positively influences the temporal stability of an ecosystem, this can be valuable if coupled with intergenerational equity concerns. People may appreciate the fact that a relatively biodiverse ecosystem is more likely to be available to future generations, on top of its availability to themselves.

3.1.2 Option value

An important yet difficult to grasp component of the economic value of an ecosystem is its option value, originally proposed by Weisbrod (1964). In its essence, option value is rooted in human risk-aversion (here, risk-aversion is extended to uncertainty or even ignorance about the future). It results mainly from uncertainty about the future, particularly regarding future preferences (demand uncertainty). A biodiverse ecosystem contains many elements which might be beneficial to the society in the future, even if they are not yet useful or not yet known. Therefore, biodiversity has been called a 'library' by some economists (Goeschl and Swanson, 2007; Weitzman, 1995). Thus, option value, as understood here, is not mainly about future uncertainty regarding future states of ecosystems themselves (for this, see the previous section on insurance value), but rather regarding preferences of future generations (see also Birnbacher, 2014). Obviously enough, these two interpretations are inherently interlinked. And they can be directly related to biodiversity: the more biodiverse a given ecosystem is, the higher the probability that it contains goods which will be beneficial for human beings in the future.

One reflection of option value as attached to biodiversity levels is often seen in bioprospecting contracts (ten Kate and Laird, 2000)—a biodiverse ecosystem is a pool of options that might be drawn upon in the future. Also, genetic diversity has gained additional option value in the era of genetic engineering. While in traditional agriculture only genetic material found in varieties of the same species or, sometimes, some related species could be used to create new, better crop varieties, today such limits do not apply any more, as DNA snippets can be potentially transferred between very different organisms.

The view of biodiversity as carrier of option value stems from the recognition that a biodiverse ecosystem, which contains many different species and genomes, can best accommodate unanticipated desires and needs (preferences) of current and future generations. Again, as in the case of insurance value, this can be coupled with some considerations of intergenerational equity: high levels of biodiversity now mean many different options for our grandchildren, who may want to extract from ecosystems technological blueprints, substances and genes which we have no use for.

3.1.3 Spill-over value

A biodiverse ecosystem can be expected to be diverse in microhabitats. Some of these microhabitats can be essential for migratory species (salmonids, geese, cranes) whose main habitats lie outside the investigated ecosystem, but for which this ecosystem is one (potential) ‘station’ in their migratory life-cycle.[4] It can thus be argued that biodiversity in an ecosystem has spill-over effects on other ecosystems. This idea is conceptually closely related to the ecosystem services *maintenance of life cycles of migratory species* or *nursery-service* in the TEEB classification (Elmqvist et al., 2010).

Under the assumption that the relevant migratory species are themselves economically valuable, the contribution of a biodiverse ecosystem to their life cycles can be argued to contribute to the overall value of this ecosystem. Importantly, the contribution of biodiversity consists not of the fact that there is a microhabitat for a specific migratory species, but that there is a multiplicity of habitats, which can (potentially) be used by such species. In a certain sense, this might be called *efficient*, as one would support a number of migratory species within one diverse ecosystem, thus minimising the area needed for their maintenance.

3.1.4 Aesthetic value

Another possible way biodiversity can contribute to the value of an ecosystem is *via* aesthetics. It is well established that aesthetic reasons have a large influence on how people perceive and value an ecosystem (e.g., Lienhoop and Völker, 2016). The expectation appears warranted that biodiversity has an influence on aesthetics. For instance, it may be argued that exceptionally biodiverse ecosystems are also perceived as exceptionally beautiful (e.g., Giergiczny et al., 2015). However, the opposite might also be the case, i.e., biodiverse ecosystems might be conceived by some people as ‘unsightly.’ Whether the effect of biodiversity on subjective appreciation of an ecosystem’s ‘beauty’ is positive or negative, is a matter of empirical investigation. The hypothesis here is solely that biodiversity has an influence on the aesthetic value of an ecosystem.

The practical relevance of biodiversity’s influence on aesthetics is, however, limited. The main reason for that is that it might be very difficult to disentangle the various components of the aesthetic value of an ecosystem, so as to ‘filter out’ biodiversity’s contribution to it. Furthermore, the expectation appears warranted that aesthetic value has strongly diminishing returns in terms of increasing biodiversity—most likely, most people would not be able to notice changes in biodiversity beyond a certain threshold. Empirical

[4] An example of such ecosystems are the *dehesas* in the Spanish region of Extremadura, where numerous species of migratory birds from Northern Europe spend winters (Diáz et al., 1997).

studies have also indicated that laypeople's ability to distinguish species and thus to notice differences in biodiversity levels is very limited (Pilgrim et al., 2008; Voigt and Wurster, 2015). This is problematic because it can lead to differences between *actual* and *perceived* diversity. In a valuation study, both stated preference and revealed preference, this distinction can be crucial. Another caveat is that it is necessary to distinguish the appreciation of the diversity of ecosystem components (species, landscapes etc.) from the appreciation of some specific elements in the mix (Jacobsen et al., 2008): for instance, the different appreciation of two forest patches may be due to the difference in biodiversity levels between them, but it may also be due to one particular species that one patch includes while the other does not. Summing up, it is important for conceptual reasons to keep in mind that biodiversity influences aesthetics, but most likely it is not advisable to distinguish between the different factors which determine aesthetic appreciation in actual valuation studies.

3.2 Fit within TEV framework

The total economic value (TEV) framework is the single most influential framework used in the area of economic valuation of environmental goods. So, it is interesting to think about how the biodiversity values suggested above fit into it. Especially, the integration of insurance value in the framework is of interest.

TEV in its most common form consists of three main value categories: use values, non-use values and option value (e.g., Pascual et al., 2010, fig. 5.3). In earlier publications, if insurance value was included in TEV, it happened as a category additional to the 'output value' of an ecosystem, which corresponded there to the usual TEV (cf. Pascual et al., 2015). However, in Pascual et al. (2010), insurance value was located outside the TEV and identified with resilience and critical natural capital (CNC). However, there is a difference between these two notions. As discussed above, resilience and stability can be linked to (the value of) biodiversity. One can have more or less stability and resilience, and it is straightforward, given that most people are risk-averse (Dohmen et al., 2011), that they would be willing to pay for changes in an ecosystem's stability and/or resilience (cf. Baumgärtner and Strunz, 2014). Conversely, CNC *ex definitione* precludes the application of economic valuation (Farley, 2008). Thus, the insurance value of CNC is of a different kind than the insurance value of biodiversity; it is not, in this sense, 'economic,' as it cannot be expressed in terms of willingness-to-pay.

So, how can biodiversity's contribution to the economic value of an ecosystem be properly included in the TEV framework? Figure 2 offers a tentative proposal of how TEV can be restructured and extended so as to make place for biodiversity-related values. The basic idea is related to Pascual et al.'s (2015), the difference being that in Figure 2, option value and insurance value are put together under the heading of 'future-related values,' i.e., values which result from uncertainty about the future (see previous section), whereas use and non-use values are 'present-related values.' From what has been said above, it is obvious that biodiversity's contribution to the TEV of an ecosystem is mainly *via* future-related values—both of its components can be directly attributed to biodiversity.

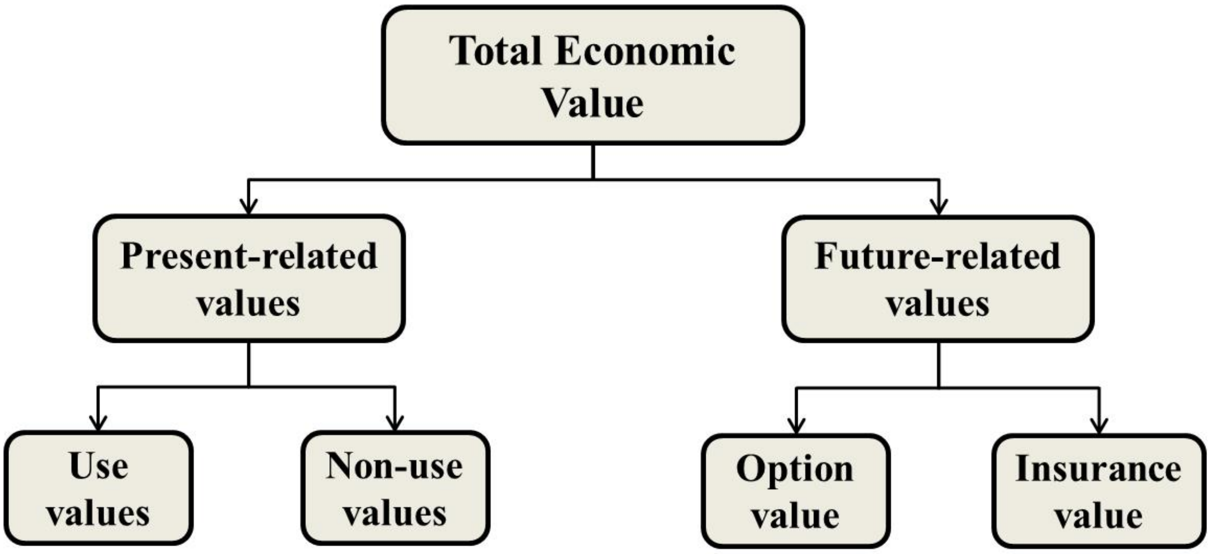

Figure 2 TEV with insurance value

Spill-over value, on the other hand, does not seem to fit any value category discussed in the literature, possibly because it is a contribution of one ecosystem to the value of another. As has been argued above, only in few contexts the estimation of this value does not account to double-counting (i.e., when only a single ecosystem's value is considered), which might explain its absence from conceptual frameworks of economic value. Nonetheless, spill-over remains relevant in these contexts in which double-counting is not a problem, and might be viewed as a kind of *value export* from the ecosystem under consideration to other ecosystem(s). To include spill-over value in the TEV framework, one would have to add the spatial dimension to it—spill-over value of (the biodiversity in) an ecosystem consists in its contribution to the TEV of other ecosystems.

4 Conclusion

The goal of the present paper was to illuminate the sources of economic value of biodiversity. By inclusion of the insights not only from economics, but also from ecology and conservation biology, four categories of biodiversity value have been identified: insurance value, option value, spill-over value and aesthetic value. It has been shown that especially the former two value categories result from uncertainty and risk-aversion. The single most important reason why biodiversity is economically valuable is its contribution to ecosystem functioning.

It has been shown, in line with the arguments developed recently by Pascual et al. (2015), that a proper understanding of biodiversity's contributions to human welfare necessitates an extension of the conventional TEV framework, which is only limitedly suited to include biodiversity values. Particularly, insurance value is missing from it. The extension proposed consists in differentiating between present-related values (use and non-use values) and future-related values (insurance and option values) within the TEV.

The framework presented here leaves a number of questions open. First, what are the appropriate valuation methods with which the framework should be applied? A tentative answer would suggest stated preference methods, because it would not be easy to find surrogate markets from which biodiversity's economic value could be possibly derived. Second, the conceptual framework is rather abstract—for application in actual valuation studies, it has to be translated into more concrete terms and possibly coupled with quantitative biophysical data and models. Third, the conceptual framework has been developed with terrestrial biodiversity in mind—whether it can be applied to, say, marine ecosystems, is a matter that should be properly investigated. Last but not least, it is essential that the framework be tested in a practical setting, since economic valuation is rooted in preference utilitarianism—this means that, in the end, it is human preferences that count. A conceptual framework, however convincing and consistent from a theoretical point of view, can only be a first step.

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